The Competency Gap Approach to Course-Level Continuous Improvement

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Abstract

The SME Study on Competency Gaps in Manufacturing Education has catalyzed the genesis and propagation of many outstanding programs to reform and revamp manufacturing education. However, the report's impact extends beyond manufacturing education - the techniques of competency gap identification, feedback and improvement can be replicated in other technical curricula. Unfortunately, curricular-level improvements are difficult without buy-in from the administration or the entire faculty. It is far easier for an individual instructor to influence pedagogical outcomes in their own classroom than at the departmental level. The authors believe that a 'miniaturized' version of the competency gap identification technique can provide a valuable pedagogical tool to the instructor. The paper discusses a test case that has been implemented in a junior-level mechanical engineering class on manufacturing processes. By tracking typical student errors on routine assessment instruments such as homework, quizzes and tests, five major categories of competency gaps were identified – comprehension, information, writing, units usage and quantitative analysis. This information has been continuously fed back to the students and used by them to continuously improve their performance. The paper will report on outcomes of this test case and discuss its scalability to other courses.

Introduction

Over the last decade, grant-awarding institutions such as Society of Manufacturing Engineers (SME) Educational Foundation are have been moving to an outcome-centric focus. Since employees of engineering graduates reported that they had to expend considerable resources to bring fresh engineering graduate hires up to speed, SME investigated the barriers to fresh graduates achieving full productivity upon hire. Fourteen major gap areas were identified [1]. These include shortfalls in Communications Skills, Teamwork, Manufacturing Principles, Reliability Materials, and Quality etc. As a result, SME has directed its educational funding to curricula that address some or all of the competency gaps, giving rise to many successful programs that have been the subject of papers at ASEE conferences.

The authors believe that the power of the outcomes-focused techniques of SME have universal application in engineering education. Any discipline or curriculum can follow the same modus operandi to identify competency gaps and then implement local and institutional changes to bridge these gaps. Without buy-in from the entire faculty or from the administration, however, curricular-level educational reform is hard for an individual instructor to implement. It is far easier to influence pedagogical outcomes in one's own classroom – at the course level, than at the departmental level.

Methodology

With this in mind, the authors focused on a 3-credit-hour (2 lecture and 2 laboratory hours) course in Manufacturing Processes taught to junior mechanical engineering students. Course-level competency gaps were identified and cast into five broad categories that should be scalable to other courses. Students were given the option to participate in this study and use it for self-improvement. The authors entered detailed feedback comments on student work. They also kept track of class-level performance statistics. Continuous feedback was provided to students. Participating students were responsible for charting and analyzing their own gaps, and asked to submit a written end-of-semester report.

As with most traditional courses, student learning was assessed through homework. The authors went the extra mile beyond the type of feedback normally given to students (such as numerical scores, highlighting errors, writing down the right answer in the booklet). In addition to the usual comments, the student errors were classified into the five categories listed in Table 1 and actually identified as such on work returned to the students.

Table 1 Error categories

Symbol	Meaning / symptoms	Probable cause/s
I	Information lacking – inadequate knowledge	Inadequate preparation, ignorance – a macro defect
U	Units are wrongly used – conversion errors or wrong choice of units	Confusion between traditional and SI units, plain inattention to units – but this could have significant effect on outcomes in industry
C	Comprehension – answers don't relate to question asked or are not in the form required	Rushed reading, glossing over details
A	Analysis of numerical problem was wrong	Wrong assumptions, weak math skills, computational errors
W	Writing errors – errors in spelling, grammar, terminology and formatting of documents	Engineering students typically underplay importance of writing skills and don't recognize importance of written word in communications

Implementation

As with most traditional courses, student learning was assessed by the use of homework assignments (about 10), quizzes (about 10), three tests and a final exam. Homework consisted exclusively of numerical problems while quizzes focused on verbal and visual concepts such as process and equipment terminology and drawings. Tests and final exam assessed the integrative learning accomplished by the students and were comprehensive in nature, unlike the more modular homework assignments and quizzes. The following feedback techniques were adopted in addition to the more traditional marking of errors and allocation of a numerical grade:

- Errors identified on student work were categorized as I, U, C, A or W and were tabulated on each piece of student work (the authors logged this data)

- Correct answers were discussed in the immediately following class meeting
- Common student mistakes were identified and categorized
- Students were made cognizant of differences in their learning styles
- Students were encouraged to self-analyze their IUCAW feedback and identify their strengths and weaknesses and develop corrective measures by themselves or by consulting with the authors
- Students that chose to participate were required to submit end-of-semester reports on their self-analysis findings and self-improvement achievements

Results

The class had an enrollment of 23, and 16 students chose to participate. Student self-analysis reports were collected at the end of the semester but before the final exam, and do not reflect their performance on that event. A sample student report is presented in Figure 1. Student comments gleaned from the self-analysis reflect overall satisfaction with the process in terms of learning their professional strengths and weaknesses. Sample comments are quoted below:

- I learned that there is direct correlation between the amount of studying time and score awarded. Secondly there is also correlation between the allotted time for assignment and the score. Those statements are supported by my high homework averages.
- I have put myself on a rigorous schedule. This schedule includes sitting my person down for at least two hours concentrating on each course, understanding the curriculum taught from the earlier class that day.
- My quiz grades are a direct reflection of me not learning key terms and definitions. My test score is a reflection of everything I have done wrong during homework and quizzes. To improve my scores, I need to try. I am now better prepared to monitor my status in future classes.
- My improvements throughout the semester were not drastic but I feel that I knew more about the class when I began keeping track of my grades and evaluating myself. I improved step by step because I felt that trying to improve at one time would have been less productive.
- This self analysis method has improved my overall grade from a C, which I received during midterm grading to an A. this method has helped me to improve my grades in several other classes also.
- I realized that I should treat every assignment as if it were a test because I put forth more effort in studying for a test than I do for quizzes and homework.

Figures 2 – 6 show student error rates on various assessment instruments. Each of the three tests and the final exam were weighed equally, and students were excused from taking the final exam if they were satisfied with their grades on the three tests. As a result, the strongest students chose not to take the final exam. Thus, it was expected that student error rates in the five categories would be higher on the final exam than on the tests.

In general, it was seen that students tend to prepare less for quizzes than for tests and hence make more mistakes in quizzes. Inadequate knowledge error rate was lowest on homework assignment and rose steeply on quizzes. Unit conversion errors were the highest on homework assignments and non-existent on quizzes. This is natural because homework had the highest numerical content whereas quizzes are non-numerical in nature. Comprehension error rate was high on tests, lower on quizzes and homework, and reduced significantly on the final exam. Analytical errors were high on tests but jumped higher on the final exam. As the final test is administered only for people with lower grades, the average jumped. In terms of writing errors, Test # 1 had the highest number of errors, but this rate decreased as time progressed and students understood the consequences of sloppy writing and spelling errors on their grades.

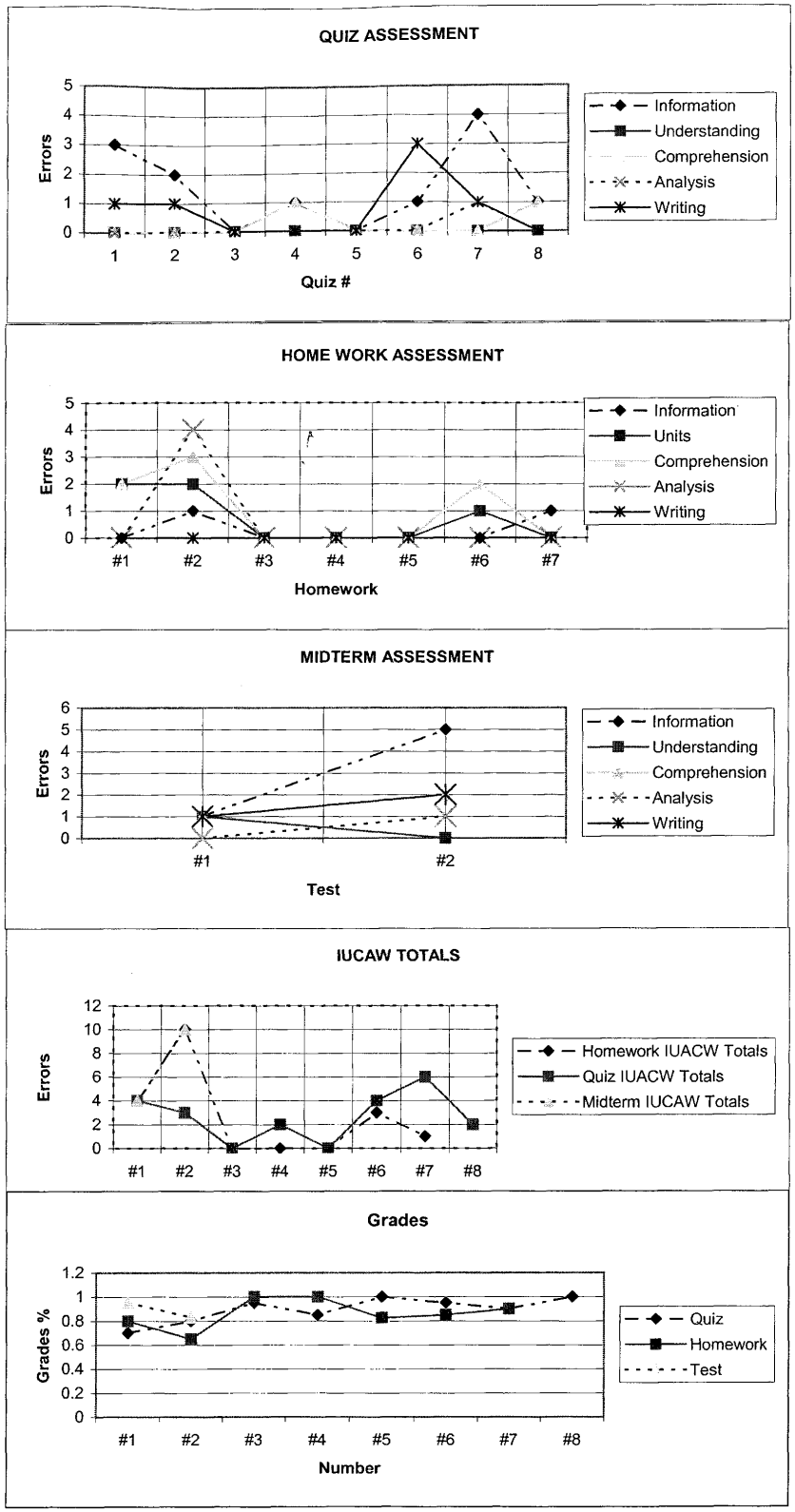

Figure 1 A student's self-analysis charts

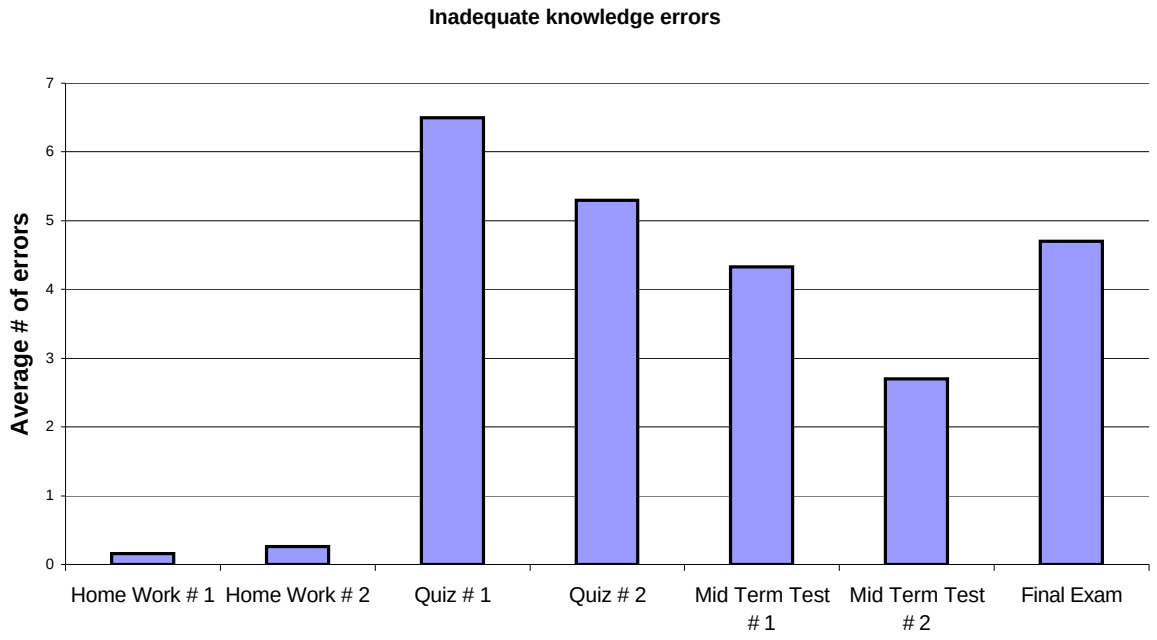

Figure 2 Inadequate knowledge errors

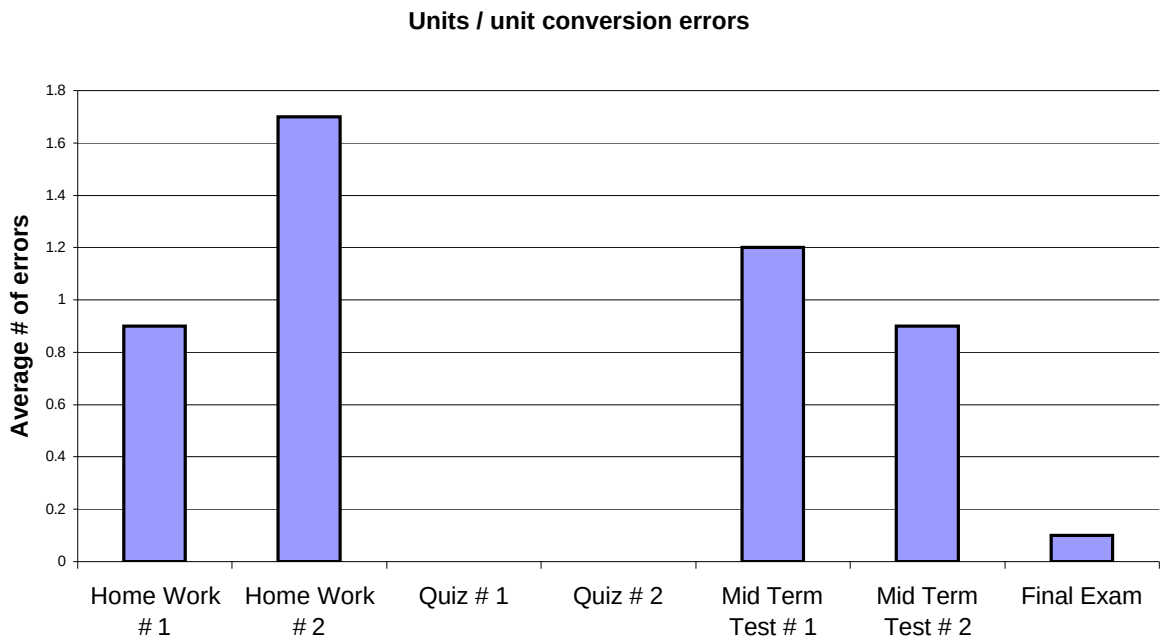

Figure 3 Units / unit conversion errors

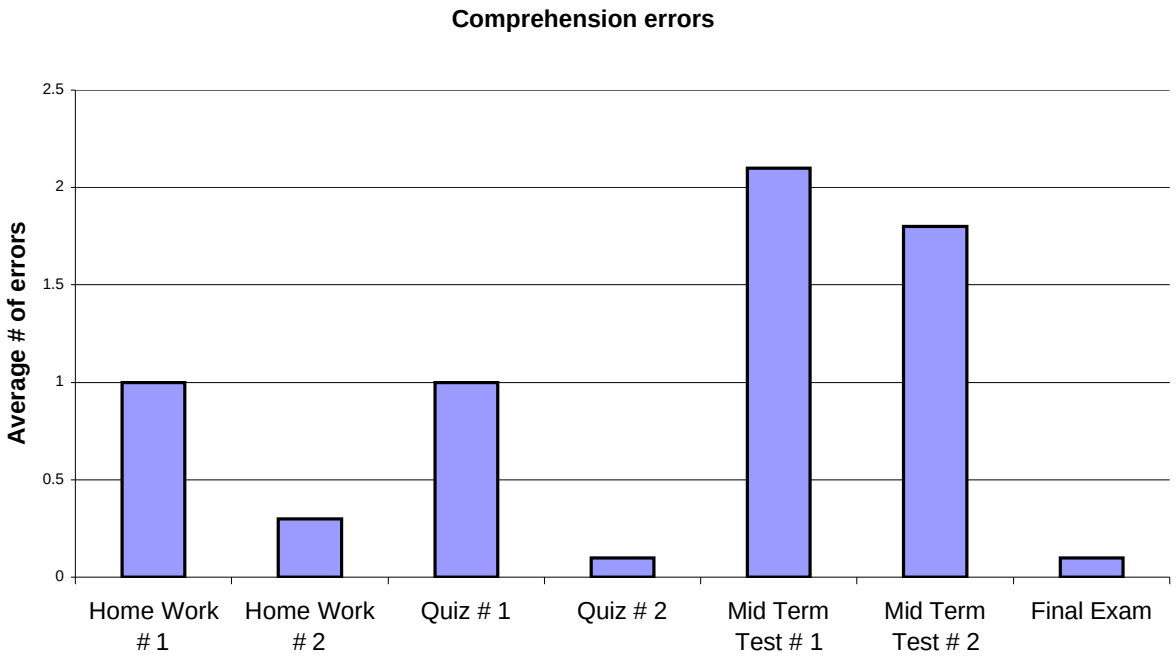

Figure 4 Comprehension errors

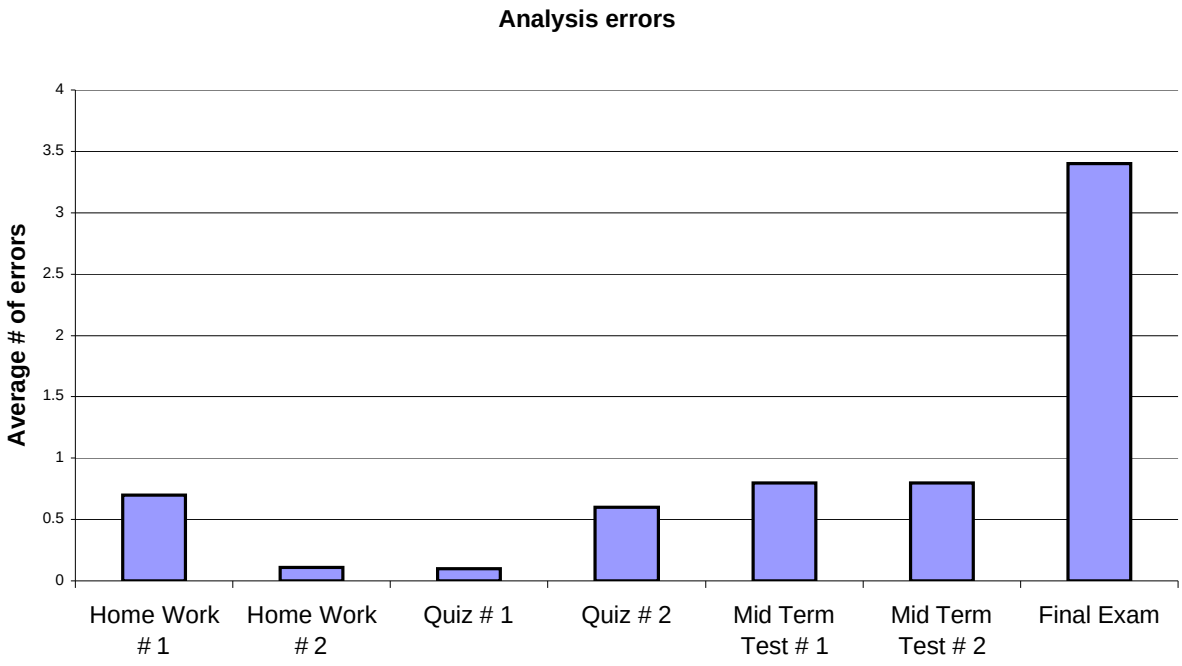

Figure 5 Analysis errors

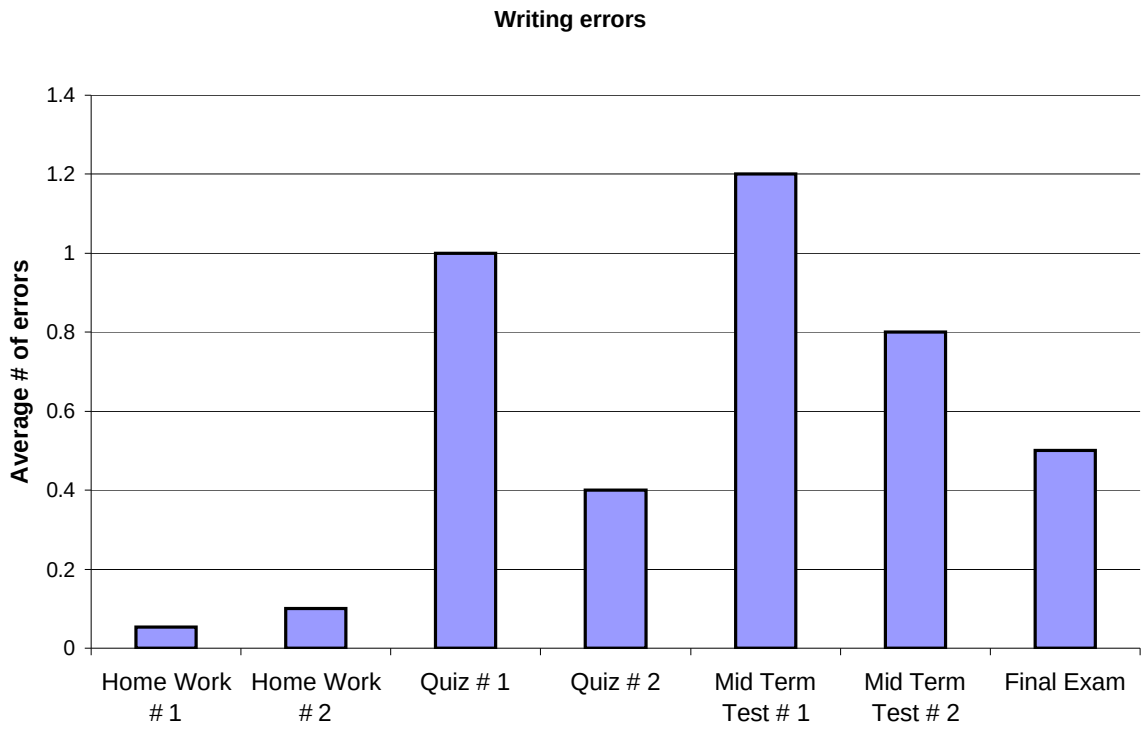

Figure 6 Writing errors

Conclusions

Courses like manufacturing processes offer a true diversity of learning challenges, since they are a blend of scientific analysis with verbal and graphical communication of a whole new vocabulary of professional terms. Thus students with a decidedly analytical bent are confronted with the challenge of learning and remembering vast numbers of terms or sketching and identifying machine and process parts, while the hands-on type of student realizes that a lot of scientific principles and useful mathematical analysis need to be mastered to successfully optimize manufacturing processes that they had traditionally done by eyeballing or referring to handbooks.

Even though more time is available for homework, students made mistakes in unit conversion. It is important for students to be equally comfortable with both sets of units to cater to the global marketplace. Errors in conversion lead to catastrophic errors. Technical writing and grammatical errors continue to persist since vast numbers of new terms are studied in this course, but it was gratifying to see the error rate drop over the semester.

There are two factors that could affect the scalability of this approach to other courses – time and course content. Classifying error type on every graded assignment is time-consuming and requires the collaboration of a faculty member with teaching assistants, especially for larger class sizes. Students are desirous of improvements in their performance but sometimes do not know areas of weakness requiring their primary attention. This analysis methodology and feedback

helps students to home in on specific areas like unit conversion, analytical techniques and terminology. Quantitative analysis will be performed when a larger dataset is available. However, the authors found the outcomes sufficiently encouraging to begin applying it again to a larger class. Secondly, this approach has proven to be beneficial for a class with both descriptive and analytical subject matter such as manufacturing processes. The approach would need to be revamped for completely analytical courses and is currently being investigated by the authors.

Acknowledgments

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References

1. SME, 1997, "Industry Identifies Competency Gaps Among Newly Hired Engineering Graduates," *Manufacturing Engineering Education for the 21st Century, Volume IV, Phase I Report*, SME, Dearborn, MI.

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