Using a Materials Concept Inventory to Assess an Introductory Materials Class: Potential and Problems

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ABSTRACT

In every engineering course there is a concern about how much the students are actually learning. The physics community has addressed this through the development of an assessment instrument called the Force Concept Inventory. More recently this has been expanded to the development of Engineering Concept Inventories. Universities affiliated with the N.S.F. sponsored Foundation Coalition have developed a number of these inventories.

A Materials Concept Inventory has been developed by faculty from Arizona State University and Texas A & M University. They have reported on their work at the 2003 and 2004 A.S.E.E. Annual Conferences[1,2]. They have encouraged further refinement of the inventory as a way to help measure the effectiveness of introductory materials engineering courses. A Beta version of this inventory has been graciously provided to Louisiana Tech University.

This inventory has been used in seven different sections of our introductory materials engineering course taught during the 2003-2004 and 2004-2005 school years. Approximately 210 students have taken the inventory at the beginning and end of the course. The use of this assessment instrument in our course has provided insight into what is being taught effectively and what areas need improvement. There was a reasonably good correlation between student performance on the inventory post test and the student grade in the course.

INTRODUCTION TO A MATERIALS CONCEPT INVENTORY

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the inventory as a way to help measure the effectiveness of introductory materials engineering courses. A Beta version of this inventory has been graciously provided to Louisiana Tech University.

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INTRODUCTION TO OUR MATERIALS ENGINEERING COURSE

We created our introductory materials engineering course in 1998 during a time of curricula reform. The course is an interdisciplinary one, taken by four out of six engineering programs at Louisiana Tech University—Mechanical, Civil, Biomedical, and Industrial Engineering. This course replaced two discipline-specific materials courses. We have previously reported on our course in a previous ASEE Annual Meeting[3]. The most important aspect of this course for the use of the Materials Concept Inventory is that our course is a two semester hour course, whereas many introductory materials courses are three semester hour courses. We therefore are forced to cover less material than in the courses for which this Concept Inventory was originally designed.

USING THE MATERIALS CONCEPT INVENTORY IN OUR CLASS

We have used this concept inventory in seven different sections of our introductory materials engineering course, MEMT 201. We gave the students this inventory on the first day and on the last day of the class. We picked up all the copies of the inventory at the end of the first day to make sure students did not have it to study from at the end of the quarter. The professors did not look at the inventories during the quarter to avoid the issue of "teaching to the inventory" rather than teaching the course they way we otherwise would have done.

In their initial report, Krause et. al reported[3] gains in overall content knowledge from 15% to 20% when comparing the pretest and posttest results. A class that used active learning reported a larger gain. However, the gain in knowledge was not uniform over all questions. On some questions students had a large amount of prior knowledge and did not report much gain in knowledge.

Our initial results for the seven sections are shown below in Table 1. In Tables 1-5 the term *pre-test* refers to the per cent correct on a test given at the beginning of the course, and the term *post-test* refers to the per cent correct on a test given at the end of the course.

Table 1 Materials Concept Inventory Results Weighted average for all seven sections		
Average score on Pre-test	Average score on Post-test	Average Gain
32	39	7

These initial results were disappointing. At this point we did a more detailed analysis of the concept inventory, and found that 12 of the 30 questions covered topics that were never dealt with in our two hour version of the course. We then eliminated these questions (and their answers) and redid our analysis. These results are shown in Table 2 below.

Table 2 Materials Concept Inventory Results Weighted average for all seven sections after uncovered questions were removed		
Average score on Pre-test	Average score on Post-test	Average Gain
37	49	12

These results are in improvement from our original analysis. Students prior knowledge increased 5% and their end of class knowledge increased 10%. Overall they showed an overall gain in knowledge of 12%, which is slightly below that reported by the original authors.

With some topics the students showed a larger increase in content knowledge. The four questions shown below were the ones with the largest gain in knowledge.

Table 3 Topics where students showed the largest increase in knowledge				
Question Number	Topic	Average per cent correct on Pre-test	Average per cent correct on Post-test	Average gain in knowledge
18	Softening metal by heating	4	23	19
19	Effect of cold working on strength	5	34	29
23	Different strengths in tension and compression	21	49	28
24	Different ductilities of metals and ceramics	20	45	25

Students had large increases in knowledge in these topics. The first two were also topics where there was very little prior knowledge. All four of these dealt with mechanical properties of materials in some fashion. The effect of internal atomic structure on mechanical properties is a topic that is emphasized a great deal in our course. That these areas would show a large increase in knowledge is not surprising.

Table 4 Topics where students showed the largest amount of prior knowledge				
Question Number	Topic	Average per cent correct on Pre-test	Average per cent correct on Post-test	Average gain in knowledge
9	Geometry of a cubical crystals structure system	68	79	10
10	Geometry of a cubical crystal structure system	70	71	1
22	Non-permanent deformation	60	68	8
25	Ductile fracture	60	77	17
26	Brittle fracture	64	79	15
30	Composite material deformation	60	67	7

The first two topics with a large amount of prior knowledge deal with geometry. The remaining four deal with deformation and fracture of materials. We are not sure what is the cause for this prior knowledge. It may be that our students have a "hands-on" background that is greater than we had anticipated.

Unfortunately, there are also some topics that were covered in the course, but which the students apparently did not learn very well. This is shown in Table 5 below.

Table 5 Topics that were covered in the class, but where the students still did poorly				
Question Number	Topic	Average per cent correct on Pre-test	Average per cent correct on Post-test	Average gain in knowledge
3	Concept of mole of atoms	27	26	-1
4	Metals existing in solid, liquid or gas form	27	30	3
14	Electrical conductivity of different types of materials	33	31	-2

These are all topics that were covered in class, but apparently covered relatively poorly. Since electrical engineering students do not take this course, we cover electrical properties of materials in one lecture period. It is apparent that this is not enough time to adequately introduce why different types of materials conduct electricity with different capabilities.

CORRELATING MATERIALS CONCEPT INVENTORY RESULTS WITH STUDENT GRADES

All professors would like to have student grades be an accurate reflection of each student's knowledge at the end of the course. One additional application we did with the Materials Concept Inventory was to determine if the students grades at the end of the course would correlate well with their post-test Concept Inventory scores. If there is a good correlation, then this would indicate that our grading is being done in an adequate manner and can be used to evaluate student gains in knowledge.

Initial attempts to correlate the more than 200 student grades with Concept Inventory scores did not prove successful due to the large amount of scatter in the data. In order to do the analysis we examined each section of the course separately. Within each section, we grouped the grades into seven categories. For example, for grading based on a traditional 90=A, 80=B, etc. system, then we would group the grades as follows:

- High A scores of 95-100
- Low A scores of 90-94
- High B scores of 85-89
- Low B scores of 80-84
- C scores of 70-79
- D scores of 60-69
- F scores of 59 or lower

Within each category of grades, we computed average of the students percentage grade in the course and the average concept inventory percentage score. An example of this for one section of the course is shown below in Table 6

Table 6
Correlating Grades and Concept Inventory Scores for one section of MEMT 201 in Fall 2004

Grade	Average Percentage Score in Class	Average Materials Concept Inventory Percentage Score
High A	96	63
Low A	90	60
High B	88	37
Low B	83	42
C	76	30
D	64	38
F	45	17

There is still some considerable scatter in the data for each section. This is shown in Table 6 above where the D students performed as well on the Concept Inventory as did the High B students. When the results for all six sections where we had grade data were combined, the scatter was much less. We took results for each class and averaged the data as follows. For all of the sections we averaged the percentage score in the class for the high A's. We then averaged the Materials Concept score for the high A students. We then did this for each grouping of grades. This provides us with seven data points, the average results from each grade combination. We then plotted the data to see if there was a good correlation. The results are shown below in Figure 1.

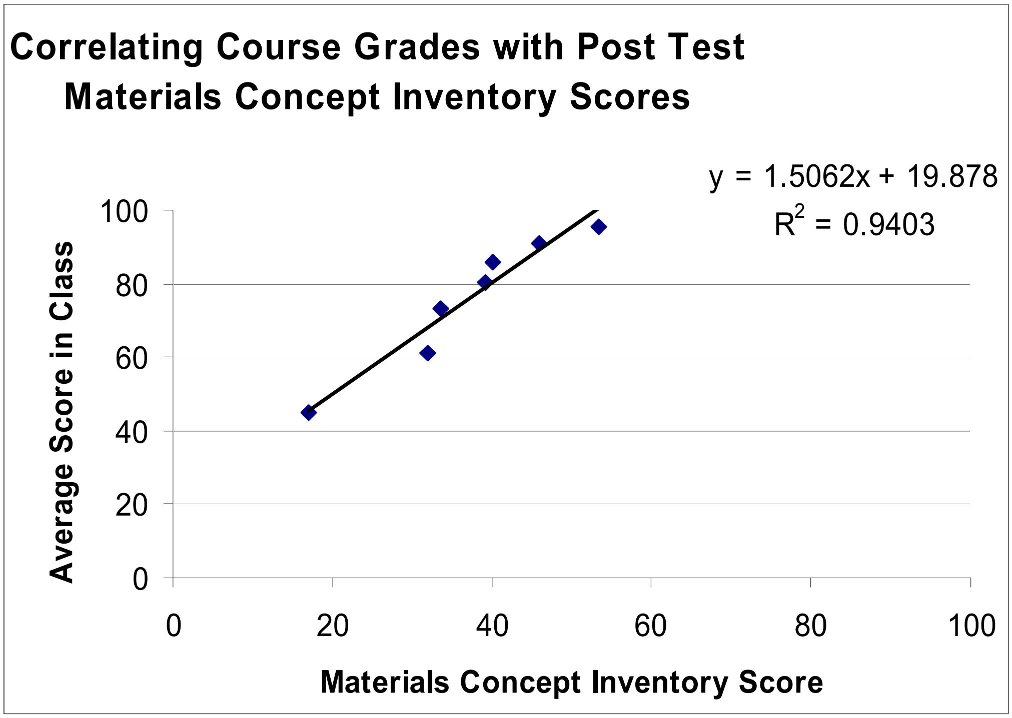

Figure 1—Correlating MEMT 201 Course Grades with Materials Concept Inventory Scores

There is a good correlation between course grades and Materials Concept Inventory scores. The R squared (coefficient of determination or variance squared) value of 0.94 shows that this is a good correlation. Assuming the Materials Concept Inventory to be an adequate instrument to measure student content knowledge, this indicates that the grading in the course itself is also adequately measuring the student content knowledge. It is important that professors assess the quality of their teaching. This indicates that the grading in this class is doing an adequate job of such assessment.

POTENTIAL AND PROBLEMS IN USING THE MATERIALS CONCEPT INVENTORY IN OUR CLASS

We had some problems in our initial use of the concept inventory. This is largely because it was designed for a three semester hour course. Our materials introduction course is a two semester hour course. Our course emphasizes some engineering concepts (such as relating strength to internal structure) while not dealing with some of the more fundamental issues that the concept inventory was apparently designed to measure.

However, when we examined the questions where the students gained the most knowledge and where they gained the least knowledge, we were able to use the concept inventory to assess what we were doing. Our course emphasizes the relationship between internal structure and mechanical properties, and these are the questions where we showed the greatest gain in knowledge. Our course only covers electrical properties of materials in a limited fashion, and this shows in the small gain in content knowledge in this area.

There was also a good correlation between course grades and concept inventory results, which indicate that our grading in the course can be used to help assess the quality of our teaching. This can be used in our next accreditation cycle to show we are continually assessing the quality of our teaching.

To make a materials concept inventory more useful, one that is aimed at a course like ours needs to be developed. This would be one that emphasized the specific topics we cover as well as our own emphasis on engineering mechanical properties. However, if the professor who teaches the course were to write the inventory, there would then be the potential problem of "teaching to the inventory" which is something we do not want to happen.

One way to try to deal with this issue might be to have one of the professors who has taught the course, and knows the type of course it is, to create a concept inventory that can be used by the faculty who are actually teaching the course that given quarter. This is something we would like to try during the 2005-2006 school year. This would enable us to have a relatively external assessment that is more suited to our individual course.

REFERENCES

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BIOGRAPHICAL INFORMATION

WILLIAM JORDAN is Professor and Program Chair of Mechanical Engineering at Louisiana Tech University. He has B.S. and M.S. degrees in Metallurgical Engineering from the Colorado School of Mines. He has an M.A. degree in Theology from Denver Seminary. His Ph.D. was in mechanics and materials engineering from Texas A & M University. He teaches materials oriented courses and his main research area deals with the mechanical behavior of composite materials. He also writes and does research in the areas of engineering ethics and engineering education. He is a registered metallurgical engineer in the state of Louisiana.

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Dr. CHAD B. O'NEAL received his Ph.D. in Microelectronics-Photonics from the University of Arkansas, Fayetteville. Dr. O'Neal received an NSF IGERT Traineeship that supported his doctorial studies. Dr. O'Neal has been researching the areas of micro and nano systems design and packaging for the past eight years. He currently has twenty publications and five patents pending. In 1999, Dr. O'Neal co founded SYSCONN Corporation to develop wafer scale packaging and integration processes for microsystems. He joined the mechanical engineering faculty at Louisiana Tech University and the Institute for Micromanufacturing in 2004.