Educative Self-Assessment Using Web Technology

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Introduction

Student performance assessment can serve two purposes. It can be used as a measure of learning outcomes and as a tool for improving student learning. In the latter case, the aim of assessment is to identify students' misconceptions and subsequently offer them timely corrective feedback. As an outcome-measuring tool student assessment occurs a limited number of times during the curriculum. As an educative means, assessment is a continuous activity throughout the curriculum.

The benefits of educative assessment for enhancing student learning are obvious. Its integration in engineering curricula, however, is impractical because of the tremendous time requirements that it imposes on the faculty, the size of the student population, and the general unwillingness of students to expose their misconceptions to their peers and instructors alike. These obstacles can be overcome by developing and making available to students software tools that support automated educative self-assessment. Such tools have the potential to qualitatively affect student learning without draining school resources in the process.

This paper examines a self-assessment system for students who are learning to construct shear and moment diagrams. This is an important topic in structural analysis and design, one that many students have difficulty mastering without a significant amount of practice and help. The approach described here involves automatically constructing a knowledge map for the students at the same time as they interactively construct shear and moment diagrams for various problems. The map, which highlights the student's mistakes and misunderstandings, is then used to provide the student with meaningful corrective feedback at several levels. If the frequency of mistakes is not diminished over time, expert human intervention can be provided upon the student's request.

Scope

Learning-outcome assessment is the process of gathering, analyzing, and interpreting evidence to determine how well performance matches established learning expectations [1]. In engineering, learning-outcome assessment usually occurs during the course of teaching, with student performance on homework assignments, examinations, and projects providing evidence of the level of learning. The instructor interprets this evidence to judge a student's learning progress and then assigns a course grade that reflects this judgment. Although this assessment process could act as an incentive for learning, its primary purpose is to measure the level of a student's learning, not reinforce learning.

Learning-outcome assessment can take place at several levels: the program level (i.e., do students have the competencies required for graduating?); the subdiscipline level (i.e., have structural engineering students developed core competencies in the analysis and design of certain types of structural systems?); the course level (i.e., have students learned enough to advance to the next level?); and the concept level (i.e., do students know how to construct shear and moment diagrams for beams?). Here we focus on assessment at the concept level, because that is the level at which learning usually starts before expanding outward to methods and theories, and their applications in engineering disciplines.

Perspective

Learning does not take place when the student is exposed to new information by reading notes and books or listening to lectures. Rather, learning takes place when the student internalizes that information—when the mind constructs meaning from the information and retains it by associating it with existing knowledge.

Even during the process of learning it is all too common for students to construct inaccurate and/or incomplete meaning from the information presented to them. Therefore, for meaningful learning to take place, it is important that misconceptions and inaccuracies are identified and remedied while the student is actively engaged in the learning process.

This can be accomplished by the continual assessment of students' learning in order to identify and remedy knowledge gaps as they emerge. It is widely known that the learning process can be substantially enhanced by providing the learner continuous feedback on the progress she has made and by pointing out specific areas where additional work is needed. Without feedback, learning can be slow and difficult, even, under some conditions, virtually impossible [2].

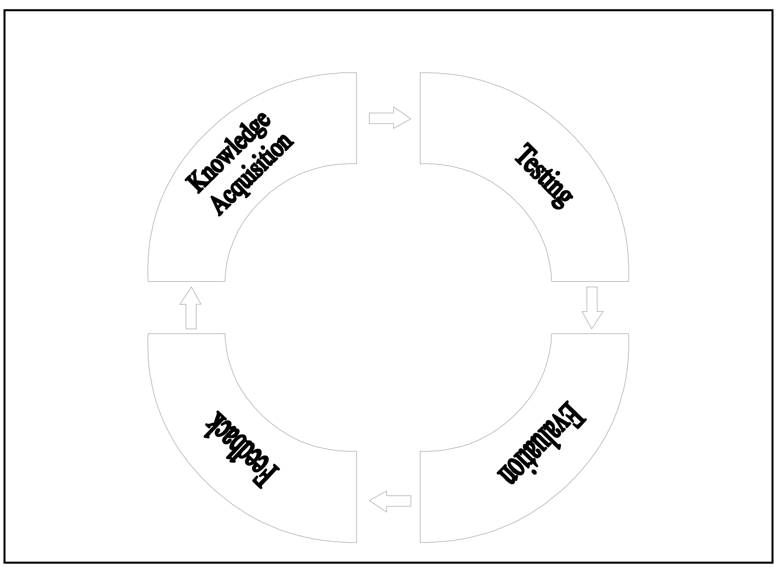

Figure 1: Learning Process as a Cycle

Figure 1 represents learning as a cyclic process. The process begins when the learner internalizes new information from lectures, discussions, printed materials, or other learning resources. In most cases, this newly gained knowledge contains gaps and misconceptions, and it therefore must be refined. Clearly, however, such knowledge gaps and misconceptions must first be identified before refinement can take place. This can be achieved using tests designed to compare what has been learned against established learning objectives. The test results, when properly evaluated, should identify knowledge areas that require refinement. Once those areas have been identified, the learner can be given appropriate corrective feedback. Over time, through repetitive application of this cycle, knowledge gaps are reduced and misconceptions are transformed into deeper understanding of the underlying concepts.

Although this cyclic approach to learning has obvious advantages, its implementation in most academic settings faces two major obstacles. First, the time required to continuously assess every student in a course and provide her with corrective feedback throughout the semester far exceeds the amount of time generally available to the instructor for such purposes. Second, even if enough resources were made available for student assessment, the existing engineering curricula do not readily support the integration of such activities into the overall learning experiences of students. Here we present a technological solution for overcoming the first obstacle. The solution to the second obstacle, however, lies in the further transformation of the structure of engineering course and curricula models—an ongoing activity in most engineering schools.

Self-Assessment System

This paper describes a Web-based system for learning how to construct shear and moment diagrams. The system consists of three main steps, as shown in Figure 2. The system presents to the learner a series of shear and moment diagram construction problems. The learner responds by interactively constructing the diagrams; the system generates meaningful feedback, which is displayed to the learner. The system also uses the learner's responses to incrementally construct a map that highlights the learner's knowledge gaps and misconceptions. This map is then used to further refine the learner's knowledge by identifying and presenting to the learner relevant study materials.

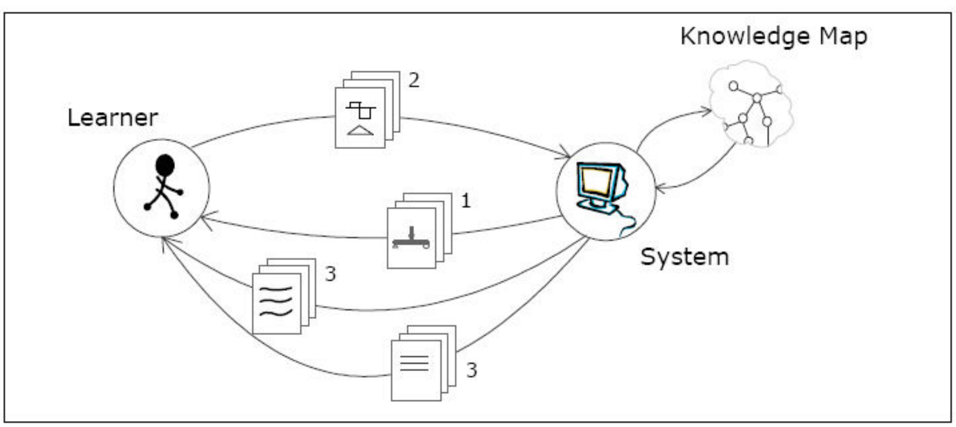

Figure 2: The Cyclic Operation of the Self-Assessment System

The following paragraphs explain in more detail how the system works.

Problem Generator

The system contains a set of problems covering the major concepts pertaining to the construction of shear and moment diagrams. A sample problem is shown in Figure 3. The content covered within the problems centers on beams with various boundary conditions subject to concentrated, distributed, and mixed loading. The system provides a graphical tool for constructing shear and moment diagrams for each problem. The learner interactively constructs diagrams by dragging and dropping graphical elements on the diagram lines. If necessary, shear and moment values can be adjusted either graphically—by dragging control points—or by directly entering the values.

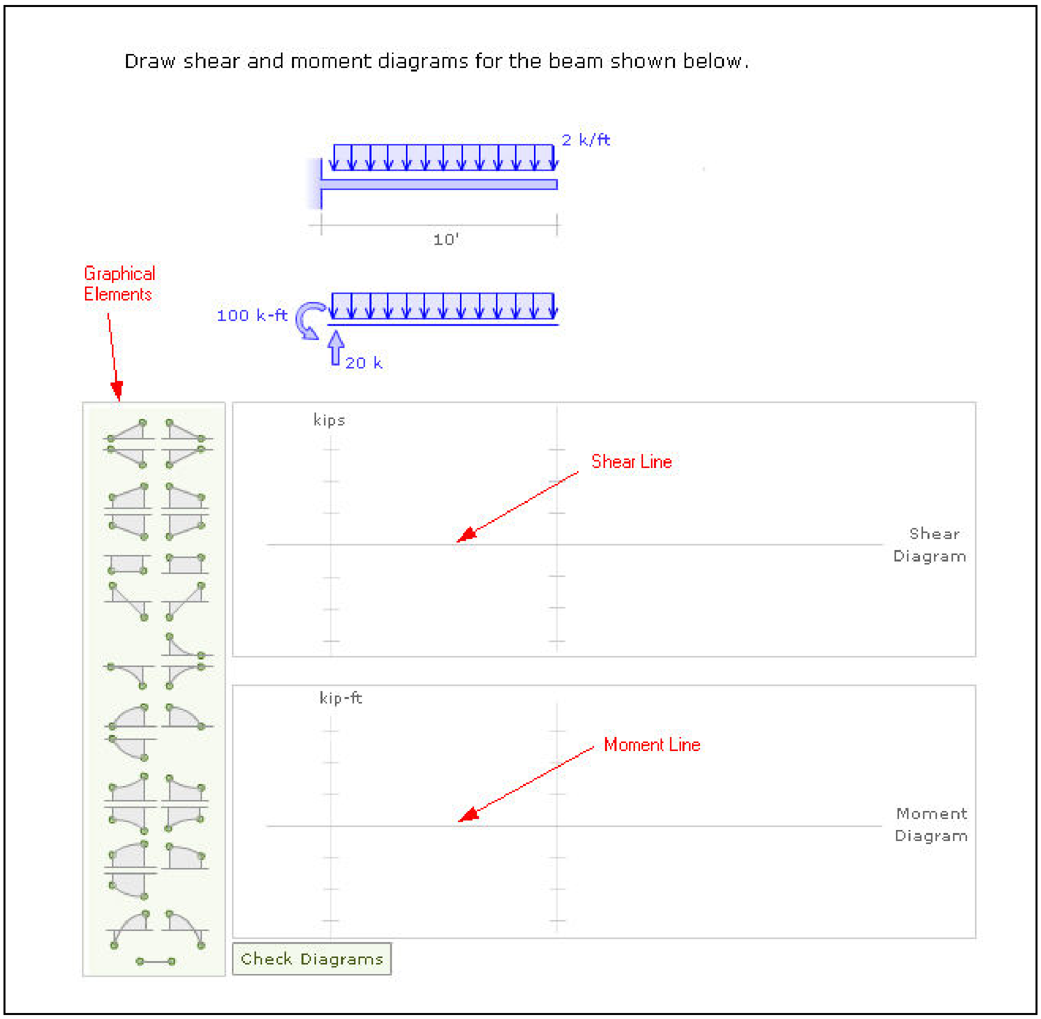

Figure 3: A Sample Shear and Moment Diagram Construction Problem

Analysis

Once the learner has completed the problem, the system analyzes the constructed shear and moment diagrams to determine if they are correct. This is performed by comparing the shape and magnitude(s) of the diagram constructed by the learner, in each segment, with the correct ones. Incorrectly constructed segments of a diagram are highlighted, allowing the learner to request corrective feedback (see Figure 4).

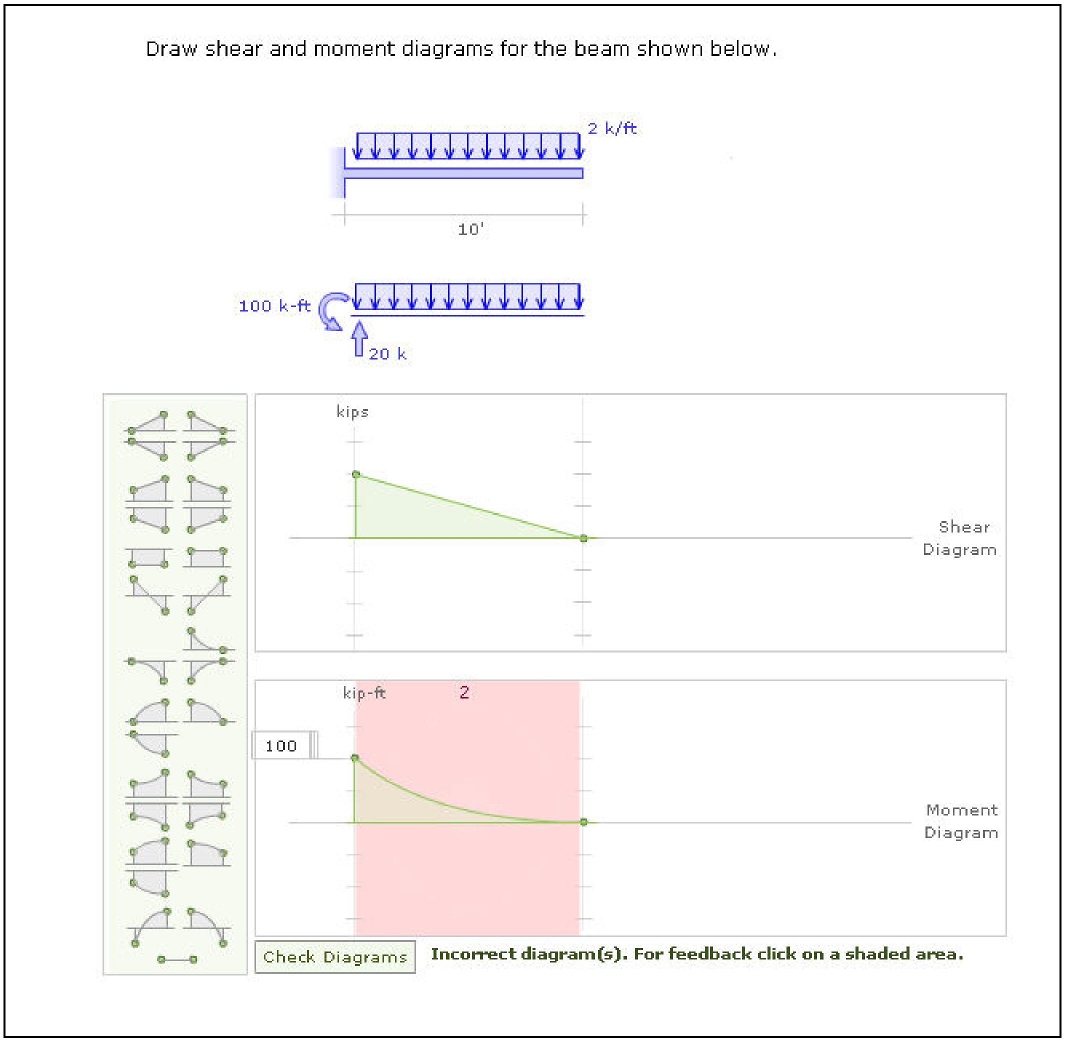

Figure 4: Initial System Response to Learner-Constructed Diagram

Feedback

If the learner constructs any part of a diagram incorrectly, the system generates appropriate feedback alerting the learner to her mistake(s). The feedback includes the correct diagram segment and how it is obtained. Figure 5 shows an example of corrective feedback.

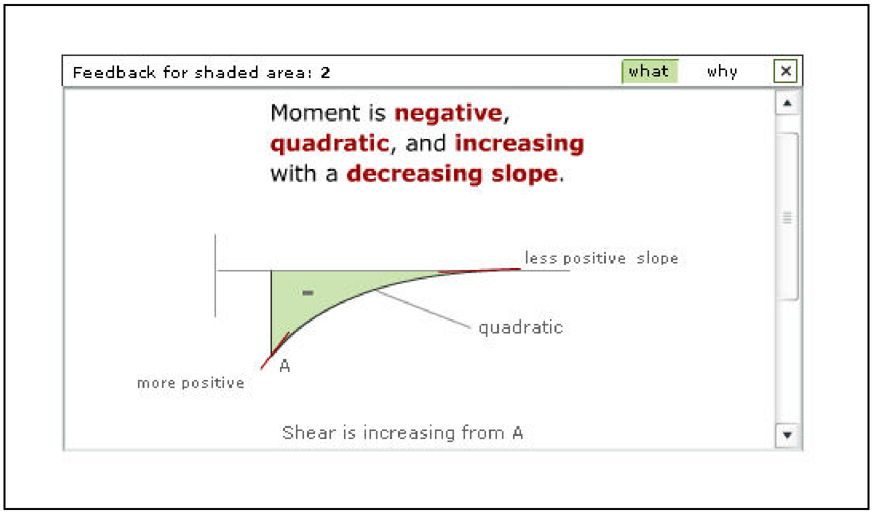

Figure 5: An Example of Corrective Feedback

Knowledge Map
The system contains an internal representation of all the relevant relationships among applied loads, internal forces, and shear and moment diagrams. This internal representation is referred to as the relations map. The relationships in the map, which permeate the problems generated by the system, must be understood if the learner is to construct the diagrams correctly.

When the learner constructs a diagram, the system evaluates the accuracy of her understanding of the underlying relationships and marks the relations map accordingly. The markings on the map increase as the learner continues to use the system. Eventually the map evolves into a representation of the learner's understanding of the marked relationships. The relations map saturated with such markings constitutes the *knowledge map*.

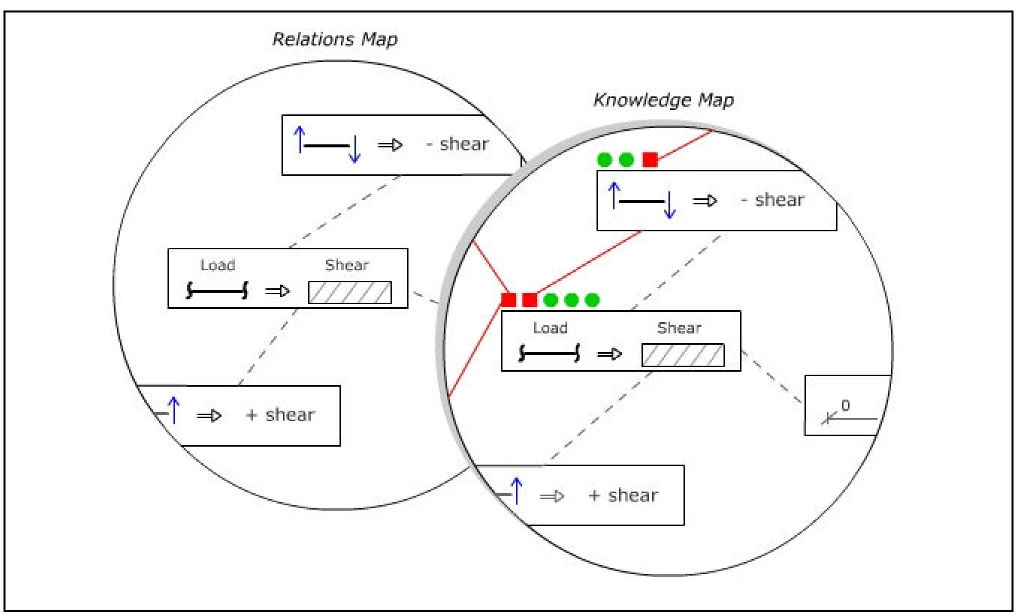

Figure 6: The Relations Map and a Matching Knowledge Map

Figure 6 shows a part of the relations map and its transformation into a knowledge map. The figure focuses on a relationship between a load diagram and a shear diagram; when a beam segment is not subjected to any distributed load, shear remains constant in the segment. The knowledge of this relationship is essential for constructing shear and moment diagrams in many problems.

As the learner constructs shear and moment diagrams, the system marks the relations map reflecting the learner's understanding of the relationship. The markings provide three pieces of information:

1. Whether the relationship was correctly recognized. A correct recognition is marked by a circle; otherwise, the relationship is marked with a square.
2. In the case where the relationship was not correctly recognized, the other relationships that were missed at the same time. All the other missed relationships are linked to the square associated with the target relationship.
3. A tag (not shown in the figure) that uniquely identifies the problem that has resulted in the current marking.

The system regularly analyzes the learner's knowledge map to determine the level of help needed for knowledge refinement. When help is needed, the system compiles a collection of online learning materials for addressing the emerging knowledge gaps and misunderstandings. Upon the request of the learner, the system can also relay the knowledge map to a human expert for further feedback and guidance.

Implementation

The assessment system has been implemented as a Web application. It resides on a commercial Web server ready for use by engineering students. To obtain additional information about the application, visit http://EducativeTechnologies.net, or go to http://EducativeTechnologies.net/ebooks/SAS2.html to access the application directly.

The system has a calendar for keeping track of the learner's self-assessment sessions. The calendar also serves as the point of entry for initiating self-assessment. Figure 7 shows an example calendar. The calendar shows two pieces of information associated with the learner's daily sessions for January 2005. For each session, the number of problems solved correctly and the total time for solving them are shown as two horizontal bars. The first (top) horizontal bar indicates the number of correct solutions (based on a maximum of 10 problems). The second (bottom) horizontal bar shows the total time (in seconds) spent solving the problems. This information helps the learner keep track of her progress over time. It is important to note that the system does not require the involvement of an educator unless it is requested by the learner. The system can be directly accessed by the learner anytime from anywhere using a Web browser.

"Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition

Figure 7: An Example System Calendar with Performance Data

The calendar allows the learner to initiate the self-assessment process once per day. In each daily session, the learner is presented with a few randomly generated shear and moment diagram problems. On average, each session takes between 10 and 25 minutes to complete. This affordable daily exposure to the mental task of constructing shear and moment diagrams grants the mind sufficient time to absorb, refine, and reinforce knowledge, thereby deepening the learner's understanding of the entire process.

Summary

This paper presents a system for learning how to construct shear and moment diagrams for beams. The system provides two levels of feedback for knowledge refinement: at the problem level, when any part of a diagram is constructed incorrectly; and also based on the knowledge map, which the system generates according to the learner's performance over time.

It is postulated that such a self-assessment system enhances comprehension and promotes student-directed learning in a cost-efficient manner. Clearly, further investigation is necessary to better assess the efficacy and impact of such systems on student learning and engineering education.

References

[1] Thomas A. Angelo, *AAHE Bulletin,* November 1995, Page 7.

[2] Alexander W. Astin, *Assessment for Excellence: The Philosophy and Practice of Assessment and Evaluation in Higher Education* (Oryx Press, 1993).

Biographical Information

Dr. Sivand Lakmazaheri received his Ph.D. in civil engineering from North Carolina State University in 1990. He served as a member of the civil engineering faculty at Auburn University before joining the civil engineering department at the Catholic University of America in 1994. In 2002 he formed Educative Technologies LLC, a pioneering technology company specializing in the development of Web-based learning and teaching tools for engineering students and educators. Dr. Lakmazaheri's primary interest and work is focused on research and development of computer-based tools and methodologies for improving student comprehension and problem solving skills and abilities. He has published numerous research articles on computing applications in civil engineering. From 1997 to 2001 he served as a senior editor of the ASCE *Journal of Computing in Civil Engineering.*