A Template for a Manufacturing Outreach Unit for Middle Schools

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Abstract
A template for an outreach activity to middle school students on manufacturing engineering is presented. The template includes three components: a filed trip to a manufacturing facility, an in class-presentation on the fundamentals of manufacturing, and a hands-on activity in manufacturing. A structure for the outreach program is proposed.

Introduction
Over the past three summers the authors have taught an introduction to mechanical engineering class to gifted middle school students as part of the two week Mathematics, Science, and Technology Program at Michigan State University. Two of the ten class periods have focused on manufacturing engineering. As this unit has evolved over the three summers, it has developed to the point that it could be used as a template for a college outreach program on manufacturing engineering for middle schools. Certainly the value of such engineering outreach programs is obvious based on the predicted future shortages of engineers, and the need to attract more and diverse people into engineering. It has been recognized that middle school outreach can be very effective in the recruitment of the next generation of engineers. This paper provides the template for such an activity.

There are three components to this manufacturing outreach template. Each component can be implemented in a once a week, one or two hour experience for a middle school science or technology class. Thus the program could serve as a three week unit in manufacturing for the class. The first component involves a tour of a local manufacturing facility. It is the authors' experience that manufacturing occurs in nearly all communities across the country and that most companies welcome the opportunity to show off their facilities to the public, and especially to school children. The second component involves a class presentation on the basics of manufacturing. Such topics as material processing, forming, fastening, finishing, and assembly lines are covered. Because the students will have seen several of these activities on their tour of the manufacturing facility, there will probably be considerable class participation during this presentation. Following this presentation, a hands on activity is carried out that includes the design and implementation of an assembly line for the simplified manufacturing of a bean bag animal toy. By doing this activity in teams, a friendly competition can be held to see which team designed the fastest assembly line. The activity concludes with a wrap-up in which the students evaluate the advantages and disadvantages of the assembly line designs. Details of these three components are provided in this paper, along with results of this activity with the Mathematics, Science, and Technology program. We continue this paper by suggesting some mechanisms for
using these components as an outreach program, which will include staffing ideas and means to establish ties between colleges and middle schools.

**Proposed Outreach Structure**

In this section we propose an organizational structure for this outreach program. Each university has a different approach to outreach, so this proposed structure will need to be customized for the institution’s approach. Certainly, the most important component is that the university has a commitment to K-12 outreach. As with most service activities conducted by the university, the key to a successful program is the participation of a faculty champion that is motivated to direct the service activity. Since faculty members are always busy with their other obligations, teaching and research, it is strongly urged that the program utilizes a student group, such as an ASME student section, SWE section, or honorary (e.g., Tau Beta Pi) to participate in and lead many of the activities involved in the program. This participation is consistent with the service charge of most student organizations. It has also been the authors' experience that college juniors and seniors relate especially well to middle school students, perhaps even better than most engineering faculty. With the student organization leading the tour, presentation, and hands-on activities, the faculty member is then able to put his/her efforts into developing the contacts with middle school classes, training the members of the student organization for their participation, organizing the manufacturing facility tour, and soliciting the small amount of funding required. The need to develop the three activities of the program, manufacturing facility tour, class presentation, and hands-on project, are, hopefully, thoroughly addressed in this paper.

There are many different ways that contacts may be made with middle school classes. If the department already has an outreach program, then those high school or middle school teachers involved in the activity can serve as key contacts. Through these teachers an appropriate class, most probably a science or technology class, can be identified. If such an outreach program does not exist, then possible contacts through faculty or students in the department should be explored. Quite often department faculty will have children of middle school age or department students may be former students of some middle schools in the area. If none of these opportunities exist, we have found that contacting a middle school principal with no prior introduction has also been effective, as most middle schools welcome the opportunity to interact with the local college or university.

The use of department students in the outreach activity must include a training program for these students. It will be useful for the student organization to have previously taken the manufacturing tour. Again, this is consistent with the expected activities of a student organization. Practice sessions for the presentation component need to be conducted. Most engineering students should be familiar with the technical aspect of the presentation. An expert in middle school education from the University’s education college or the middle school teachers involved in the program should attend these sessions to provide the students with criticism and feedback concerning their presentations. For engineering programs that have a strong communications component, only one of these practice sessions will probably be needed, but in most cases a second practice session should be held to allow the students to implement the suggestions made at their first presentation. During these practice sessions it is important to discuss the nature of the middle school student and some tricks of the trade in teaching middle school students. The hands-on assembly line activity should be done as a student organization
activity. In this way the students, as participants, will learn the ins and outs of the activity, and be prepared to handle problems that arise during the activity with the middle school students.

The costs for this outreach program are minimal, but with the current trends in educational funding it is important to outline these costs and suggest some possible funding sources. The principal cost for the manufacturing facility tour will deal with the transportation. It is possible that the cost of a bus to transport the class to the manufacturing facility will be covered by the school district. However, with the budget cutbacks in the public schools it may be necessary for the outreach program to provide these transportation costs. For the presentation component, the only real costs involve the audio/visual equipment needed. This equipment, computer and computer projector, should be available through the middle school or the university. The final costs for the outreach program deal with the hands-on assembly line component. These costs include the supplies (e.g., material and split peas) and tools (e.g., scissors, staplers). An estimated budget for the program is shown in Table 1. There are several possible sources for these required funds of approximately $400. Many universities provide internal grants for proposed outreach activities. It has been our experience that the effort to win such a grant is minimal and the success rate is fairly high. The parent/teacher organization for the partnering middle school may prove to be a good source of funding. Another excellent source of funding are the local sections of the professional engineering societies, such as the American Society of Mechanical Engineers (ASME), the Society of Manufacturing Engineers (SME), and the Society of Automotive Engineers (SAE). Finally, the national organizations for several of the student engineering societies provide funding for outreach programs. Two examples are the Tau Beta Pi Greater Interest in Government program and the ASME Diversity Action Grant program.

The organizational structure suggested above is based solely on volunteer participation of the engineering faculty and engineering students. For nearly all situations this will probably be the only realistic way for such a program to function. However, in the unlikely event that funds are available, a very positive impact could be made by providing a small stipend ($50-$100) to the engineering students involved in the program. Similarly, a university commitment to this program might involve an adjustment in the teaching load of the involved faculty.

Tour of Manufacturing Facility
A very effective mechanism of introducing youngsters to manufacturing engineering is through a field trip to a local manufacturing facility. Nearly all locales, even those that are very rural, have manufacturing facilities in fairly close proximity. For those areas that have several facilities to choose from, it proves to be most useful to choose one that is assembly line based, and has as many of the basic manufacturing activities as possible. The Mathematics, Science, and Technology program has used the two General Motor’s facilities in Lansing, MI. Both facilities run tours for the public on a regular basis, so that they are more than capable of conducting a tour for twenty middle school students. Though many facilities may not regularly run public tours, it has been our experience, mainly through the ASME student section at Michigan State University, that for the sake of positive public relations nearly all manufacturing facilities are open to the idea of conducting a tour. In setting up the tour it can be important to utilize a personal contact with the plant through faculty members, engineering students that have had co-op or intern experiences, or the parents of students at the middle school. It is suggested that no specific briefing of the students concerning manufacturing principles be done prior to the tour.
We have done the class presentation component both before and after the tour, and it is our opinion that the program works better with the class presentation done after the tour. The students do need to be reminded of the purpose of the tour, that they should be attentive, and well behaved. Engineering students should accompany the middle school class on the tour to begin to build rapport with the class. It is also expected that the typical number of parents will accompany the class.

Table 1  Estimated Budget for Manufacturing Outreach Program

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>One half day bus</td>
<td>$200</td>
</tr>
<tr>
<td>Rental of computer projector</td>
<td>$50</td>
</tr>
<tr>
<td><strong>Supplies (for 5 teams of six students)</strong></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>$20</td>
</tr>
<tr>
<td>Split Peas</td>
<td>$15</td>
</tr>
<tr>
<td>Staples</td>
<td>$2</td>
</tr>
<tr>
<td>Cups</td>
<td>$2</td>
</tr>
<tr>
<td><strong>Tools</strong></td>
<td></td>
</tr>
<tr>
<td>Scissors</td>
<td>$20</td>
</tr>
<tr>
<td>Staplers</td>
<td>$15</td>
</tr>
<tr>
<td>Markers</td>
<td>$10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$334</strong></td>
</tr>
</tbody>
</table>

**Class Presentation on Manufacturing**

A power point presentation on manufacturing has been developed for the Mathematics, Science, and Technology program, and is very suitable for this outreach program. The presentation is available for viewing and download from the web at

http://www.egr.msu/~somerton/ManufacturingOutreach

The presentation begins with an introduction to engineering. Several engineering disciplines are introduced and the products manufactured by these disciplines are discussed. At this point the hands-on assembly line activity is hinted at. Then the basic four manufacturing activities, material processing, forming, fastening, and finishing, are presented. The class is asked to provide examples of these activities from the manufacturing tour. The presentation concludes with an examination on the functioning of assembly lines.

**Beanie Eel Assembly Line**

The hands-on manufacturing activity asks the middle school students to design and then implement an assembly line to manufacture several beanie eels as quickly as possible. The pattern of the beanie eel is shown in Figure 1, while in Fig. 2 middle school students proudly show off their finished product. To begin, the middle school class needs to be divided into equal numbered groups of six or seven students. It is critically important that the groups have the same
Figure 1  Pattern for Beanie Eel

Figure 2  Finished Beanie Eel
number of students. Since this may not be possible with the number of students in the class, engineering students or class aides should be used to equal out the numbers for each group. It must be made clear that the engineering students or class aides should not participate in the design of the assembly, but can only serve as workers on the assembly line. A handout, shown in Fig. 3, is then distributed to the class and discussed with the students. The competition procedure is reviewed. The teams will be asked to make the number of beanie eels equal to the number of workers on the assembly line. In this way, each worker will have their own beanie eel at the end of the activity.

If there are no questions concerning the activity, then the teams are directed to collect their tools and supplies and begin their design process. To assist in the assembly line design, a second handout, Fig. 4, is provided that outlines the manufacturing processes involved in the making of the beanie eel, and the time for each process. While designing their assembly lines the teams are required to complete this handout, assigning workers to various tasks. As noted in the procedure, students may not change manufacturing stations unless it is in their plan, and this must be policed during the competition. With their assembly lines designed, the students are asked to staff their lines, and at a given signal begin making their beanie eels. As each beanie eel comes off the assembly it must pass inspection, principally that it does not leak split peas, which is the main flaw that appears. As each team completes the required number of beanie eels their time is recorded. The competition continues until each team has completed the required number of eels. The winning team is the one with the lowest time, and some simple prizes should be distributed to the members of the winning team. Figure 5 shows the competition in action. Table 2 provides some typical results, with the exception that the time produced by the winning team was extraordinary, lower by several minutes over the best times produced over the three years this activity has run. We have found that following the competition it is useful to have a debriefing session with the students, in order to reinforce the students’ learning. There are three aspects of the project that need to be noted. First, extra staples need to be readily available as it is not unusual for a stapler to run out during the competition. Second, time must be set aside for clean-up as split peas will be everywhere following the competition. Finally, even after three years running this activity, we find that stapling the two pieces of material together problematic with respect to leaking of the split peas, but we have yet to find a better way to achieve this as sewing is impractical and gluing ineffective.

Table 2  Some Typical Results of Assembly Line Competition

<table>
<thead>
<tr>
<th>Team</th>
<th>Production</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grape 2</td>
<td>6 eels in 6m 36s</td>
<td>66 sec/eel</td>
</tr>
<tr>
<td>Grape 1</td>
<td>7 eels in 9m 43s</td>
<td>83 sec/eel</td>
</tr>
<tr>
<td>Aqua 1</td>
<td>7 eels in 17m 44s</td>
<td>152 sec/eel</td>
</tr>
<tr>
<td>Aqua 2</td>
<td>6 eels in 18m 1s</td>
<td>180 sec/eel</td>
</tr>
<tr>
<td>Tangerine 2</td>
<td>6 eels in 19m 7s</td>
<td>191 sec/eel</td>
</tr>
<tr>
<td>Tangerine 1</td>
<td>7 eels in 27m 35s</td>
<td>236 sec/eel</td>
</tr>
</tbody>
</table>
Figure 3  Student Handout for Beanie Eel Assembly Line

Beanie Baby (Emily or Emil the Eel) Assembly Line

Objective: Using the materials, tools, and process descriptions provided design an assembly line that will produce six or seven Beanie Eels as quickly as possible.

Design Considerations:
1. Determine which processes should be in parallel and which in series
2. Determine how personnel and tools are to be utilized

Tools & Supplies Available:
- 14 or 16 7” x 14” Swatches of Cloth
- 2 Pairs of Scissors
- 1 Beanie Eel Cardboard Pattern
- 3 Staplers
- 2 Permanent Markers
- 4 1-Pound Bags of Dried Spilt Peas
- 7 8 oz Styrofoam Cups

Competition Procedure:
Each team will collect their tools and supplies
At the start signal the team will have 45 minutes to design their assembly line and test with production of one (1) Beanie Eel
At the stop signal the team is to halt their design and organization
With all the manufacturing stations staffed and the assembly line ready production will begin
Each team will assemble six (6) or seven Beanie Eels
Students may not change manufacturing stations unless it is in their plan
The team that completes production in the shortest time with all Beanie Eels passing inspection will win the competition.
Indicate which team members are assigned to the following manufacturing processes:

Manufacturing Processes in the Beanie Eel Manufacturing

**Draw Pattern on Material (60 sec.)**

Students Assigned: ______________________________

Lay the cardboard pattern on the unfinished side of the cloth and using a marker, trace the pattern on the cloth. Repeat for the second side of the eel.

**Cut out Pattern (132 sec.)**

Students Assigned: ______________________________

Using a pair of scissors cut around the pattern marked on the cloth. Repeat for the second side of the eel.

**Staple Sides Together (115 sec.)**

Students Assigned: ______________________________

With the unfinished sides facing out partially staple the two sides together, leaving the tail unstapled.

**Turn Inside Out (76 sec)**

Students Assigned: ______________________________

Take the partially stapled Beanies Eel and turn it inside out through the tail opening, so that the finished side is now facing outward.

**Mark Eyes and Mouth (22 sec)**

Students Assigned: ______________________________

With one of the permanent makers, draw the eyes and mouth on the Beanie Eel as indicated on the pattern.

**Fill with Peas (20 sec)**

Students Assigned: ______________________________

Fill a Styrofoam cup with split peas from the bag (pre-assembly). From the Styrofoam cup, pour the peas into the Beanie Eel through the tail opening.

**Complete Stapling (35 sec)**

Students Assigned: ______________________________

Staple the tail opening closed

**Inspect**

Students Assigned: ______________________________

Inspect the final product and correct any defects, especially that no peas leak.

Time to Produce 6 or 7 Beanie Eels: _________ min. ___________ sec.
Figure 5  Assembly Lines in Action
**Conclusions**

Based upon the author’s experience with a middle school summer program, a template for a manufacturing outreach program with middle schools has been proposed. The three activities for the program have been well tested and revised through three years of the summer program, and should translate well into a weekly outreach program. All of the materials for these activities may be downloaded from the web at the site referenced in the paper. The proposed organizational structure is untested, and will have to be customized for particular situation.

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