Applying Detailed Student Learning Objectives, Group Learning, and Assessments in an Introductory Polymers Course

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ABSTRACT

"Materials and Processes in the Plastics Industry" is a three credit-hour course at Northern Illinois University. It is an introductory course in plastics technology designed to familiarize the student with the basic polymers/plastics. The course has been reorganized to focus the learning process around the student and specific student learning objectives and outcomes connected to curriculum topics and various types of learning assessments. Higher-level objectives that stress designing, planning, judging, and analyzing are emphasized. Teaching is partially shifted to group learning and techniques are suggested to maximize the individual's performance in a group setting. Scoring rubrics are part of the assessment system. Traditional examination questions are retained but now each question is connected to a specific student learning objective. Specific examples of learning objectives, syllabus content, a performance task, assessment rubric, and examination questions are presented for this, or any, introductory polymers course. Results for one application (semester) of this process are also presented.

BACKGROUND

At Northern Illinois University (NIU), an introductory polymers (plastics) course is offered within the Department of Technology. This three credit-hour course (TECH 344) is titled "Materials and Processes in the Plastics Industry" and is a three credit-hour course. The Department of Technology is part of the College of Engineering and Engineering Technology along with the Departments of Electrical, Industrial, and Mechanical Engineering. The Department of Technology is comprised of three undergraduate emphases: Manufacturing Engineering Technology, Electrical Engineering Technology, and Industrial Technology. Specifically for the Industrial Technology students, there is a plastics area of study and TECH

344 fulfills one of the required classes. Industrial Technology received initial accreditation from the National Association of Industrial Technologists (NAIT) in 1998 and has been reaccredited during the 2001/2002 academic year; the program is now accredited through 2008. TECH 344 is also taken by undergraduate students from Mechanical Engineering, Mechanical Engineering Technology, and other Industrial Technology study areas such as manufacturing and computer-aided design.

"Materials and Processes in the Plastics Industry" is an introductory course in plastics technology designed to familiarize the student with the basic polymers/plastics along with some plastics fabrication processes. Topics include

- History of Plastics;
- Basic Concepts in Organic Chemistry;
- Materials: Thermoplastics, Thermosets, and Elastomers;
- Properties;
- Additives, Fillers, and Reinforcements;
- Fabricating with Plastics;
- Recycling, Environmental Aspects; and
- Plastic Processing Methods.

There is no formal laboratory although there are demonstrations, in the laboratory, of some of the common plastics processing methods. (Plastics processing is extensively studied in another course, TECH 345.) Each student will have the opportunity to learn the origin, the identity, and the characteristics of the major plastics along with current process terminology and product applications. The course is similar to introductory polymer science or polymeric materials courses elsewhere in chemical engineering, materials science, and mechanical engineering or technology departments although the emphasis in TECH 344 is more on the properties and application of polymers rather than the chemistry. For example, the basic addition and condensation reactions forming polymers are included in the curriculum but details of reaction rates and the initiation, propagation, and termination reactions are not. Typically, students meet twice a week for 75 minute sessions during a 16 week semester with the last week reserved for final examinations. Historically, students in TECH 344 are exposed to an instructor-centered command style[1] program where the instructor makes all the decisions and determines what is taught and how it is evaluated.

In 2006, in an effort to improve student instruction, performance, and retention, TECH 344 has been reorganized. Now the approach to learning is constructed around student learning objectives and outcomes connected to specific curriculum topics and various type of learning assessments. Various teaching and learning models have been incorporated with higher-level objectives of Bloom's Taxonomy[2] that stress designing, planning, judging, and analyzing rather than traditional recalling, classifying, summarizing, or naming. The reorganization of TECH 344 required revising the course content, syllabus, examinations, lectures, and projects.

STUDENT LEARNING OBJECTIVES

The first step in the reorganization process was the identification of each pertinent student learning objective (SLO) and ensure that course topics reinforced the objectives. The curriculum was adjusted to reflect all these changes. In the next step various teaching and learning models were incorporated to shift the program from instructor-centered to more student-centered where individually, or in groups, students take responsibility for the learning process. Finally, student assessments were developed to judge how well objectives are attained. This required analysis of previous course examinations, revision of these examinations, and development of new performance tasks that provide alternative assessments of the same knowledge. Rubrics were constructed to evaluate the performance tasks.

Two sets of learning objectives are present: general engineering NAIT and course-specific ones. For instance, a NAIT learning outcome or objective is:

Apply current knowledge and adapt to emerging application of math, science, engineering, and technology.

To achieve this outcome, TECH 344 includes the SLOs and sub-objectives of:

A. Students will Describe the Fundamental Structure of Plastics:

- A.1. Students will interpret and draw polymer chains.
  - A.1.a. Students will compare polymerization reactions.
  - A.1.b. Students will compare and contrast functional groups and tacticity.
  - A.1.c. Students will describe chain topology.
- A.2. Students will compare and contrast thermoplastics and thermosets.
  - A.2.a. Students will select commodity and engineered plastics.
  - A.2.b. Students will differentiate crystalline and amorphous plastics.
- A.3. Students will name, draw, and identify elastomers.
  - A.3.a. Students will explain elastomers.
  - A.3.b. Students will summarize polyisoprene.
  - A.3.c. Students will select and qualify other elastomers.

B. Students will Predict Plastics Properties:

- B.1. Students will describe effects of structural features on plastics properties.
  - B.1.a. Students will quantify and solve molecular weight distribution.
  - B.1.b. Students will qualitatively evaluate crystallinity effects.
- B.2. Students will distinguish and explain mechanical, physical, thermal, environmental, electrical, and optical properties.
  - B.2.a. Students will select ASTM techniques.
- B.3. Students will explain interactions of modifiers.
  - B.3.a. Students will classify additives, fillers, and reinforcements.

C. Students will Describe Plastics Design and Finishing Processing:

- C.1. Students will differentiate design methods.
- C.2. Students will classify ways of assembling plastics.
  - C.2.a. Students will select machining methods.
- C.3. Students will explain methods of finishing plastics.
  - C.3.a. Students will give examples of joining and decorating.
- C.4. Students will compare and contrast rapid prototyping procedures.

D. Students will Recognize the Environmental Aspects of Plastics:

- D.1. Students will explain waste reduction techniques.
  - D.1.a. Students will evaluate source control, recycling, regeneration, degradation, landfills, and incineration.

E. Students will Analyze, in Depth, Specific Plastics Topic:

E.1. Students will construct the history of a plastics topic, or
E.2. Students will differentiate a plastic, or
E.3. Students will detail a plastics processing method, or
E.4. Students will describe, in detail, a plastic product.

Appropriate textbook and lecture materials were selected to meet these objectives and the syllabus recorded the order and progress of meeting objectives and outcomes.

GROUP LEARNING ORIENTED SYLLABUS

A syllabus was planned that placed some of the burden of learning on the students. It combined instructor-centered instruction followed by student-centered group learning. As an example, part of student learning outcome A. is:

A.2. Students will compare & contrast thermoplastics & thermosets.
a. Students will select commodity and engineered plastics.

while the corresponding syllabus entries are:

Week and Objectives		**Day 1 Topics, Activities, and Due Dates**		**Day 2 Topics, Activities, and Due Dates**
Week #6 Select Thermosets Differentiate a Plastic		Commodity Thermosets.		Engineered Thermosets. Read Chapter 9 of Textbook due 10/9. Group: Students Differentiate Engineered Thermosets due 10/9. Homework: Chapter 8 Questions (evens) due 10/11.
Week #7 Name, Draw, & Label Elastomers		Polyisoprene. Group: Students Differentiate Polyisoprene due 10/11.		Other Elastomers. Performance Task 2 due 11/6. Homework: Chapter 9 Questions (evens) due 10/18.

These two weeks represent four class periods. In the first, day 1 of week 6, the focus is on instruction by lecture with the topic being commodity (common) thermosetting resins. But day 2 of week 6 represents a shift as students in groups, following the format examples from the instructor’s lectures, construct their own set of lecture notes for engineered thermosetting resins.

A due date for this assignment is given as 10/9 along with an individual homework assignment to further reinforce the material by presenting the same information from a different source to take advantage of various learning styles among students. (A similar approach is used in prior weeks for thermoplastics.)

In this regards, it is vital that any groups are legitimate cooperative learning groups where students are randomly assigned and outperform reasonable expectations by their combined efforts. Additionally, each individual in the group must be independently evaluated. Examples to accomplish this include keeping the group size small, giving written or oral examinations to students, and observing students as they interact within their group. There are systematic techniques available to maximize the individual's performance in a group setting[3,4]. These techniques cover various ways of forming groups, including ensuring that the groups are random and/or balanced. Different ways of group functioning and dynamic interaction are also documented. A sampling includes rounds where students take turns speaking; group investigation where each group is free to choose a subtopic within the area of study; discussions where students take opposing sides of an issue; and brainstorming to encourage free thinking and rapid development of ideas.

In any case, the vital elements of group learning are to assign personal responsibility to each student along with individual accountability. A group must actually engage in learning, not just doing a task or assignment; this requires the group to produce a product at the end of the session and the product must be assessed against very specific criteria. In the end, each student will perform at a level above their individual capability, benefiting from the group learning process.

Week 7 continues the process for elastomeric thermosets. Furthermore, week 7 contains an additional assignment labeled Performance Task 2 which provides another way for students to fulfill their learning objective of being able to understand specific polymers and addresses student learning objective E: *Students will Analyze, in Depth, Specific Plastics Topic*.

Performance Task 2 is also described in the TECH 344 syllabus:

You are charged with critiquing a specific plastic (or polymer) in detail. The focus is on what differentiates the plastic from other plastics by describing the features that make the plastic unique. The features would involve molecular structure, properties, and industrial, commercial, or consumer uses and applications. You must collect the appropriate information, coordinate your findings, judge the data, and write a report.

You will research the plastic from a variety of sources – internet, magazines, journals, manufacturers' datasheets, product literature, books, and conference proceedings. Keep track of all your research sources and be prepared to report on which were more useful. The research should include history of the plastic/polymer; fundamental molecular structure; molecular chain topology; molecular structural features and effects on properties; molecular weight distributions; basic, general mechanical, physical, and chemical properties; and uses and applications.

Devise a procedure for collecting your information prior to beginning the project. Choose which informational sources you will consult. Write down the procedure in a step-by-step order. Make sure proper documentation is maintained by complete referencing; use a system of referencing from a writing-style guide/handbook.

Present your findings in a written research report. Include data, tables, figures, diagrams, charts, graphs, references, and photos, where appropriate, to better illustrate your findings. The report must have a minimum of four pages of text (exclusive of references and illustrations: tables, graphs, figures, charts, photos, etc.) and be double-spaced with a 12-point font. The report should document and explain the plastic or polymer and its unique features and uses that, in your judgment, differentiate it from other plastics and polymers.

With lecture information, group learning, and homework assignments all reinforcing each other in the learning process, the student is ready to proceed to upper levels of Bloom's taxonomy; this performance task requires a higher-level of thought requiring judgment, evaluation and planning. Notice how the task is student-centered and uses verbs that promote action by the student.

ASSESSMENT

Of course to objectively assess student ability, it is necessary to provide, ahead of time, a scoring rubric specific for this assignment. The rubric covers research, writing, organization, and quality criteria of the work. A partial rubric for Performance Task 2 is:

Criterion	**Score = 3: Good**	**Score = 2: Acceptable**	**Score = 1: Weak**
Reference Use	Pertinent references are used; properly listed at end of report; and clearly cited within body of report.	Mostly pertinent references are used and properly listed at end but much text is not cited.	Little use of references.
Spelling/ Grammar	Few errors.	Some errors.	Many errors every page.
Organization	Topics are logically arranged with good flow between them. It is easy to follow lines of reasoning.	Sometimes difficult to follow topics and lines of reasoning.	Topics are mostly disorganized; hard to follow reasoning.
Critical findings or data.	Interprets results and data and properly applies interpretations to the conclusions.	Interprets results and data but does not successfully apply interpretations to conclusions.	No interpretation of results or data. No application to the conclusions.

Among assessment tools are examinations but these must truly test the material presented in class and be consistent with the SLOs. To accomplish this, an extensive test bank of questions was formulated. Question format was varied with the emphasis on questions that are objectively evaluated. Thus the format uses multiple choice, fill-in-the-blank, item matching, short answer, and true/false; it is important that lower-order as well as higher-order thinking questions are included [5]. Each test bank item may be characterized as knowledge, comprehension, application, analysis, evaluation, or synthesis, consistent with Bloom's taxonomy. Here analysis, evaluation, and synthesis represent high-order thinking test items and some test questions ought to be at such levels although higher-order problems solving may be better assessed through performance tasks and their rubrics. For TECH 344, an excerpt from the test bank gives some questions related to basic organic chemistry. The nine sample questions are grouped under student learning objective *A.1: Students will draw and explain basic organic molecules.*

1. The type of bond between two carbon atoms of a polymer is

a) covalent.
b) ionic.
c) dipolar.
d) metallic.

** For the next 6 items, write the typical number of bonds the element makes in the blank space next to the element.

2. hydrogen _____
3. sulfur _____
4. chlorine _____
5. carbon _____
6. fluorine _____
7. nitrogen _____

8. The molecular weight of heptane is a) greater than the molecular weight of heptene.
b) the same as
c) less than

9. Name the straight, four carbon-long chain molecule containing only hydrogen and single bonds: ______________.

By grouping test questions under SLOs, direct evidence is given that a specific area of knowledge is tested for. This is a useful asset in national educational accreditation programs as it provides proof of learning, once test scores and data become available. Quiz as well as midterm and final examination questions are selected from the test bank.

RESULTS

Results for one application (semester) of this process are presented. The results are grouped by significant student products such as exams and performance tasks.

Midterm Examination:

To improve on midterm scoring and in addition to lectures and homework assignments, the class was divided into two groups to assess the difference between cooperative versus individual learning in four content areas. The content areas were commodity thermoplastics, engineered thermoplastics, thermosets, and elastomers. Random assignment of students to two groups allowed us to assume the groups were equivalent. Each group had approximately 15 students while each small learning group was composed of 3 students. The actual delivery of the treatment conditions alternated across content areas and groups. An outline of the experimental model is provided:

Individual Learning vs. Cooperative Learning

	Treatment	Posttest 1		Posttest 2
Individual Learning Group	Individual Learning	Midterm 10/18/06	----------→	Final 12/11/06
Cooperative Learning Group	Cooperative Learning	Midterm 10/18/06	----------→	Final 12/11/06

Treatment				
Group	Content Area I – Commodity Thermoplastic Study Summary Questions	Content Area II - Engineered Thermoplastic Study Summary Questions	Content Area III - Thermoset Study Summary Questions	Content Area IV - Elastomer Study Summary Questions
1	Individual - 15	Cooperative Groups #1-#5	Individual -15	Cooperative Groups #1-#5
2	Cooperative Groups #1-#5	Individual - 15	Cooperative Groups #1-#5	Individual - 15

From an item analysis viewpoint, I did not eliminate any items on the midterm; it only had two questions (out of 30) considered for elimination. Both of these had low Item Difficulty (11% and 21%) and Low Item Discrimination (-0.34 and 0.20). A closer examination of the two questions revealed that they were based on reading assignments and items not covered by lectures, student group assignments, or performance tasks. But the items were judged to be reasonable thus rather than eliminating them, I emphasized that the final would also include questions on the reading of chapters. (This includes material not covered in lectures.) It was also noted that students did not perform better on the items from the four content areas related to the cooperative versus individual, traditional cognitive learning activities. Thus this led to another change to include more retention questions in the final than originally planned. A total of eight retention questions were included in the final, two from each of the four content areas.

In future courses, it would be beneficial to emphasize that students are responsible for chapter readings as well as lecture materials. Also other group learning models should be tried. There are systematic techniques available to maximize the individual's performance in a group setting. These techniques cover various ways of forming groups, including ensuring that the groups are random and/or balanced. Different ways of group functioning and dynamic interaction are also documented. A sampling includes rounds where students take turns speaking; group investigation where each group is free to choose a subtopic within the content area of study; discussions where students take opposing sides of an issue; and brainstorming to encourage free-thinking and rapid development of ideas. Overall, individuals should benefit from the group learning process but this did not occur presently.

Final Examination:

Due to rewriting of items based on experiences from the midterm, the overall class performance on the final examination was 10% better than the midterm. There were three questions (out of 50) with low Item Difficulty (14% and two at 21%). However two of these had reasonable Item Discriminations (0.44 and 0.47) while the third was at -0.34. This third item was discussed in lecture and included in the textbook readings so that there is no good explanation of why the item proved to be so difficult; only this item was considered for elimination. Three items had Item Difficulty scores of 100%; these items show no discrimination and also could be considered for dropping. But, in the end, all items were retained as a database to be expanded as future exams give more guidance as when to eliminate items. Certainly, it is expected that the experiences from these two examinations will provide for better future test items.

There was even better improvement on the eight retention questions; the students scored 12% better on the retention questions than on the final as a whole. This indicates that if special, or extra, attention is given to critical topics, students are able to perform. Different teaching and/or learning models ought to be considered for such topics. This, in conjunction with better group learning processes, should increase test performance, including performance on retention items.

Performance Assessments:

Three performance assessment tasks were assigned. Generally, scores were better on these than the standard tests as the tasks gave students an alternative opportunity to give evidence of their knowledge. The tasks also tested the students at higher levels of Bloom’s taxonomy. One of the reasons for the success of these was the presence of rubrics that were a great asset in the execution of the performance assessment tasks. Students clearly knew the expectations and tailored their work to fulfill the requirements. This led to higher scoring and the better scores were justified.

The third task included group activities. It appears that students working in groups towards performance tasks benefit more than groups preparing for the midterm and final examinations. Students seem to do better in group settings where more creative, open-ended projects are the goal. Future courses should explore and exploit this trend. Or a cooperative versus individual learning study for performance tasks could be conducted.

CONCLUDING REMARKS

After several offerings of TECH 344 with its revised format, more data should be collected to determine whether or not student learning has improved. Test scores and grades from this initial offering is a baseline. However, if there remain too many uncontrolled variables, meaningful quantitative, statistical findings will be difficult. Nevertheless, even qualitative data and instructor experience should provide an evaluation of the program. Of course reorganization of TECH 344 is expected to be a continual process as more feedback and information arrives each time the course is given.

REFERENCES

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