**Session 2570**

# An assessment of the redesigned Computational Methods course at the University of Michigan.

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Abstract

In the spring of 2000, the junior level Computational Methods for Engineers and Scientists course at the University of Michigan was redesigned as part of the Department of Civil and Environmental Engineering curriculum restructuring. The broad objective of the old computational methods course was to apply numerical methods to solve various problems in engineering and science. The redesigned course has similar objectives to the original course, however a computer laboratory section was added and the presentation of material was changed. Previously, numerous alternative solution methods were covered in a very deductive matter. Now, fewer solution methods are introduced and the class is taught more inductively with a problem solution approach. The instructors consider the redesigned course to be a vast improvement over the old course; however, a more quantitative evaluation of the effectiveness was desired. The first comparison was of the student evaluations for the two courses. While student evaluations are not the best indicator of a successful course, they can give an indication on how the course is being received. The second comparison was of the results of an assessment quiz that was developed for this study. The quiz consists of a multiple-choice test along with a qualitative rating system of course effectiveness. The quiz was designed to be administered one year after course completion to determine the effect the new course has on material retention and the overall student view of course usefulness. The assessment quiz was administered in April of 2000 to a group of students who completed the old version of the course. The quiz was subsequently administered in March of 2001 to students who completed the redesigned version of the course. The assessment quiz results provide an indication of how effective the redesigned course is at teaching numerical methods.

## Course Description

The College of Engineering at the University of Michigan recently underwent a restructuring of its engineering curriculum as part of its Curriculum 2000 initiative. The object of the restructuring was to strengthen the undergraduate curriculum and to better address the needs of future engineers. Curriculum 2000 officially listed eleven educational outcomes that undergraduates of the college will have upon graduation. To obtain these outcomes, all departments underwent an internal review to update and improve their undergraduate course offerings. One effect of this review was that courses were updated and viewed in the context of the entire curriculum. In the end, every undergraduate course in the Civil and Environmental Engineering Department was altered to address one or more of the individual outcomes.

The junior level Computational Methods course has always had the broad objective of showing students how to utilize numerical techniques to solve engineering problems. According to the 1998-1999 university catalog, before restructuring, the course is described as:

> CEE 303. Computational Methods for Engineers and Scientists.
> Prerequisites: Eng 101, Math 216 (3 credits)
>
> Applications of numerical methods to problems in various areas of engineering and science; personal computer case studies; development and comparison of techniques for roots of non-linear equations, simultaneous linear algebraic equations, curve fitting, numerical integration, and ordinary differential equations. Lecture.

In the 1999-2000 university catalog the course description changed to:

> CEE 303. Computational Methods for Engineers and Scientists.
> Prerequisites: Eng 101, Math 216 (4 credits)
>
> Applications of numerical methods to infrastructure and environmental problems. Development of mathematical models and computer programs using a compiled language (FORTRAN). Formulation and solution of initial and boundary value problems with emphasis on structural analysis, fluid flow, and contaminant transport. Lecture, recitation and computation.

At a glance, there is very little difference between the two courses, with both versions of the course having the same title, designation number, and prerequisites. However, closer inspection reveals two significant differences. The first is the addition of a credit hour. The re-designed course has the same three hours of lecture, but an additional three-hour computer laboratory was added to the course. The second exists in subtle word differences in the course descriptions. Both versions stress the application of numerical methods to solve problems, but that is where the similarities end. When comparing the descriptions, the old version of the course description reads, "development and comparison of techniques for …", while the new version has been rephrased to, "formulation and solution of…" This change of wording represents a pedagogical change in the way the course is being taught.

In the original format of the course, the students were taught very inductively with numerical techniques presented first and solution routines second. For example, when determining the root of an equation, the students first learned about alternative root determination techniques. The students were presented as many as five solutions techniques including Bisection, Newton-Raphson, Secant, False Position, and Open Iteration. The techniques were discussed in detail with information on theoretical development, applicability, and convergence. The students then had to solve problems using each where the problems were typically mathematical functions without specific physical meaning. Finally, the students were presented a problem with physical meaning and were required to write a computer program using a language of their choice implementing one or more of the root determination techniques.

In the redesigned course, the approach is more inductive. The discussion typically starts with a problem similar to the one that concluded the original approach. After the students are presented with the physics of the problem, they are shown a couple of approaches that could be used to find the solution. For example, root determination is now introduced by the necessity of determining uniform flow depth in open channel hydraulics. After the problem is introduced in class, two root determination techniques (Bisection and Newton-Raphson) are developed. The students then use the computer laboratory section to develop a code that solves an open channel flow problem. The root determination portion of the program is included as a subroutine that is general enough to be easily applied to other problems requiring the determination of a root. By the end of the class the students have developed subroutines for numerous mathematical functions that they could apply to other problems that require programming.

Course Goals

The instructors of the redesigned course had three primary goals in mind with the new course:

- To increase retention of the course material.
- To integrate the material with the rest of the civil engineering curriculum.
- To improve the overall "usefulness" of the course.

The instructors believe that the new format will improve student comprehension and retention of the material. Instead of students concentrating their efforts on learning numerous alternative methods, they now only investigate a couple of techniques. This approach is more practical since students still get an appreciation for numerical solution techniques and applications without laboring on the details of numerous methods they likely will never apply. Also, numerous studies have indicated that a majority of undergraduate engineering students have a preferentially inductive learning style. The redesigned course should cater to a larger portion of the student body.

As part of the restructuring, the instructors hope to better integrate the course material into the rest of the civil engineering curriculum. This is accomplished by introducing a variety of civil engineering problems that should be covered in more detail in other courses. For example, the students now solve problems on topics such as open channel flow, beam deflection, contaminant transport, and heat transfer. Students may not fully understand the complexities of the individual problems, but they can better appreciate the numerical methods used for their solution.

The final goal is less definable. The instructors wanted to improve the overall "usefulness" of the course as perceived by the students. In general, the old version of the course was not well received. A majority of students did not see the relevance of a numerical methods course and tended to only be concerned with short term goals, i.e. getting a good grade. The instructors hope that the redesigned version of the course is received more positively than the old version. It is hypothesized that if the students can see the use of the material, they will retain more of the knowledge and continue to apply it in the future.

Overall, the instructors consider the redesigned course to be a vast improvement over the old version of the course. The modifications seem to address the goals set by the instructors and were well received by the students in the initial offering of the redesigned course. However, a more quantitative evaluation of the effectiveness of the new course was desired. This would remove the instructor's bias towards the new course and help determine whether the new course was an improvement over the old course and truly did address the goals the instructors set.

## Quantitative Evaluation

The first attempt to evaluate the two versions of the course was to compare the end of the semester student evaluations. It can be argued that student evaluations are not a very good measure of course effectiveness, but they are an indication of how students view the course. At the University of Michigan, all courses are evaluated independently at the end of the term by the Examinations and Evaluations Department. The students respond on a scale of 1 to 5 with 1 being strongly disagreed and 5 being strongly agreed. In the five semesters prior to the restructuring the average student responses to the statement, "overall, this was an excellent course," were 3.19, 3.62, 3.69, 3.70, and 3.62. These results are well below the typical University wide median of 4.1 for that statement and, in fact, below the typical university wide first quartile of 3.7. It is also interesting to note that four different faculty members taught the class during those five semesters, yet the results, except for one very low semester, are quite similar. In response to the statement, "I learned a great deal from this course," the results were a little better, 3.60, 3.94, 4.04, 4.06, and 3.96 respectfully. These values are only slightly below the typical University median of 4.1.

The results for the lecture portion of the redesigned course were slightly better with a score of 3.89 for "overall, this was an excellent course" and 4.20 for "I learned a great deal from this course." The students were also asked to evaluate the laboratory sections and the average student response to the new format was 3.46 and 3.89 respectfully. These ratings are relatively low compared to the University median. The original course did not have a laboratory section so a comparison to the old format cannot be made. Additionally, the laboratory for the redesigned course had multiple sections and student responses varied significantly between the sections. The highest responses were 4.31 for the first statement and 4.78 for the second statement, well above the University median.

One of the drawbacks to student evaluations is they are frequently spontaneous reactions to numerous factors. For example, it is thought that students will frequently rate a course higher when they like the professor and lower when the course is perceived as "hard." Another drawback with student evaluations is they are taken in the context of the course as a single entity. Students might have a different opinion of a course when viewing the course as a portion of the entire curriculum. Student evaluations also do not address student learning or memory retention. In recognition of these drawbacks, an assessment quiz was developed.

The assessment quiz was developed to be administered approximately one year after course completion. The purpose of the quiz was to determine whether the new course addresses the goals as outlined by the instructors: improved retention of the material, better integration with the rest of the curriculum, and overall positive student view of course usefulness. To address these goals, the assessment quiz consists of two components. The first is an eight question multiple-choice exam on material covered in both the original and redesigned courses. This portion of the quiz addresses memory retention. The second portion of the quiz was a qualitative rating system of the course. The students were asked to respond to four questions using a numerical scale of one to five (one being the worst and five being the best).

The assessment quiz was first administered in April of 2000 to a group of students who completed the old version of the course in the spring of 1999. The quiz was subsequently administered in March of 2001 to students who completed the redesigned version of the course in the spring of 2000. The quiz was completely voluntary and anonymous. Additionally, it was administered in a monitored classroom to limit any irregularities.

Figure 1 shows the results of the eight question multiple-choice exam. Coincidentally, 33 students took the quiz each time, which is approximately 2/3$^{rds}$ of total course enrollment. The multiple-choice exam was the same for both groups of students and only included material that a student in either version of the course would be expected to know upon course completion. The figure clearly shows a larger proportion of high scores attained by the students who completed the redesigned course. The mean student score for the old version of the course was a 4.52 with a standard deviation of 1.52. The mean student score for the new version of the course was a 5.30 with a standard deviation of 1.5. Perhaps a more telling statistic of course difference is the median. The median student score increased from a 4 to a 6. Overall it appears that the new version of the course has improved memory retention. The reason for the apparent increased retention of material is unknown, but there are several logical possibilities including delivery style of the material, addition of the laboratory, increased student interest, and better course integration with the rest of the curriculum.

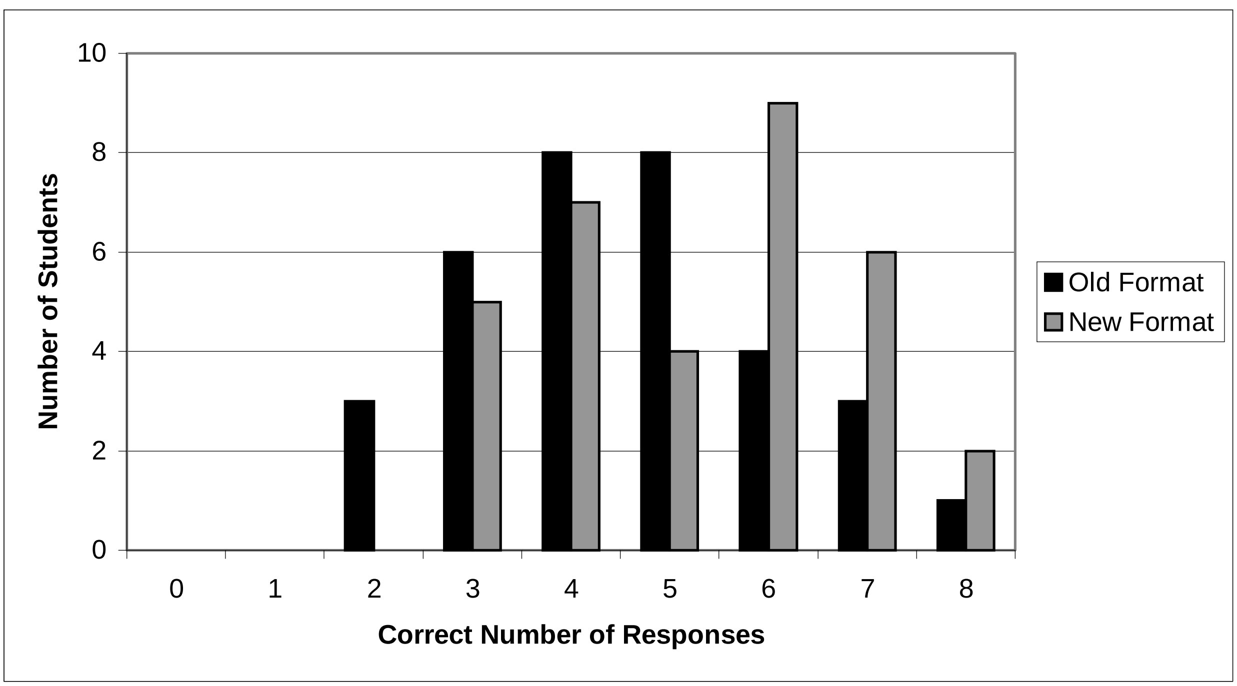


Figure 1: Results of the multiple-choice exam.

The other portion of the assessment quiz was a qualitative rating system about course effectiveness and student perception of their performance in the class and on this exam. The students were asked to respond on a scale of one to five, with one being the worst and five being the best. The four questions, along with mean and standard deviation, of student responses for the old format of the course were:

| | Mean | σ |
|---|---|---|
| How would you evaluate your performance in CEE 303? | 3.97 | 0.94 |
| How would you evaluate your performance on this exam? | 1.61 | 0.74 |
| Since you took CEE 303, how often have you used the material in other courses? | 1.46 | 0.66 |
| Now that one-year has passed, how valuable a course would you consider CEE 303? | 1.85 | 1.02 |

These results were the distressing portion of the assessment quiz. While most students graded their performance in the course positively, they had little faith in their answers on the multiple-choice exam. Additionally, they found the course to have little value and rarely used the material again.

The responses to the redesigned version of the course were improved:

| | Mean | σ |
|---|---|---|
| How would you evaluate your performance in CEE 303? | 4.091 | 0.87 |
| How would you evaluate your performance on this exam? | 2.273 | 1.05 |
| Since you took CEE 303, how often have you used the material in other courses? | 2.469 | 1.03 |
| Now that one-year has passed, how valuable a course would you consider CEE 303? | 3.50 | 1.23 |

These results represent an overall improvement. While the students still were not very confident in their responses on this exam, they are using the material more often in other courses. Additionally, students who completed the redesigned version of the course consider it to be much more valuable than those who completed the original course.

Figures 2 and 3 show the individual student responses to the questions ".. how often have you used the material .. " and ".. how valuable a course." The figures clearly show improved responses for students who completed the redesigned version of the course. In fact, the median student response to both questions was 1 for the old format of the course and increases to 2 and 4 respectively for the redesigned course.

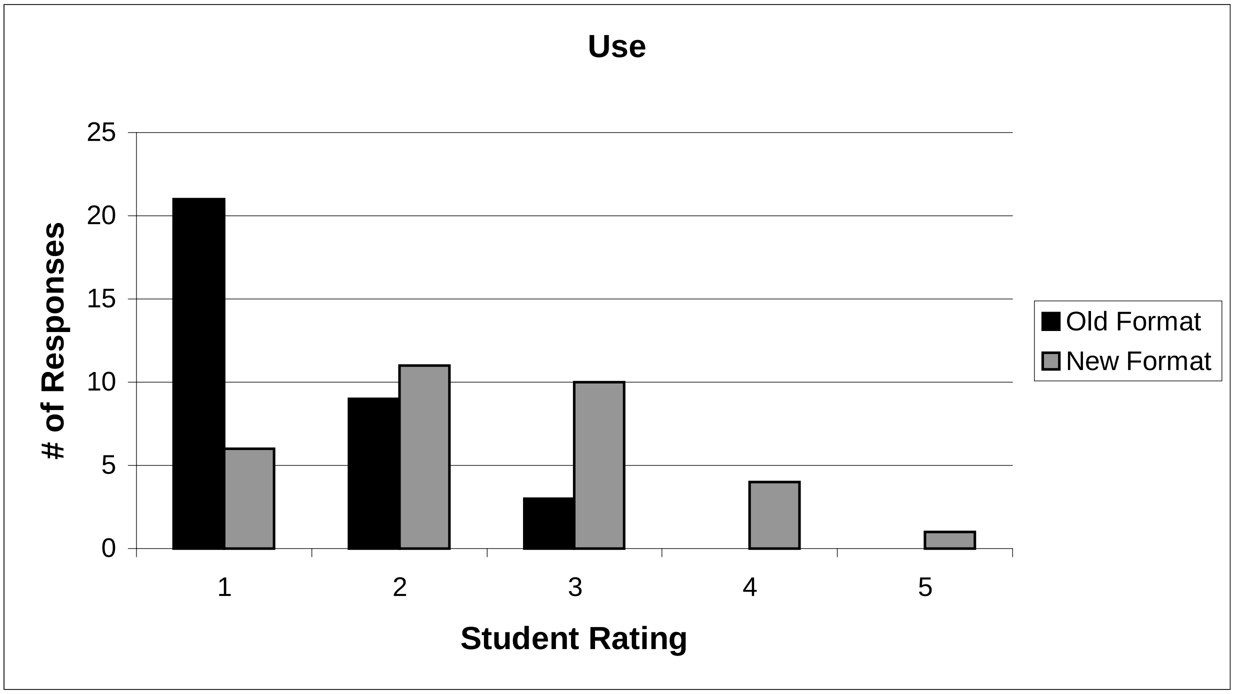


Figure 2: Student responses to the question, "Since you took CEE 303, how often have you used the material in other courses?"

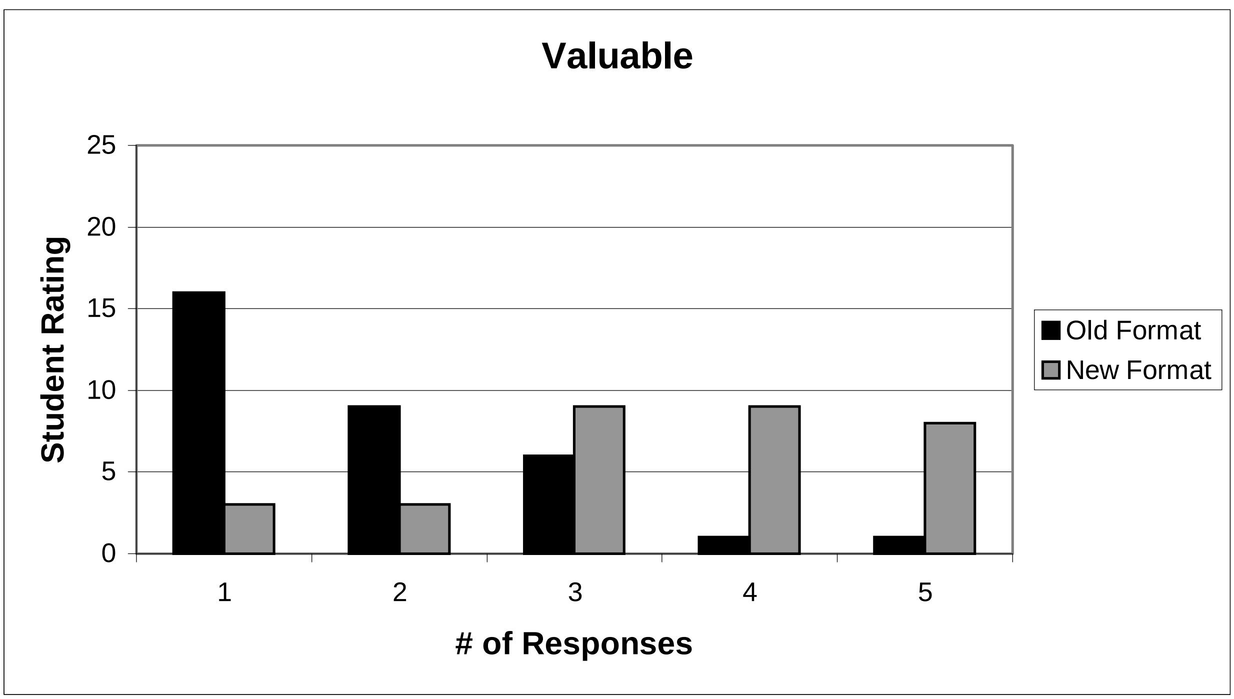


Figure 3: Student responses to the question, "Now that one-year has passed, how valuable a course would you consider CEE 303?"

The instructors were also interested if there was any correlation between a student's performance on the multiple-choice test and how they answered the questions. The coefficient of determination ($r^2$-value) for each of the above questions with respect to their exam score was calculated. The following table shows the coefficient of determination for each question for both formats:

| | $r^2$ old | $r^2$ new |
|---|---|---|
| How would you evaluate your performance in CEE 303? | 0.03 | .11 |
| How would you evaluate your performance on this exam? | 0.08 | .17 |
| Since you took CEE 303, how often have you used the material in other courses? | 0.01 | .05 |
| Now that one-year has passed, how valuable a course would you consider CEE 303? | 0.01 | .01 |

Overall there is little correlation between exam score and how a student responded to a question. The values are slightly higher for students taking the redesigned course, but there is very little information that can be deduced from these results.

## Conclusion

The instructors of the Computational Methods course at the University of Michigan consider the redesigned version of the course to be a significant improvement over the old version. The initial offering of the course was well received by the students, but the instructors desired a quantitative assessment of course improvement. The first comparison between courses was made using end of the term student evaluations. Student evaluations of the redesigned course were slightly higher, but comparisons did not show significant differences between the two courses. The second comparison was to examine results on an assessment quiz administered one year after course completion. These results were more conclusive on determining whether the redesigned course is an improvement and if instructor goals are being met. Increased quiz scores by students completing the redesigned version of the course indicate increased memory retention, accomplishing the first goal. The other two goals, curriculum integration and course value, were assessed using the qualitative portion of the quiz. Results indicate that students are using the material more often in other courses and consider the redesigned course to have significant value. This is much better than the previous version of the course, which was perceived to have little value and contained significant useless material.

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