

# Computerized Dynamic Assessment

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**Abstract-** Recent studies have reported on the benefits of dynamic assessment (DA) in improving student learning and achievement. Dynamic assessment is an interactive assessment technique that involves diagnostic monitoring of student misunderstandings, providing context-specific feedback, and assessing the improvement thereafter. This paper presents a computer-based DA system developed by us and its use over six semesters in a junior level undergraduate course. Results collected over this period are presented to demonstrate that, since implementation of this system, performance of the students in traditional in-class tests and in the Fundamentals of Engineering (FE) Examination has improved. Student surveys indicate that this system is preferred by the students over traditional teaching methods.

*Index Terms* – Student learning, dynamic assessment, computerized assessment, interactive assessment

## INTRODUCTION

Dynamic assessment (DA) is a subset of interactive assessment techniques where, the process of learning and knowledge acquisition is tracked so that instruction could be modified to improve student achievement. It involves planned mediation of teaching and the assessment of effects of that teaching on subsequent performance [1]. DA procedures have been shown to yield different types of information including: more valid measures of student abilities than through static tests; measures of learning ability or “modifiability”; insights into the cognitive processes that students use or fail to use; and clues about instructional methods [2, 3]. Almost all researchers working on DA have found that test performance improves after mediation through DA [1-5]. It is in contrast to traditional static tests that test acquired knowledge, without any attempt to intervene in order to change, guide, or improve the students’ ability to learn and potential for achievement [2, 5, 6].

Several other benefits of dynamic assessment have been recognized in the cognitive research literature. DA with diagnostic monitoring and context-sensitive prompting and feedback has been found to be an effective approach to improve student achievement [1]. DA facilitates near and far transfer of mediated strategies to the solving of new problems [1, 3, 7]. Extent of gain in DA tasks has been shown to be a good predictor of later academic accomplishments [1]. Researchers studying intelligence tests have reported that pretest-DA mediation-posttest gains were higher for students from minority groups and low socioeconomic levels, and those with learning difficulties than for other groups of students [2, 3, 8, 9, 10].

However, a negative aspect of DA is that class-room implementation of DA demands considerable effort and time on the part of the instructor. As such, we have developed a prototype version of a computer-based DA system for use in an undergraduate hydraulic engineering course. Details of this system, its development and refinement, and its validity have been presented elsewhere [11, 12]. In the following section, we present an overview of the current version of the system and its use in the above course. Data collected over six semesters are presented in the Results section to demonstrate improved performance by the students.

The computer-based system that we present here was initiated in 2000 to replace the traditional homework assignments in a junior level hydraulic engineering course. Over the years, the system has been formatively refined based on our experiences, peer evaluations, and student feedback [12]. During 2003, it was modified incorporating DA.

The current version of the system has five Modules with three Quizzes in each of them, each Quiz covering four concepts (C1 to C4). Each Quiz consists of a review of the four concepts (C1, C2, C3, and C4) and a Concept Quiz, followed by five Problems (P1 to P5). Each one of the 5 multiple-choice problems has five Versions (V1 to V5) with “surface variations” where the problem statement, the numerical data, the required result, and the correct response choice are changed dynamically at runtime, for each session. The first problem (P1) requires application of two of the four concepts (C1 and C2) and the second problem (P2) requires application of the other two concepts (C3 and C4). The third problem (P3) requires application of all the four concepts (C1 to C4). The fourth (P4) and fifth (P5) problems require application of all four concepts as well as concepts learned previously in this course and in other prerequisite courses (e.g. statics).

The problems included in this system are designed to assess students’ ability to remember (retrieve from memory), understand (construct meanings of knowledge), apply (use appropriate procedures), analyze (break into parts and related parts to one another), evaluate (make judgements), and create (assemble elements to form functional whole) factual (basic elements and definitions), conceptual (relationships among basic elements), and procedural (algorithms, methods, and techniques) knowledge in hydraulic engineering.

All the problems have optional built-in Hints to guide the students towards the solution. However, the Hints cost them 20 points. If a problem is solved correctly without requesting any Hints, a score of 100% is given; if Hint is requested and the problem is solved correctly, a score of 80% is given; and if the question is not solved correctly, with or without hints, a score of 0% is given. Students are allowed unlimited number of attempts for each Module within a week, but each Module has to be attempted at least twice,

even if a perfect score of 100% is received at the first attempt. The average score of the top two attempts is taken as the score for that Module. This motivated the students to return to the system as often as they wished, so that they could achieve the highest scores that they were satisfied with. Because of the variation of the problems at runtime, and the randomly picked versions (V1 to V5) of each problem (P1 to P5), the students had repetitive opportunities to work “different” problems each time they attempted a Module. This helped in strengthening individual competency and minimizing cheating.

In any Module, all the students are first offered Problem P3. Depending on their performance in this problem they will be directed to either Problem P1 or P4. If they solved Problem P3 correctly without requesting Hints, they get 100% for it and continue on to Problem P4. If they solved Problem P4 also correctly without requesting Hints, they get 100% and continue on to problem P5. On successful completion of problem P5 without the use of Hints, they receive an average score of 100% for that Module. If they solved P3 incorrectly without requesting Hints, the solution is presented, and they are offered another version of P3 after reviewing the on-line notes. Alternatively, if they requested Hints for Problem P3 and solved it correctly, they are given 80% for Problem P3 and directed to Problem P4. If students failed to solve Problem P3 correctly after reviewing the Hints, the solution will be presented. They will then be directed to Problem P1 and sequentially through the next four Problems. On completion of a Module, if the students are not satisfied with the average for that Module, they can redo that Module following the above cycle until they are satisfied with their average score. An outline of the program flow is shown in Figure 1.

The system keeps track of the progress of each student through the Modules. Information such as time spent, number of attempts, number of problems answered in the first attempt, frequency of failure to solve a problem, etc. are recorded for review by the instructor. A summary sheet is generated by the computer for each student and each Module. This information has enabled the instructor to identify not only the students who were having chronic difficulties, but also the concepts that were not well understood by majority of the students. Using such information, the instructor was able to provide further remedial instruction in a timely manner.

## RESULTS

We present summaries of student surveys as well as internal and external measures of student achievement as evidence of the value of the computerized DA system. Table I shows extracts from mid-semester student surveys about desirable and undesirable features of the DA system. The most common concern expressed by the students is their inability to get partial credit for their efforts even if the problems are not solved correctly and completely. However, when it was pointed out to them that engineers do not get partial credit in professional practice and, that examinees do not get partial credit in the licensing exams such as the FE exam, students accepted the system and the scoring policy as fair. End-of-

semester evaluations by the students collected over the past six semesters are summarized in Table II. These evaluations are generally in favor of the computer-based DA system, and most students agreed that such a system would be beneficial in other courses as well.

As an internal measure of the improvement in student achievement, we have used the percentage of students receiving a score of 70% or more in the traditional in-class tests given over a semester. Data collected over the last six semesters are presented in Figure 2, comparing the improvement among minority students (Hispanics and Native Americans) against that of others. This figure shows somewhat greater improvement among minority students, with a statistically significant positive trend. This finding is in agreement with literature studies that have reported similar results [2, 8, 9, 10, 3].

As an external measure, we have used the results of the Fundamentals of Engineering (FE) examination to assess the improvement in student achievement. The FE examination, administered biannually by the National Council of Examiners for Engineering and Surveying (NCEES), is a nationally normed exam that most civil engineering graduates take during their senior year in college. The morning section of this test covers 12 subject areas common to all fields of engineering, including fluid mechanics. A summary report of the results of the FE exam showing the number of questions answered correctly in each subject area by the students as a group is provided by NCEES to students' departments. This report also includes corresponding percentages for candidates from three comparator groups- candidates from the Carnegie 1 (Research Extensive), Carnegie 2 (Research Intensive), and Carnegie 3 (Masters) institutions, as well as the National average. We have used a performance index,  $PI$ , defined as follows to assess the improvement of our students: % of questions correctly answered by group  $j$ /National average of % of questions correctly answered in fluid mechanics.

The author has been teaching the hydraulic engineering course since 1997. Prior to initiation of the computerized system in 2000, the performance of our students in the FE exam was significantly below the National level, with average  $PI$  of 0.87 ( $\sigma = 0.148$ ). During the initial stages of the implementation of the system,  $PI$  increased to 0.96 ( $\sigma = 0.081$ ). Since implementing DA in 2004,  $PI$  has increased further to 1.04 ( $\sigma = 0.056$ ), exceeding the National performance. Since the instructor and the teaching methods have remained almost the same over the years, the increased achievement in the FE exam is primarily due to the computerized DA system. Further analysis of the FE exam results presented next support this claim.

Figure 3 compares the performance of our students in fluid mechanics against the average of their performance in all the other subjects covered in the morning section of the FE exam over the past six administrations. This figure shows that the performance of our students in the fluids mechanics area is above the National level while that in all the other subjects remains below the National level. Even though the DA system was implemented in students in the hydraulic engineering course in 2004, students in that course take the

FE exam two semesters later, when they are in the senior year. Since the computerized DA system is being used only in the hydraulic engineering course and, since our students do not take any further courses in that area, these results suggest that the higher performance in fluid mechanics area is not due to the innate skills of the student pool but due to the DA system that helped improve their learning.

Figure 4 compares the *PI* of our students against that of the three comparator groups over the past six administrations of the FE exam. This figure shows that our students are performing above the top student groups. This affirms that the higher achievement of our students is not due to fluctuations in the quality of the exam over the period, but due to the DA system that helped improve their learning. The manner in which we have implemented the system whereby students are allowed unlimited number of attempts at different versions of the problems further helped improve their learning and problem solving skills. As suggested by [13], this system provides repeated opportunities for students to make multiple connections between different concepts in different contexts that helps them solve problems in “new” contexts.

### CONCLUSIONS

The computerized DA system presented in this paper has been shown to be effective in increasing student achievement. Performance of the students in traditional in-class tests and the nationally normed FE exam has increased, mainly due to the use of this DA system. The system enables students to learn the material better by working problems by themselves with help provided by the DA system. In contrast to traditional homework assignments where students tend to work on the problems in groups, this system helps students to solve problems individually and learn from their errors by themselves, with immediate feedback and prompting. This feature of the system which promotes individual performance could be a reason for the superior performance of the students in the FE exam, which measures individual competency rather than group effort.

### ACKNOWLEDGMENT

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### REFERENCES

- [1] Campione, J. C. and Brown, A. L., “Guided learning and transfer: Implications for approaches to assessment” in *Diagnostic Monitoring of Skill and Knowledge Acquisition*, Ed. Frederiksen, N., Glaser, R., Lesgold, A. and Shafto, M. G., Lawrence Erlbaum Associates, NJ, 1990.
- [2] Daniel, M. H., “Intelligence testing”, *American Psychologist*, 52, 10, 1997, 1038-1045.
- [3] Elliott, J., “Dynamic assessment in educational settings: realizing potential”, *Educ. Review*, 55, 1, 2003, 15-32.
- [4] Embreston, S., “Diagnostic testing by measuring learning processes: Psychometric considerations for dynamic testing”, in *Diagnostic Monitoring of Skill and Knowledge Acquisition*, Ed. Frederiksen, N., Glaser, R., Lesgold, A. and Shafto, M. G., Lawrence Erlbaum Associates, NJ, 1990.
- [5] Haywood, H. C. and Tzuriel, D., “Applications and challenges in dynamic assessment”, *Peabody Jour. of Educ.*, 77, 2, 2002, 40-63.
- [6] Shepard, L. A., “The role of assessment in learning culture”, *Educ. Res.*, 29, 7, 2000, 4-14.
- [7] Burns, S., “Comparison of two types of dynamic assessment with young children”, *Int. Jour. Dynamic Assess. & Instr.*, 2, 1991, 29-42.
- [8] Hessels, M. G., “Low IQ but high learning potential”, *Educ. & Child Psych.*, 14, 1997, 121-136.
- [9] Tzuriel, D., “A novel dynamic assessment approach for young children”, *Educ. & Child Psych.*, 14, 1997, 83-108.
- [10] Robinson-Zanartu, and Aganza, J. S., “Dyanmic assessment and sociocultural context”, in *Dynamic Assessment*, Ed. Lidz, C. S. and Elliott, J. G., Elsevier, New York, 2000.
- [11] Nirmalakhandan, N., “Computer-aided tutorials and tests for use in distance learning”, *Wat. Sci. & Technol.*, 49, 8, 2004, 65-71.
- [12] Nirmalakhandan, N., Computerized adaptive tutorials to improve and assess problem-solving skills, To appear in *Computers & Educ.*, 2007.
- [13] Clough, M. P. and Kauffman, K. J. “Improving engineering education: A research-based framework for teaching” *J. Engrg. Educ.*, 1999, p 527-534.

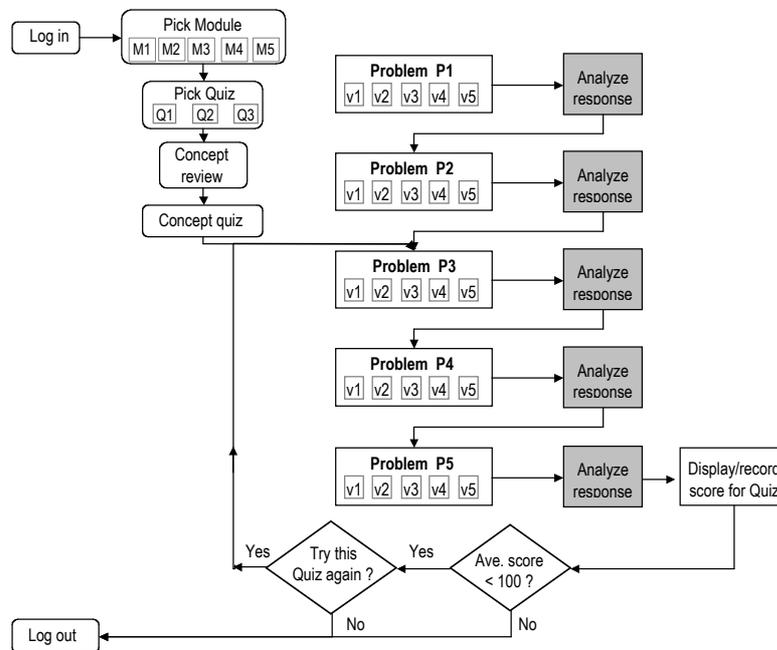
TABLE I

#### EXTRACTS FROM MID-SEMESTER STUDENT SURVEYS

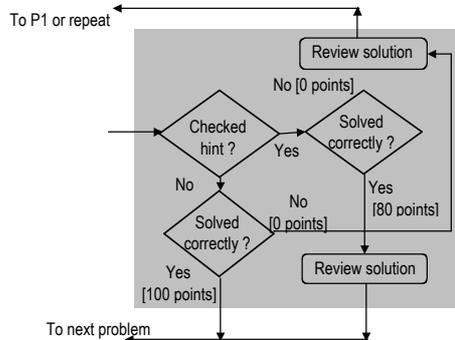
Desirable features	Undesirable features
<input type="checkbox"/> Instant feedback on assignments	<input type="checkbox"/> We don’t get partial credit
<input type="checkbox"/> Feedback and hints helped me solve problems myself	<input type="checkbox"/> Grading is harsh
<input type="checkbox"/> Ability to improve grades by trying again and again	<input type="checkbox"/> Computer lab gets crowded at times
<input type="checkbox"/> Hints and solutions clarified my understanding of the subject	<input type="checkbox"/> I could improve my grades if more time is allowed
<input type="checkbox"/> Learned how to solve problem	
<input type="checkbox"/> Efficient use of my study time	
<input type="checkbox"/> Exposure to different forms of the same problem	

TABLE II  
SUMMARY OF END-SEMESTER STUDENT SURVEYS

	SD	D	N	A	SA
1 The computerized system is preferable to the traditional assignments	0	0	0	22	78
2 The feedback/help provided by the computer system was beneficial to me	0	0	0	16	84
3 I did not need any help from my friends or the instructor to solve the problems	0	0	0	10	90
4 I would have preferred a Teaching Assistant to help me with the problems.	40	56	3	1	0
5 I would have scored better if I had worked the assignments with my friends	11	83	5	1	0
6 I was able to understand the material well through this system	0	0	0	17	83
7 I believe the system was fair and gave me the final score that I deserved	0	1	0	14	85
8 I would prefer similar computerized system in other courses as well	0	0	5	17	78



1a. Main program flow



1b. Details of response analysis

FIGURE 1.

SCHEMATIC OF COMPUTERIZED DYNAMIC ASSESSMENT SYSTEM

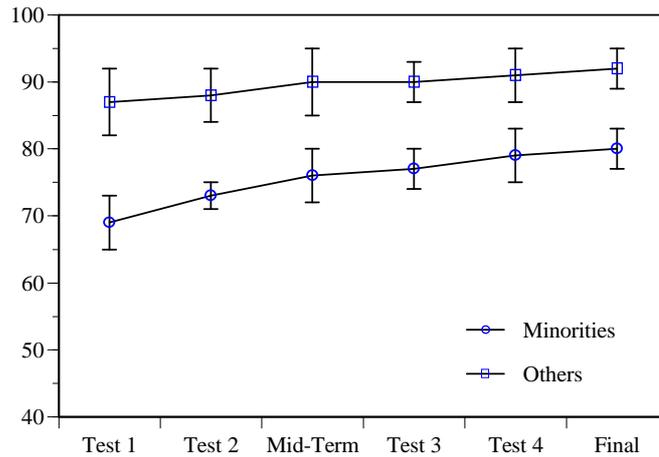


FIGURE 2.  
IMPROVEMENT IN TEST SCORES OVER A GIVEN SEMESTER  
(DATA AVERAGED OVER 6 SEMESTERS: SP 04 TO FA 06)

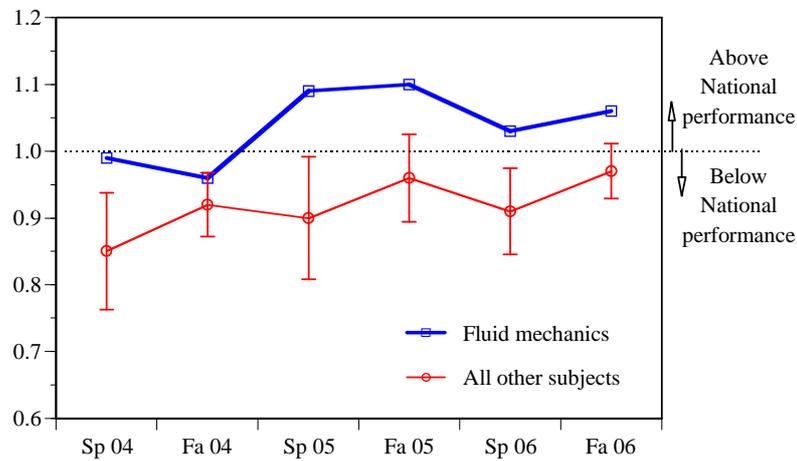


FIGURE 3.  
PERCENTAGE OF QUESTIONS CORRECTLY ANSWERED BY NMSU STUDENTS  
RELATIVE TO NATIONAL PEERS IN THE AM SECTION OF THE FE EXAMINATION

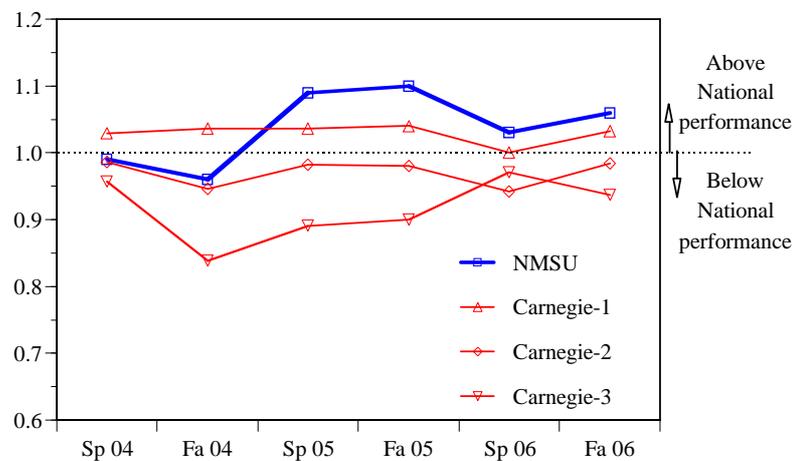


FIGURE 4.  
PERCENTAGE OF QUESTIONS CORRECTLY ANSWERED IN FLUID MECHANICS AREA  
IN THE FE EXAMINATION BY NMSU STUDENTS RELATIVE TO NATIONAL PEERS