2006-1932: YOU'VE BEEN SLIMED!: PROCESS AND PRODUCT DESIGN EXPERIENCES FOR RECRUITMENT AND RETENTION OF CHEMICAL AND INDUSTRIAL ENGINEERS

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You've Been Slimed!: Process and Product Design Experiences for Recruitment and Retention of Chemical and Industrial Engineers

Abstract

This paper will compare and contrast the use of a one-day "slime" project as part of a week-long summer program for high school students and the use of the same project as a multi-week project for an orientation class. One of the key project goals was to compare the chemical engineering and industrial engineering disciplines. Pre and post survey assessments were done and will be discussed.

In the summer of 2005, a week-long academy, Reaching Engineering and Architecture Career Heights, was hosted by the College of Engineering, Architecture and Technology at Oklahoma State University, Stillwater. A Chemical Engineering/Industrial Engineering six-hour module was a part of this academy. During this module, the students worked on product and process design concepts related to the manufacturing of slime. The students also generated new products that used slime as a base.

In the fall of 2005, a freshman-level engineering orientation class worked on the project in a multi-week venue. The orientation course was focused on chemical engineering, but comparisons to industrial engineering were made. The paper will compare student surveys and outcomes for the slime project for high school students versus college freshmen.

Introduction and Background

Recruitment and retention of engineering students have become increasingly important. Trends in engineering enrollment show that beyond the enrollment highs of the 1980s, the numbers of students entering and remaining in the field have either decreased or remained constant[1]. Positive perspectives of engineering help to increase the persistence of students studying engineering[2].

Multidisciplinary approaches have been used recently as a method to increase both recruitment and retention[3]. Froyd and Ohland state that the multidisciplinary approach improves retention by making explicit connections to engineering, engineering practice and engineering careers. Second, it allows students to see connections between their mathematics and science courses and their future careers in engineering. Third, faculty would also like the students to better apply the introductory math and science courses[3].

To aid recruitment and retention, the authors have developed a multidisciplinary workshop, which has been utilized for a summer recruitment academy and a fall orientation to engineering course. These activities build on the past activities and experiences of the authors[4,5] with the REACH academy and orientation courses.

REACH Academy

Reaching Engineering and Architecture Career Heights (REACH) is a week-long resident academy hosted by the College of Engineering, Architecture and Technology (CEAT) at Oklahoma State University (OSU), Stillwater. Financial support for the academy is provided by the Oklahoma State Regents for Higher Education, Conoco-Phillips, NASA, and OSU CEAT. The academy is designed to introduce Oklahoma high school juniors and seniors to engineering, architecture, and technology through hands-on, experiential modules.

For the one-day academy project/workshop prepared by the authors, the students were given a recipe and procedure to follow to make slime from poly(vinyl alcohol) bags (Table 1). They were also given relevant cost information (Table 1).

There were two components of the design project: to come up with a robust process to manufacture the slime and to develop a new product that used the slime as a basis. The students were motivated by an ending evaluation that selected the best new product and the best product presentation.

Table 1. Recipe, Procedure and Cost Information for Slime

Standard Recipe for Slime:
20 x 40 cm piece of PVA bag
50 mL of hot water
10 mL of Borax solution (1/2 tsp. Borax & 3 Tbsp. warm water yields 25-30 mL)

1. Measure and cut a 20 x 40 cm piece from the PVA (polyvinyl alcohol) bag.
2. Measure 50 mL of hot water and pour it into a cup.
3. Put the piece of PVA into the hot water and stir. Stir well to dissolve and disperse the polymer.
4. Measure 10 mL of the Borax solution.
5. Pour the Borax solution into the cup of dissolved PVA and stir well. Fast, circular stirring motions are required to completely mix the parts.
6. Remove the material from the cup and knead it with your hands. The material will become firmer and lose some of its stickiness.

Slime Procedure:

1. Mixing and kneading
2. Weigh the batch
3. Package in smaller quantities (4 packages per batch)
4. Weigh individual packages

Cost information:

PVA bags	$86 for 100 bags
Borax	$3 per box (box weighs 4 lbs/12 ozs)
Hot water	$0.05/1000kg
Miscellaneous materials	$1.00/batch
Ziploc bags	$0.05/each

Safety and environmental issues were addressed, as well as background information on polymerization. The students were then tasked with developing a process to make their slime, and they produced their first batch. Next, the students prepared a second batch but were confronted with process upsets and/or environmental changes. These included supply issues, loss of group members, sitting versus standing, and changing the assigned tasks. Performance and quality control issues were discussed. The next activity involved brainstorming about products that could be developed from slime. The students were to think about the name of their product, how it would be packaged and how the process would be impacted. They were also tasked with determining product cost and marketing plans. Over lunch, extra materials requested by the student teams to create their new product design were purchased. The students were restricted to supplies that could be obtained at Hobby Lobby or Wal-Mart. The two instructors together rapidly purchased the supplies.

Following lunch, the students wrote process plans, manufactured their new product, and prepared and delivered oral presentations. The most creative project that fulfilled the objectives of the activity was the "Cushy Tushy", a toilet seat that is filled with slime to make a comfortable seat.

Introduction to Engineering Course

The Introduction to Engineering Course was taught by Dr. High for the fall 2005 term. The course was made up of college freshmen that predominately chose to major in Chemical Engineering. The class met for 15 hours during the semester, plus there was extra time for meetings with success coaches/peer mentors. The six main areas covered in the class are detailed below:

- Academic Success- study skills, time management, finding help for classroom material, test-taking skills, and college survival skills.
- Professional Success – career planning and effective presentations.
- Chemical Engineering Information – career and advisement information and research presentations/laboratory tours.
- Engineering Design and Problem Solving – creativity, effective teams, brainstorming, process design, and product design.
- Societal Issues of Engineers – ethics, diversity/international issues, environmental issues/sustainability, medicine and bioengineering.
- Personal Development – stress management and other wellness issues.

The major feature of the engineering design and problem solving section are to explain to the students the differences between product and process design. As an introductory example, Dr. High used Nylon 6-10 as a one-day demonstration of these concepts. Nylon 6-10 is made from the polymerization reaction of hexamethylenediamine and sebacoyl chloride. The polymerization is a condensation reaction where the polymer forms at the interface of two liquids and is pulled as a fiber. The students discussed how scientists developed the product and how engineers figure out how to mass produce Nylon 6-10. This was done as an informal discussion where the instructor provided verbally the definition of product and process design. The students conjectured about issues that might arise during product or process design. This was done before the multi-week slime project was started to provide the students information on the differences between scientists and engineers and to help them understand product and process design.

The students then started the multi-week slime project to understand more fully the concepts of product and process design and to present multidisciplinary ideas to the students. Table 2 shows the layout of the project over the course of the semester.

Table 2. Slime Project Schedule for Orientation Class

Week	Topic	Assignment
8	Slime Project; Safety and Environment; Polymerization; Process Flowcharting	
10	Processing with Environmental Changes Group Dynamics	Flowchart Cost Analysis
12	Brainstorming New Product Impact on Process	Environment Discussion Group Dynamics
13		Supply List
14	Processing New Product	New Product Plan
15	New Products/Presentations	New Flowchart PowerPoint Presentation

The orientation course students did many of the same activities that the REACH students did, but it was spread over several weeks of the second half of the semester. The first day was spent introducing the students to the slime project, describing environmental issues and safety concerns, discussing the basis of polymerization and explaining how to create process flowcharts. The students then processed several batches of slime. Two weeks later, a flowchart and a cost analysis were due. For the flowchart assignment, the students were asked to develop a process flowchart with their group that describes how the slime was "processed." For the cost analysis, the students were asked to find the total cost per batch, the total cost per package, and a good price for selling their product. Of the total number of points for the semester (325), 80 of them were for the slime project. Other points were given for attendance and other individual/group assignments.

The next period that the class worked on the project, the students again worked on processing slime but with a variety of environmental upsets/changes given to them (Table 3). Each group was given two scenarios for each of two processing trials (two batches being produced). The times were given in minutes. Examples of these change notices are given in Table 3 (A changes were given at 2 minutes and B changes at 4 minutes).

Table 3. Examples of Change Notices for Environmental Upsets

Group A
1A - Equipment breaks down. You must dispose of any materials in your Borax cup and wait for 60 seconds (until 3:00) to use it again.
1B- One person on your team is transferred to Group C; your team gets a transfer from them.
2A - All team members must rotate between tasks every minute (2:00, 3:00, 4:00, etc.).
2B - Power outage; can't do anything for 45 seconds (until 4:45).
Group B
1A - You must wipe down the lab table with a wet paper towel after each stirring step in the process.
1B - There was a chemical spill at your factory; you must evacuate the room and stay in the hallway for 60 seconds (until 4:00).
2A - One team member breaks his/her arm; this person must sit out for 2 minutes to heal (until 4:00).
2B - Power outage; can't do anything for 45 seconds (until 4:45).

For the environmental discussion assignment, the students were asked to comment on the environmental changes/calamities that their groups were exposed to in the second week of the project. They were asked to consider how they might change their process to make it more robust and to update their process flowchart. They were also asked which were the toughest kinds of changes to deal with, how this exercise relates to the real world, and what implications this might have on an engineer doing process design. There was not a formal assessment of how the student's understanding of what an engineer does was impacted by seeing these environmental upsets other than the instructor reviewing and summarizing the written comments for the assignment during class. Can you add anything about a specific comment or two???

The students were also asked to contemplate how well their groups worked together. For the group dynamics assignment, the students were to consider who has become the natural leader of the group, who is the quietest member, what (if any) conflicts have arisen in the group so far, and if no conflicts have arisen, why do you think this is so? They were asked to review a handout on effective team building[6] and to determine which of the five guidelines their team addressed: define clear roles, agree upon goals, define processes and procedures, develop effective interpersonal relationships, and define leadership roles[6]. They were also asked to consider which of the guidelines they have not addressed and how their group might start working together to accomplish them. Some class time was spent discussing how the students responded and to consider the guidelines when taking part in future team activities.

For the third period on the slime project, the students spent time brainstorming to come up with a new product. They needed to address the following:
- Name and function of product
- Product and process changes
- Packaging
- Marketing
- Cost/pricing

For the supplies assignment, the students were asked to determine the supplies that they were going to need to produce their new product. For the new product plan, the students were asked what is the new product that you are going to make (name and function), how are you going to market the product, what is the estimated cost of the new product, what price will you sell it for, how will you process the new product, and how will you package the new product. They were asked to develop a new process flowchart related to manufacturing their new product.

For the fourth slime project period, the students produced their new product. This was a period of high creativity and also frustration as some of the products did not turn out the way the groups expected. The groups looked at how their original processing plan for the slime had changed to accommodate the new product. They presented their new process and product on the fifth day to a panel of judges.

For their final PowerPoint presentation, the students were asked to incorporate the following (in 6-7 slides):

1) Title slide (with group name and members listed)
2) Assignment
3) Name and function of product
4) Changes in product and process from original
5) New process flowchart
6) Packaging
7) Marketing plan
8) Costing and pricing
9) What concepts of chemical engineering and engineering in general have you learned from the Slime Project?

The judges selected the best presentation, the best new product and the best overall (equally weighting the presentation and product). For this class, the best products that were developed were a stress-relieving balloon that was filled with slime and a doggie bed filled with slime in the cushion.

Chemical/Industrial Engineering Information

As part of both the REACH academy module and the orientation course, the similarities and differences between Chemical and Industrial Engineering were described. This was to give the students a broad description of the variety of areas that Engineering covers.

The following information was given to students in a PowerPoint presentation/discussion format:

Chemical & Industrial Engineering

- Both
  - Rely on Mathematics & Science
  - Design and improve processes

  - Consider safety, environmental, legal, & economic issues and impacts
  - Monitor and control processes to obtain high levels of quality
  - Work as *professionals*
- Chemical Engineering
  - Mostly continuous processes
  - Industries (pharmaceuticals, food, specialty chemicals, materials & polymers, biotechnology, petrochemicals, healthcare & medicine, pulp & paper, and electronics).
  - Job functions - process design engineer, environmental engineer, process safety engineer, product engineer, research and development engineer, attorney, consultant, biomedical specialist and others
- Industrial Engineering
  - Mostly discrete processes
  - Industries- manufacturing (automotive, electronics, medical devices, food, etc.), service (healthcare, retail, banks, airlines, consulting, etc.), government, public service & regulatory organizations
  - Job functions - industrial engineer, process engineer, production engineer, management engineer, quality engineer, ergonomist, operations analyst, consultant, others.

Assessment

REACH Academy Assessment

A simple before and after assessment was given for the summer academy. The first question asked what type of processes Chemical Engineers and Industrial Engineers work with. The expected answers were continuous and discrete, respectively. None of the students responded to this open-ended question correctly, both before the workshop module and after. This concept needs to be explained in greater detail and strengthened for the summer 2006 academy.

The following question was also asked:

Which of the following characteristics does not apply to both Chemical and Industrial Engineering?

A. Both rely on mathematics and science.
B. Both design and improve processes.
C. Both perform detailed analyses of the chemical reactions that occur during processes (the correct answer)
D. Both consider safety, legal, environmental, and economic issues and impacts.

At the beginning, there were 11 of 30 incorrect or incomplete answers. At the end of the module, there were 4 of 30 incorrect or incomplete answers.

Dr. Greg Wilbur was the REACH academy director for summer 2005 (and will be for 2006 as well). In an assessment that he did for the project[7], he evaluated the pre and post academy knowledge of the students in the following areas: Architecture/Architectural Engineering, Biosystems & Agricultural Engineering, Chemical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Industrial Engineering and Management, Mechanical and Aerospace Engineering, and Engineering Technology.

The students did a self-assessment and faculty evaluated the students as well. For Chemical Engineering, the self-assessment pre and post academy scores were 2.90 and 4.57, respectively (where 1= no knowledge and 7=very high level of knowledge), and the faculty assessment scores were 1.90 and 4.07. For Industrial Engineering, the self-assessment pre and post academy scores were 2.33 and 4.33, and the faculty assessment scores were 1.43 and 4.10. These scores show that the students increased their knowledge in the fields somewhat and are consistent with the knowledge gains found by the other disciplines. It is not surprising that the post-academy scores were around 4 out of 7, since the time available for the module (6 hours) was not enough to give extensive knowledge of the disciplines. Also, the combination of industrial and chemical engineering may have confused the students somewhat.

For the summer of 2006, the authors plan to use a more rigorous assessment tool (such as was used for the orientation class, described below). The authors felt that they learned a lot from the REACH 2005 experience, and the project structure was a good starting point for implementation in the orientation class for the fall of 2005. The lessons learned will also be applied to making the 2006 academy much stronger.

Introduction to Engineering Orientation Course Assessment

An assessment was administered to the students in the Introduction to Engineering class before the project was started and at the project's conclusion. The students were given twenty statements to strongly agree with, agree with, be neutral, disagree with, or strongly disagree with. They are:

- Q1. I know the concept of product design.
- Q2. I understand the concept of process design.
- Q3. I am aware of steps in problem solving.
- Q4. I am comfortable working in groups/on teams.
- Q5. I am confident in my brainstorming abilities to solve problems.
- Q6. I am confident giving presentations using PowerPoint.
- Q7. I am able to develop a project plan.
- Q8. I understand safety and environmental issues in experimentation.
- Q9. I know what polymerization is.
- Q10. I know how to determine production costs, price a product and market the product.

The results of the assessment are presented in Table 4. The three questions that received the highest scores at the beginning of the project were Q3, Q4, and Q5. The students already had some confidence with some engineering skills (problem solving, teamwork, and brainstorming).

At the end of the semester, the three highest scores were for Q3, Q4, and Q5, problem solving, teamwork, brainstorming.

Table 4. Results of Orientation Class Assessment

	Begin N=14	End N=11	Difference (End – Begin)
Q1	3.71	4.18	0.47
Q2	3.71	4.18	0.47
Q3	**4.36**	**4.45**	0.10
Q4	**4.57**	**4.64**	0.06
Q5	**4.29**	**4.45**	0.17
Q6	3.86	4.36	**0.51**
Q7	3.43	4.18	**0.75**
Q8	3.71	4.00	0.29
Q9	3.21	3.91	**0.69**
Q10	3.50	3.91	0.41

5=Strongly agree, 4=agree, 3=neutral, 2= disagree, 1=strongly disagree. Bold numbers indicate the highest numbers in each column.

The largest differences from beginning to end were for Q6, Q7, and Q9. The students gained the largest confidence in giving presentations and developing project plans. Also, their appreciation of polymerization was enhanced.

In addition to the quantitative before and after survey that was administered (described above), a qualitative survey was also given at the end of the semester. The questions and comments from that survey are addressed next.

Are you more informed about product/process design strategies based on information obtained in this class?

Ten yes, one no.

Positive comments:

- "All the activities were great."
- "Product development involves a lot of research."
- "I have learned that product and process design can be very complicated."
- "I now know how…creating products in mass can be a challenge."
- "The slime project informed the process/product design strategies."
- "You learn through experience."

The sole negative comment was "I learned it better in my design class."

Are you now more comfortable working in groups based on experiences in this class?

Ten yes, one "a little."

Positive comments:

- "I enjoy working in groups and this just furthered my enjoyment."
- "The numerous activities were great for group based works."
- "Groups make projects easier."
- "Groups are much easier now."
- "I learn much about working in groups and including everyone in on the project. My group worked together well."

The one partially negative comment was the following: "Well I was comfortable but my group members weren't all that social."

Comment on the slime project and its relevance to the two above questions.
The following positive comments were provided by the students:

- "Good group relation."
- "These help prepare for the project."
- "It was awesome and really fun."
- "The slime project showed me that research is very important."
- "It was a great experience, very informative."
- "Easy area of design to get a broad spectrum of designing processes."
- "The slime project was very fun. It teaches a person more about product/process design and working in groups through experience."
- "The slime project has shown me that a production and distribution process is very complicated to come by."
- "It was good on how to actually learn how to produce things and the obstacles that come up."

Negative comments were:

- "It stunk."
- "Teamwork was questionable."

Suggestions for improvements to this course.
The following comments were obtained:

- "It was great."
- "More pizza and ding dongs."
- "More EXCEL exercises."
- "Keep Dr. Karen High as the teacher."
- "Make it cooler."
- "Maybe force the groups to conspire outside of class."

I understand the similarities and differences between chemical and industrial engineering.

One strongly agree, six agree, two neutral (3.89 average).

Dr. High evaluated the qualitative comments given by the students. Of the nine students that answered the survey, four seemed to have an excellent grasp on the differences, three had a very good grasp, and two had a good grasp. The comments themselves are too lengthy to include here.

The assessment results show that, overall, the slime project was a successful approach to show the students in the orientation class the major facets of engineering. The students in the class were very willing to be creatively challenged, and it provided an excellent vehicle to introduce the students to engineering.

Concluding Comments

When comparing and contrasting use of the slime project for the REACH academy and the orientation course, the authors identified a variety of important differences, which are summarized in Table 5. Both authors feel that the project worked best in a multi-week venue with freshman-level students taking the orientation course. Reflecting on the differences between the two offerings, the authors think that five of the dimensions contributed to the varying outcomes observed. First, the orientation class was more successful because of the greater maturity level of the students. The REACH students were typically one to two years younger than the college students in the orientation class. Second, the smaller class size made it easier to manage the class and to generate discussion. Third, the smaller teams helped to get all students on the team engaged in the activity. There were some students in the summer academy who did not actively participate with their teams. Fourth, the students that were in the orientation class had already selected Engineering as a major, so they were fairly interested in learning about engineering. The REACH students were exploring whether engineering was an appropriate career choice. The REACH students were also exploring college life, and several of the students were much more intrigued by the fun and excitement of campus, as opposed to the learning opportunities. Finally, the college students were able to successfully use the intermittent time between class meetings effectively for creative thinking and planning. For example, the economic analyses prepared by students in the orientation class were much more detailed than what the high school students accomplished. The orientation class students were required to do out-of-class assignments that required considering the past week's activities and how they will impact the next activities. The REACH students did not have any time between activities to reflect.

Table 5. Comparison of REACH Academy to Engineering Orientation Course

	REACH Academy	Orientation Course
Age of students	16-17	18-19
Class size	30	13
Team size	5	3-4
Major	Undecided (H.S. students)	CHE and 2 undeclared**
Multi-disciplinary approach	Balance between CHE and IE concepts; activities related to each	More emphasis on CHE with some IE concepts brought in
Length of project	6 hours (in 1 day)	5 hours (across 5 weeks)
Assessment approach	Self-assessment & knowledge test	Self-assessment

**One of the students was completing deficiencies before he/she entered the program and the other student was undeclared but taking CHE Freshman courses.

In 2006, the REACH academy and the orientation class will be held again. Based on our experience using the slime project in these two venues in 2005, several changes are planned for the future. The orientation class project will be tweaked to gain a better understanding of how students are using their out-of-class time. Timesheets or other mechanisms will be used to determine the amount and kind of creative thinking and planning taking place outside of class. The authors plan to make more significant modifications to the summer REACH module by scheduling it over two days and possibly splitting the class in half by gender. This is expected to reduce many of the problems that occurred, including the large class size, large team sizes, and distractions created by classmates of the opposite gender. It will also give the students extra time overnight for brainstorming in order to develop more creative products. For the summer of 2006, Dr. High will also be involved with K-12 teachers and introducing them to engineering. The teachers will be involved with the REACH program to learn about engineering and to be exposed to product/process engineering and chemical and industrial engineering. This K-12 involvement is for the North Central Consortium for Mathematics and Science, Title IIB Mathematics and Science Partnership. The teachers will be from the North Central area of Oklahoma, which includes Stillwater and Ponca City. The involvement of the teachers will help to enhance the experience for the high school students and to make sure the activities are relevant for both the high school students and the teachers.

The use of the slime project as a retention/informational tool for the orientation class appears to have been successful based on post-module feedback and analysis of retention from the first to second semester of the freshman year. Of the 13 students that were in the orientation class in the fall, 10 are declared as CHE majors. One is ENG undecided but is taking classes this semester such as organic chemistry and biology that indicate that he is planning to go Chemical Engineering. Another student is developing the credentials to be able to successfully declare Engineering as his major. He is enrolled in the appropriate Chemistry and Math courses. The only other student in the class switched from CHE to Arts and Sciences. So, the retention of students that were interested in CHE was 12 out of 13 students. The retention of students for this class (about 92%) is higher than the overall college retention (about 60-70%).[4,5] Of course it is important to be careful when drawing conclusions from small numbers. The students from the orientation class of 2005 will be monitored for the next four to five years to see if they remain in Engineering and graduate with engineering degrees.

The use of the slime project as a recruitment tool for Engineering needs to be refined. Based on student self-assessments, knowledge testing, and observation of the participating students, the authors do not believe that the module was effective. The authors will compare the assessments between 2005 and 2006 to see if planned modifications to the module generate improved feedback. It will be one to three years until the authors can determine the actual recruitment effect of the REACH academy. The project leader, Greg Wilbur, monitors long-term recruitment statistics. He will determine the number of students that choose to go into engineering and where they choose to enroll in college.

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