Rapid Evaluation On-Line Assessment of Student Learning Gains for Just-In-Time Course Modification

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Abstract—**Internet-based multiple-choice assessments administered on a pre/post basis offer rapid and automatic evaluation of student learning outcome achievement. Data from on-line assessments are available instantly with little instructor time or labor, providing feedback rapid enough to facilitate "Just-In-Time Course Modification," the immediate use of pre/post results by an instructor to adjust content delivery techniques to complement students' learning styles in the current class. Unlike post-tests alone, which only gauge cumulative knowledge and skill, performance comparisons between a pre-test given prior to content delivery and a post-test given immediately after content delivery quantify what students learned from the class session, providing a direct measure of content delivery effectiveness. This approach also enables comparisons between different content delivery methods. Engineering education practitioners can use this method to test the knowledge base and learning styles of their students and rapidly adjust course content and delivery methods to accommodate the needs of a particular cohort. Here, this assessment technique is validated by showing that it differentiates between student learning outcome achievement arising from a traditional lecture versus an in-class group-based problem-solving exercise. This result is consistent with previously reported engineering education literature results that use conventional assessment techniques.**

Index Terms—**Instant and Automatic Assessment, Just-In-Time Course Modification, Online Pre/Post Assessment**

Introduction

Well-designed Internet-based assessments can rapidly, practically, and automatically evaluate student learning outcome achievement while being easily implemented by engineering education practitioners. Once deployed, online assessments that map directly to course learning outcomes allow instructors to quickly measure student achievement without labor-intensive manual grading. Moreover, results are instantaneously available; a turnaround so rapid that instructors can use this feedback to evolve course content and delivery methods in days.

We coin the phase "Just-In-Time Course Modification" to describe this technique - immediately using student pre-/post test results to reinforce weaknesses revealed through the assessments and deploying content delivery techniques that complement students' learning styles. For example, when starting each new course module, an engineering instructor could use an on-line pre-test to measure students' existing knowledge and tailor lectures to focus on material students do not already know. An identical on-line post-test would then probe knowledge and skills gained to provide quantitative feedback on effectiveness of the content delivery technique. In the next class module, the instructor could use a content delivery method matching the revealed learning style of the student cohort to educate the class more effectively.

According to Sherry, the instructor must have knowledge of students' preferred mode of learning to teach effectively, and if the instructor makes material delivery adjustments to accommodate different learning styles represented in a class, student success is positively influenced [1]. On-line assessments can rapidly reveal students' knowledge base, cognitive reasoning abilities, and learning styles. Performance comparisons between a pre-test given prior to a class session and a post-test given after the class session quantify what students learned from the content delivery method of that session, providing a direct measure of the instructor's teaching effectiveness. Critically, pre/post on-line assessments can also gauge students' learning styles and measure the effectiveness of various content delivery methods in addressing those styles. Thus, a well-designed instrument provides comparisons between different content delivery methods and quantifies their impact on student achievement of learning outcomes. By using this technique to measure and identify which educational delivery methods are most effective for engineering subjects and student cohorts, student learning can be optimized and student achievement in engineering courses improved.

Here we report results of a pre/post on-line assessment evaluation to test the effectiveness of this approach in discerning between two different content delivery methods in an introductory engineering course. We show that this technique differentiates with adequate statistical significance between student learning arising from a traditional lecture versus an in-class group-based problem-solving exercise. Measured outcomes are consistent with results previously reported in the engineering education literature that used techniques too slow or labor intensive to accommodate Just-In-Time Course Modification. While existing conventional techniques are sound for engineering education research, they require more time and labor to implement than on-line assessments and cannot be used by practitioners to expediently modify their current course. On-line pre/post assessments are so facile that any engineering instructor can use this technique for a class section of any size to extract student learning style information and outcome achievement data to better tailor class content delivery methods to meet students' needs. Near-instant access to these data allows instructors to implement Just-In-Time Course Modification to create the best learning environment for each cohort of students.

I. BACKGROUND

Comparisons between different course content delivery techniques pervade the education literature, and the outcomes of these studies remain in conflict. For example, student achievement in a hybrid on-line course versus face-to-face lectures was evaluated by Ernst [2]. Summative assessment results were compared for students in two successive offerings of a technology education course on digital photography. Only post-tests were used, meaning students' cumulative knowledge was measured and not solely what they learned in the course. The study found no significant difference between the cumulative assessment scores of those students enrolled in traditional instruction compared to those enrolled in online instruction. By contrast, Reasons, et al used an assessment technique similar to Ernst but found that students in pure Internet-based sections outperformed pupils in both traditional and hybrid sections based on course grade [3]. Subjects of the Reasons, et al study were from two courses: Introduction to Educational Psychology and Introduction to the Health Care Delivery System. Inconsistent results between these two reports might be explained by differences in the cohorts studied. Most students of Ernst (mostly technology education majors) could have had different learning styles than the students of Reasons, et al (mostly healthcare majors). It is to be expected that cohorts of students with dissimilar interests (and perhaps different learning styles) performed differently when exposed to on-line versus face-to-face content delivery.

With respect to engineering students, Mourtos and McMullin compared outcomes in a required junior-level fluid mechanics course and a graduate-level seismic design class [4]. Both courses were taught in two sections with one section being face-to-face and the second being on-line. In the undergraduate fluids course, the face-to-face cohort performed significantly better with 82% of students earning A's or B's versus only 31% of on-line students. Moreover only 4% of the face-to-face students failed while 46% of the online students failed. Online students who failed were not keeping up with their weekly assignments, nor were they seeking help. By contrast, outcomes in the graduate seismic design class were more closely matched with face-to-face students, earning 100% A's or B's versus 87% of on-line students. Mourtos and McMullin speculate that the dramatic differences in achievement observed between these two courses with respect to the on-line students resulted from higher levels of discipline expected among graduate students. Importantly, this result shows that learning styles and discipline can change significantly even among engineering students spaced only a year or two apart in school. Learning styles can also change among different cohorts of students in adjoining class years. In other words, a content delivery technique that was successful with last year's juniors might not be as successful with this year's juniors because the learning style makeup of each cohort is different.

A pre-/post-test diagnostic tool comparable to the method in this paper was developed by Dollár and Steif [5]. The test consisted of 110 college students enrolled in an Engineering Statics course. The students were assigned to complete nine online modules and were quizzed over the content for 2% of their overall course grade. Pencil and paper quizzes were given before class (a pre-test) and immediately after (a post-test). Dollár and Steif concluded that test scores closely correlated with duration of on-line module usage. The authors further infer that if learning outcome achievement and learning style data could be properly interpreted and delivered in a timely manner, the information could be insightful for the instructor as well as the students. However, the pencil and paper assessment technique did not provide rapid enough feedback for Just-In-Time Course Modification.

Another effective engineering student assessment technique too labor intensive to accommodate Just-In-Time Course Modification is video/audio recording of student interactions. Pembridge et al compared design processes of two sophomore-level student teams [6]. While both teams met face-to-face during class, outside of class, one team exclusively used remote meeting technology for collaboration while the second team met face-to-face. Despite both teams converging to very similar final designs, the virtual meeting team was more goal oriented. Data were collected for this study by videoing each team's interactions and transcribing audio recordings to obtain additional dialog detail.

By contrast, the pre/post online assessment approach piloted here is an easy, fast way for engineering education practitioners to obtain information about their students and apply it rapidly enough to address the needs of their current classes. Importantly, the study described in this paper contains at least five unique attributes.

1) Statistical comparisons of pre/post on-line assessments measure students' learning exclusively due to exposure to the class; not just their overall knowledge, as measured by un-paired post-tests or the amount of time on-task.

2) Automated on-line assessments dramatically reduce faculty labor and time required to obtain results, even for a large class (i.e., co-author Traum routinely assesses course sections with enrollments above 150 students [7,8]). This technique is therefore applicable to engineering education practitioners. For example, compare the ease of automated data collection and extraction from on-line testing to the research of Pembridge et al, which required audio transcription [6].

3) Past studies compare face-to-face with on-line and hybrid teaching methodologies. The current method uses on-line assessment to compare two face-to-face teaching methods intentionally tailored to different student learning styles.

4) Instead of using course or assignment grades to assess student performance (which is considered an inaccurate assessment technique [9]), this study gauges student performance on individual questions mapped directly to course learning outcomes with no consideration of the overall course grade.

5) Instead of a focus on identifying the superior content delivery method for a particular engineering course or student cohort, this paper introduces an approach allowing

engineering practitioners to assess different delivery methods on their own. We validate this approach by comparison to existing benchmark literature results.

To demonstrate validity of the pre/post on-line assessment method for course content delivery evaluation, two course content delivery methods were intentionally selected that are known to induce different learning responses in most engineering students: lecture and in-class group work. According to Felder and Silverman of the 32 identified learning styles, most engineering students are visual, sensing, inductive, active, and global [10]. These types of students are more comfortable with and responsive to active in-class exercises beyond simply listening and watching: discussion, asking questions, arguing, brainstorming, or reflecting. Passive learners, which are in the minority among engineering students, are more comfortable in lecture-based learning environments.

A group-based learning environment where students work in teams to answer questions is an example of active learning, which should resonate strongly with most engineering students [11]. Therefore, it is expected that more students will demonstrate a larger increase in learning from in-class collaboration than from a conventional instructor-delivered lecture because the latter is an example of passive learning. This result is validated by a comprehensive multi-year study (that did not employ on-line assessments to evaluate learning) by Roselli and Brophy, which taught identical course content using two different approaches [12]. Immersing engineering students in a challenge-based instruction (CBI) environment induced better performance than a traditional lecture environment because the CBI classroom encouraged active learning. Moreover, compared to traditional lecture students, CBI students demonstrated elevated achievement in tasks demanding high cognitive reasoning.

A study with an enormous sample size surveyed pre-/post-test data in 62 introductory physics courses enrolling a total of 6,542 students [13]. Of the participating courses, 14 were taught using "traditional" lectures while 48 used interactive-engagement methods. This author found that students in the interactive-engagement learning environments achieved an increase in conceptual understanding almost two standard deviations above students in traditional courses. These results demonstrate that student achievement does change in a measurable way when identical content is presented via different teaching delivery methods. It also indicates that delivery methods emphasizing active learning promote higher student achievement, particularly on more cognitively challenging tasks.

II. METHODOLOGY

Before the study Institutional Review Board approval was obtained from the University where the research took place. Students were informed of the study's purpose in advance and could voluntarily opt out with no adverse impact to their course grades. Opt-out students still completed the pre/post assessments as these on-line exams are normal course components, but their results were excluded from the study.

The study was conducted in an entry-level one-semester-credit-hour undergraduate course required for all the engineering department's students. This seminar-based course emphasizes engineering ethics and professional conduct. It is taught once per year in the spring semester and is led by a single instructor who previously taught the course three times. The instructor teaches the engineering ethics component of the class, which lasts 10 weeks. Engineering practitioners from industry are invited to class during the remaining 5 weeks to discuss engineering professionalism and practice [14,15]. Collected data reported here arise from the course module on the "Ethics of Sustainability," which lasts one week and covers a single chapter in the course textbook.

The 38-question on-line assessment was administered using the Blackboard assessment function, and all 38 multiple choice questions were developed in sets and validated following the "outcome-based assessment" test item development scheme of Turner and Carriveau [16]. In the study's first semester, 50 students opted to participate in the study (56 were enrolled), and in second semester, 73 students opted to participate (74 were enrolled). In both years, students were given the 38-question on-line pre-test in the week prior to the associated lecture covering the material. The assessment was completed by students individually outside of class. As the pre-test was being announced, students were reminded of the purpose of the study, and they were instructed not to read the textbook or prepare in any way for the pre-test because its purpose was to provide an accurate measurement of what course content the students knew before enrolling in the class. A completion grade of 3 points was given regardless of the students' performance on the pre-test to compel completion. Although the pre-tests were automatically graded and scores were released to students, the students were not told which pre-test questions they had answered correctly.

A. *Content Delivery Method 1: Traditional Lecture*

After the pre-test was closed, the instructor presented a traditional 50-minute face-to-face lecture to the class supported by overhead slides. As with any lecture, students had the opportunity to ask questions about the material as it was delivered. All the lecture slides were posted on the course Web site for students to freely access after class. At the end of the lecture, students were instructed to read the relevant textbook chapter and respond to a post-test, which was a set of questions identical to the pre-test. Students were told to work individually to complete the post-test. They were given a grade on the post-test based on how many of the 38 questions they answered correctly, and this grade along with the pre-test completion points was factored into their course grade. After the post-test was closed, student inputs were automatically graded. The raw pre-/post-test scores were then collected and analyzed using embedded tools within Blackboard.

B. *Content Delivery Method 2: Self-Directed Peer Groups*

In course's next semester, the same process was followed with respect to the pre/post assessment. The only difference between semester was that instead of passively absorbing a lecture between the pre-test and post-test, the second student cohort worked in self-selected groups of two to five to answer the post-test questions in class. No lecture was given to the second cohort. Everyone received a print-out of the slides from the relevant lecture delivered by the instructor in the previous year. Students were also given hard-copy printouts of the 38-question assessment to help guide their group discussion and manually record the answers they converged upon with their groups. The instructor was available during the period and roamed the classroom to answer students' questions concerning the exercise and the given information. Upon completion of the 50-minute class meeting, students could take home with them the hard-copy lecture notes and assessment question printouts, which they had marked up during the group exercise. Students were then to enter their answers to the online post-test individually on their own time outside of class. After class, a redundant copy of the lecture notes was posted on the course Web site to provide the same electronic access to these notes that the earlier student cohort had.

C. Statistical Evaluation of Data

Pre-/post-test data were evaluated using the "Comparing Proportions From Two Independent Samples" statistical method to determine whether the two content delivery methods produced any difference in student performance at a 95% level of confidence. To account for changes in students' knowledge and abilities between the pre-test and post-test arising from course exposure, this statistical method was applied to the differences in pre/post performance for students receiving the lecture as well as the group work. As shown in Figure 1, this approach tests the probability of three unique outcomes. To test whether a higher proportion of students working in groups answer more questions correctly than individuals in the lecture, the following null hypothesis was chosen: "There is no statistically significant difference between the proportion of increased correct student responses after participating in a group learning exercise verses the proportion of increased correct student responses after receiving a lecture," and the following alternative hypothesis was chosen: "The proportion of increased correct student responses after participating in a group learning exercise exceeds the proportion of increased correct student responses after receiving a lecture".

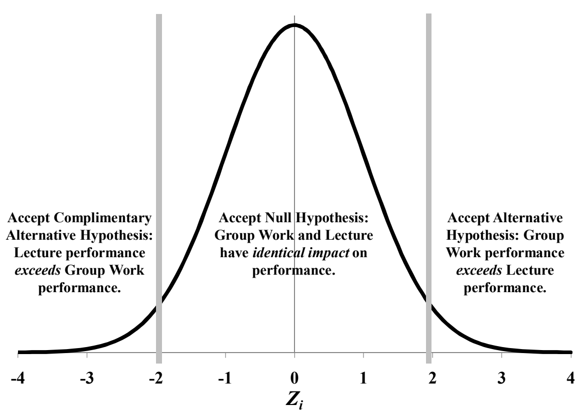

Figure 1. Diagram illustrating three possible outcomes for statistical testing of the null hypothesis and its alternatives at a 95% confidence level.

Under scrutiny was the proportion of increased number of correct student answers on each individual question between each pre-/post-test. However, the number of participants between each pre-test varied slightly from each post-test in both cases [Lecture: Pre = 50, Post = 49 and Group Work: Pre = 70, Post =73]. So, the pooled proportion for each individual question, $\hat{p}_i$, used for statistical evaluation is

$$\hat{p}_i = \frac{\overline{n_{lec}}p_{i,lec}+\overline{n_{grp}}p_{i,grp}}{\overline{n_{lec}}+\overline{n_{grp}}} \qquad (1)$$

Where $\overline{n_{lec}}$ $(= 49.5)$ and $\overline{n_{grp}}$ $(= 71.5)$ are the average numbers of pre/post student respondents receiving content delivery by lecture and by group work respectively, and $p_{i,lec}$ and $p_{i,grp}$ are the proportions of increased correct responses for each individual question number, i, between pre- and post- tests given to students receiving content via lecture or via group work respectively. The calculated standard error for each assessment question is therefore

$$\hat{S}_i = \sqrt{\left(\hat{p}_i(1-\hat{p}_i)\right)}\sqrt{\frac{1}{\overline{n_{lec}}}+\frac{1}{\overline{n_{grp}}}} \qquad (2)$$

and the test statistic for each assessment question, z_i, is

$$z_i = \frac{p_{i,lec}-p_{i,grp}}{\hat{S}_i} \qquad (3)$$

If z_i for a particular question exceeds 1.96, the critical value for 95% confidence attainment, the null hypothesis is rejected for that question. For 27 out of 38 questions, the null hypothesis is rejected. The alternative hypothesis is true for 23 out of 38 questions, indicating that for over 60% of the questions, the positive performance enhancement (at a 95% confidence level) in correct responses from students performing group work exceeded the positive performance enhancement from students sitting in the lecture.

To test whether a higher proportion of students in the lecture answer more questions correctly than individuals working in groups, the following complimentary alternative hypothesis was chosen: "The proportion of increased correct student responses after receiving a lecture exceeds the proportion of increased correct student responses after participating in a group learning exercise." The proportion of all questions (4 out of 38) in which the null hypothesis is rejected and the complimentary alternative hypothesis is true indicates that for less than 11% of the questions, the positive performance enhancement (at a 95% confidence level) in correct responses from students sitting in the lecture exceeded the positive performance enhancement from students performing group work.

III. RESULTS

The statistical results show that on over 60% of the questions, overall class performance in the cohort participating in group work demonstrated a larger improvement on the post-test than the class who sat through lecture. On less than 11% of the questions, students in the lecture cohort showed more improvement on the post-test than the group work class. On the remaining questions (about 29%), there was no difference in student learning between the two content delivery methods.

To demonstrate these results, student achievement data were visualized in two ways. First the percentage of participating students answering each question correctly on the lecture-based pre-/post-tests (Figure 2) and the group-work-based pre-/post-tests (Figure 3) were plotted to quantify student learning resulting from exposure to each class session type. Second, the pre/post differences in the percentages of participating students answering each question correctly for lecture-based and group-work-based assessment were plotted together in Figure 4. This representation illustrates different student learning performance from the two disparate content delivery methods. Consistent with statistical results, the increase in percentage of students answering correctly from the group-work-based cohort exceeds the lecture-based cohort for 31 of the 38 questions (23 of those cases are statistically significant at the 95% confidence level).

While the same faculty member taught both the classes, his direct handling of the data could potentially have introduced some form of bias into the results. To eliminate the possibility of instructor-induced bias, a different researcher who is external to the university, has no connection to the and does not know the students processed all the data to ensure that a formal, objective approach was used.

IV. DISCUSSION

As expected, both face-to-face lecturing and in-class group-based problem-solving methods induced positive impacts on student learning. The percentage of students answering correctly increased between pre-tests and post-tests on 33 of 38 questions from lecture exposure (Figure 2) and on 36 of 38 questions from group-based problem solving (Figure 3).

Importantly, pre/post assessment data allow for two unique types of student performance comparison. As stated previously, post-test data evaluated alone provides a measure of total cumulative student knowledge and skill, which is a composite of development from exposure to a class along with innate ability and knowledge prior to enrolling. Additionally, variations in pre/post data isolate the change in students' knowledge and skill resulting directly from exposure to a class. Comparisons among student cohorts and content delivery methods using this later type of data specifically illuminate student learning styles and effectiveness of content delivery methods because student knowledge and skill prior to enrollment is effectively filtered out, meaning observed changes arise only from course exposure.

Consistent with the results of Roselli and Brophy and Hake, students engaged in active learning outperformed the passive learning traditional lecture group along both axes of comparison. First by contrasting the post-tests, a larger percentage of the active learning group students got more questions right (26 out of 38). Second by contrasting the percent change (Figure 4) between two groups (i.e., the increase in learning derived directly from the course), the active learning group displayed a larger percentage increase on 31 out of 38 diagnostic test questions.

Among these two cohorts of engineering students, the students subjected to an active learning approach demonstrated a statistically significant increase in learning (at the 95% confidence level) for 23 of the questions owing to exposure to active learning group work versus a passive learning lecture. The result is exactly the outcome anticipated based on previous research asserting the active learning styles of most engineers. [12,17]. Critically, this outcome confirms that the on-line pre/post assessment method returns a valid result for these cohorts of engineering students and selections of active-/passive-learning content delivery methods.

Importantly, these results were obtained instantly and automatically via Internet-based assessment and analysis using much less instructor time and labor than similar student learning gains assessment techniques appearing in the engineering education literature. For Just-In-Time Course Modification, results were available immediately after the post-test closed, and they could be used to inform modified content and delivery techniques in preparation for the next ensuing class session. This pre-/post-test assessment diagnostic technique can be rapidly applied to any area of engineering study to give a more specific picture of student learning styles than through post-tests alone. The technique allows engineering education practitioners the opportunity to use assessment tools previously used only by education researchers to assess student education needs and rapidly modify course content and delivery accordingly.

This study carries some important limitations that must be mentioned and considered. First, no attempt was made to match student demographics from year to year, and no adjustment was made in the data to account for gender, race, years in college, or previous grades. Second, an important general criticism for the pre/post approach is that by seeing all the assessment questions in advance, students can anticipate what elements of the lecture were relevant to their grades and ignore the rest. It might also be argued that prior assessment question knowledge enhanced post-test performance. While this drawback could be true, it did not appear in the results. Even with this advantage, students performed better after the active learning group exercise than the passive lecture, showing that the approach still provides valid information about students' learning styles. If students had used the pre-tests to enhance their post-test performance, results from the two content delivery methods would be expected to be equal, and they were not. Third, the study does not drill down to the level of individuals but merely reports results from large engineering classes of 56 to 74 students. Thus, by using the class-scale on-line assessment approach described, it is possible that a small minority of students whose learning styles are inconsistent with the content delivery methods selected to resonate with most of the class will be poorly taught. Although this study reports results at the class level, data for individual students can also be analyzed in Blackboard to glean individual learning styles and signal need for personal attention or intervention. Fourth a specific criticism of the method used here is that by working in groups, under-performing students could blindly glean the correct answers to assessment questions from higher performing students without appreciating why the given answers were correct. The possible viral dissemination of correct answers to under-performing students might account for the result differences between the two classes.

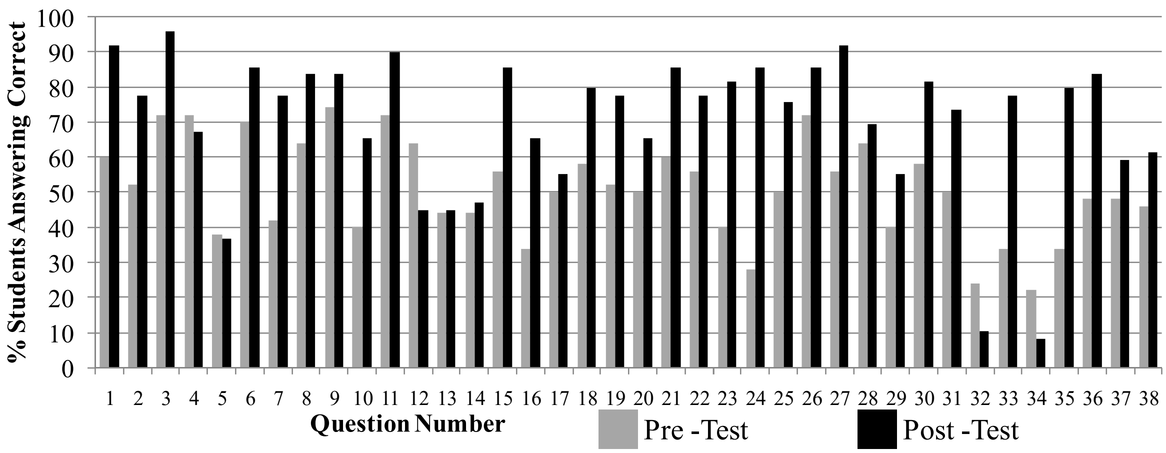

Figure 1. Percentage of participating engineering students answering each of 38 assessment questions correctly on pre- (N = 50) and post-tests (N = 49). Students in this cohort received a traditional face-to-face lecture covering course content between the pre- and post-tests.

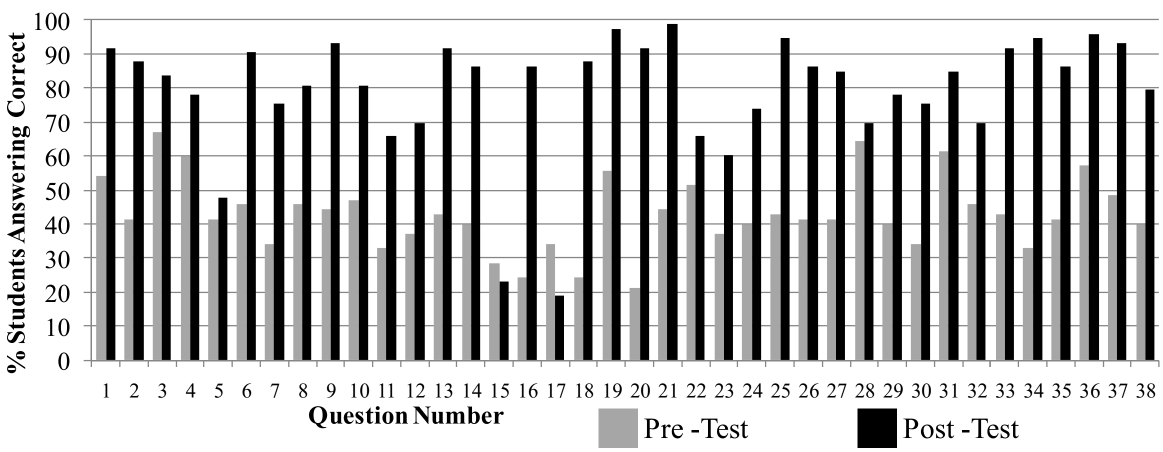

Figure 2. Percentage of participating engineering students answering each of 38 assessment questions correctly on pre- (N = 70) and post-tests (N = 73). Between the pre- and post-tests, students in this cohort worked in self-assigned groups of two to five individuals during class to answer assessment questions.

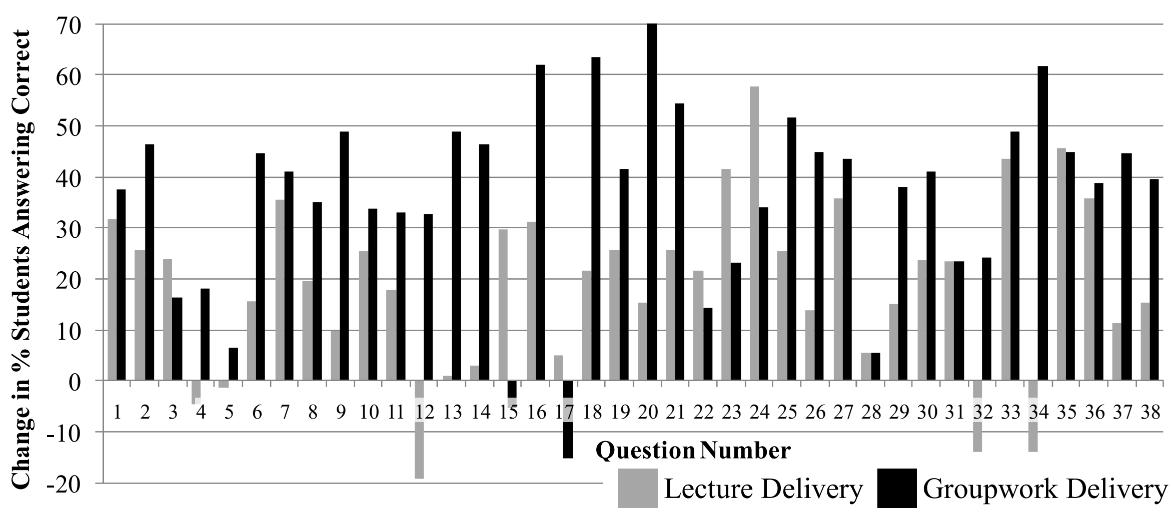

Figure 3. Comparison of the pre/post change in percentage of participating engineering students correctly answering each of 38 assessment questions.

Moreover, there are some important anecdotal instructor observations from the in-class group-based problem-solving exercise that deserve mention. First, while role was taken in both classes, the instructor made no effort to prevent students from leaving either the lecture or the group-work-based session. Upon realizing that no lecture would be given in the group-based session, about 5 students out of 74 enrolled immediately left the class and did not partake of the group exercise. Second, on more than one occasion, the instructor encountered a group in which the students had divided the problems among themselves with the intent of having individuals answer a subset of questions and share results with the group. This observation tends to validate the criticism of viral results dissemination, and this valid criticism is being addressed by a planned future study to convey content to students in active learning mode while isolating them from each other.

On the other hand, most groups were observed working collectively on each individual problem one at a time. Group dynamics attributed to active learning were observed from all members of most groups: reading, discussion, problem solving via reasoning, analysis, synthesis, and evaluation [18]. A secondary benefit of the group-based exercise was faculty-student interaction that illuminated unexpected student reasoning processes. While the assessment questions were validated using small groups of engineering students prior to formal release of the questions, the students in the course conveyed logical thought processes to the instructor as he was circulating in the class that led them to select incorrect answers (especially for the problems of the highest cognitive complexity). These interactions allowed the instructor to correct misconceptions or errors in students' deduction processes. However, in one case, a group of students was able to convince the instructor that two of the given answers to a multiple-choice assessment question were both viable solutions. These important interactions, which could not easily occur in a lecture-based passive learning environment, enabled the instructor to improve the on-line pre-/post- assessment for future course offerings.

V. CONCLUSIONS

The effectiveness and speed of an on-line pre-/post-assessment to measure students' increase in knowledge and skills exclusively from exposure to two different classroom content delivery approaches was validated by comparison between two cohorts of lower-division engineering students. The following specific conclusions were drawn from this study.

1) Both face-to-face lecturing and in-class group-based problem-solving methods induced positive impacts on student learning.

2) While post-test data evaluation alone provides a measure of total student knowledge and skill (a composite of what students knew before the class and what they gained from the class), variations in pre/post data isolate the change in students' knowledge and skill resulting directly from exposure to a class. This comparison provides a measure of student learning styles and content delivery effectiveness.

3) By delivering well-designed pre-/post-assessments through an automated, on-line, multiple choice medium, engineering education practitioners can easily and rapidly determine the predominant learning styles in each class cohort and adjust content delivery methods accordingly. Using conventional engineering education assessment techniques, these data are not available rapidly enough to implement Just-In-Time Course Modification.

4) Students engaged in active learning outperformed the passive learning traditional lecture group in terms of cumulative knowledge and skill and increase in knowledge and skill attributed directly to class exposure. This result agrees with previous studies that compare engineering student performance in active/passive learning environments.

5) The on-line pre/post assessment method returns a result consistent with existing engineering education studies. This outcome demonstrates that the on-line pre-/post-assessment technique is a valid alternative approach to conventional assessment. However, this approach is much more rapid and less labor intensive than existing methods.

6) Students participating in the in-class group-based problem-solving exercise demonstrated behaviors that can both reinforce and invalidate the validity of the on-line pre-/post assessment. Most groups observed by the instructor displayed active learning behaviors that reinforce their resonance with the intended learning environment. However, a few groups enabled behaviors allowing correct answers to be virally transmitted to students who did not understand why the result was correct, possibly skewing the results.

This paper demonstrates that a well-designed Internet-based assessment can rapidly, practically, and automatically evaluate student learning outcome achievement, giving results consistent with conventional assessment techniques in the engineering education literature. Data from on-line assessments is available instantly with little instructor time or labor, and it can be used for Just-In-Time Course Modification to focus content on gaps in student knowledge and tailor delivery methods to the unique learning styles of each class cohort. Unlike conventional assessment techniques used by engineering education researchers with long elapsed time and heavy labor requirements to extract data, automatic on-line assessment can be used by engineering education practitioners to rapidly evaluate students' needs and implement Just-In-Time Course Modification to create the best learning environment for each cohort of students.

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