
AC 2012-3685: OUTREACH ACTIVITIES FOR MIDDLE SCHOOL STUDENTS: PROJECT FOR MECHANICAL ENGINEERING UNDERGRADUATE STUDENTS

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Outreach Activities for Middle School Students: Project for Mechanical Engineering Undergraduate Students

Abstract

The ASME Student Chapter, the SWE Student Chapter, the Mechanical Engineering faculty and staff have hosted a “Mechanical Engineering Day” at Gannon University, Erie, PA every spring since 2008. In average, 66 middle school students have participated in this event per year; while in 2011, the average participation was 90 students. The ASME’s Center for Leadership & Diversity awarded a Diversity Action Grant (DAG) to the ASME student chapter to partially fund this event. This paper presents the “Mechanical Engineering Day” event where the participating middle school students were introduced to different areas of mechanical engineering, and were guided and supervised by college students as they performed three activities associated with different aspects of mechanical engineering. Every year, seniors and juniors were in charge of proposing and selecting the projects/activities for the event as well as preparing all the necessary guidelines and instructions. For the juniors, the proposals for activities were part of a course grade and students had to showcase an area of Mechanical Engineering. The selected activities have included the design and construction of an egg-drop module, heat transfer experiments demonstrations, design and construction of a beam, design and construction of a watercraft, and design and construction of a zip line, amongst others. Through active participation in the event, the mechanical engineering undergraduate students at Gannon University have learned the importance of involvement in community outreach programs and team work, have had the opportunity to improve their leadership and communication skills, and have appealed to the young minds of the middle school students to give a thought to how they can impact and change their lives and the society in a positive way.

The objectives of the “Mechanical Engineering Day” were to establish an effective program to increase middle school student’s exposure to engineering, to inspire middle school students to consider mechanical engineering/engineering as a future career, and to provide the undergraduate students opportunities for leadership and professional development. Middle school students learned about engineering and mechanical engineering careers, how engineers impact everyday life, and according to the survey, that engineering is fun. The event will be discussed from a project-based perspective in a classroom setting. The paper will describe the involvement of the undergraduate students in the organization and execution of the event, the activities proposed and selected, and the advantages of students’ active participation. Finally, the lessons learned and challenges experienced will be discussed.

1 Introduction

Outreach events have demonstrated to be an effective approach to promote engineering majors amongst young generations at the same time that they support the mission of engineering professional societies and universities. Literature presents a large number of examples of pre-college (K-12) level outreach programs undertaken by universities, government institutions and their partners to promote Science Technology Engineering and Math (STEM) education ¹⁻⁶.

The original goal of the project was to start a “Mechanical Engineering Day”. Seniors, juniors and sophomores, members of the American Society of Mechanical Engineers (ASME) and Society of Women Engineers (SWE) student chapters, were to host middle school and high school students one afternoon when they would learn about engineering careers, how engineers impact everyday life, and they would have the opportunity to participate in three different activities guided by college students showcasing different aspects of Mechanical Engineering. In 2008, the authors mentored the two student groups to apply for the ASME Diversity Action Grant⁷ with the purpose to secure funds to implement the project. In four consecutive years, 2008-2011, the student chapters were awarded the grant. They received \$1,500 the first three years and \$3,000 on the 2011 cycle to host two events instead of one. Additional funds for the project have been provided by the Admissions Office, the Dean of the College of Engineering and Business, and the Mechanical Engineering Department.

The objectives of the project have evolved since its original conceptualization and implementation, nevertheless the ideology has remained constant.

1. Inspire middle school students to consider engineering as a future career.
2. Establish an effective program to attract a larger population of middle school students to the engineering field.
3. Target minorities and women in the middle school population to consider engineering as a future career. Table 1 presents the current demographics of Gannon University. It is a clear example of the need to attract and retain these groups.
4. Provide a venue for the mechanical engineering students to develop leadership, communication, and organizational skills.

Table 1: Gannon University / STEM Demographics

	2008-2009	2009-2010	2010-2011
University FT undergrad enrollment	2344	2444	2468
Engineering & Computer Science FT Enrollment	185	194	209
University Minority Representation	7.9%	7.8%	9.4%
STEM Minority Representation	3.7%	5.4%	6.0%
University Gender Mix	60% Female	59% Female	59% Female
Engineering & Computer Science Gender Mix	12% Female	12% Female	13% Female

Several desired benefits were identified during the conceptualization of this project. These benefits were grouped into four categories that relate to the cohorts/organizations involved.

1. Middle school students
 - Learn about engineering
 - Spend a day at an university
 - Interact with other students with similar interests
 - Interact with college students and faculty and clarify any doubts regarding engineering


2. College students⁸
 - Work as a team to showcase engineering
 - Act as mentors having the opportunity to impact younger generations' career choice
 - Execute a project with budget and time limitations
 - Develop leadership and communications skills
3. Middle School Teachers
 - Provide students with the opportunity to experience a college setting
 - Facilitate the interaction with possible role models
 - Network with engineering faculty
4. University and the School of Engineering
 - Community outreach
 - Reach minorities and under-represented groups
 - Increase number of service-learning activities and hours⁹

2 Integration of Outreach Components into Curriculum

Outreach activities are effective in helping students develop leadership skills. The proposal of activities for the outreach event is a required assignment for the juniors enrolled in a core mechanical engineering course taught by one of the authors, Machine Elements. Any course can adopt this outreach project and include requirements or characteristics of the proposed activities that relate to the course offerings. The outreach project is a great experience for leadership development and provides the authors with a continuous and updated pool of possible activities for outreach events.

In teams, the students must propose an activity showcasing engineering, test the activity, create a budget, create a handout with instructions for the middle school students, create scoring criteria to determine the success of the activity, select the activities for the event, participate in the event, and evaluate the event. Appendix A presents the assignment guidelines provided by the faculty to the juniors enrolled in the Machine Elements course. The activities will be described in more detail in the following section. For illustration purposes, Figure 1 presents two deliverables from the required assignment: guidelines for participants and scoring sheet.

The project guidelines are distributed to the faculty in the Mechanical Engineering Department in a yearly basis to encourage the adoption of the project. In 2008, the first year of implementation, the professor teaching Heat Transfer Lab adopted the project and supervised the seniors who performed the demonstrations; Table 2 lists the heat transfer demonstrations as one of the selected activities that year. In the following years, the rest of the faculty in the mechanical engineering department have taken the opportunity to give extra credit to the students that participate; but not other faculty has adopted the project as a required activity in any of the courses they teach. Therefore, the students enrolled in Machine Elements, course taught by the author, propose new activities every year as a group project in this course. The authors can report that students' participation to man the event has never been a problem even when 91 (see Table 3) middle school students attended.



MECHANICAL ENGINEERING DAY 2008
Egg Drop Module

Description:

The strength of structures is very important in engineering because the structures that are used everyday, like bridges, buildings, machines, cars, etc. need to be designed for longevity and safe human use. This activity will illustrate the force of gravity on an object, and the importance of structures and their strength in engineering.


Your Task:
Design and build an apparatus, with the least materials, that will allow an egg to be dropped from a height of about 8 feet without breaking when it hits the floor. Think of the egg as a passenger in a car going through a crash test.

Scoring:
The materials that you use to design your apparatus will come at a cost. Each team will begin the competition with 100 points. See the back of this page for the material's costs.

Penalty: If your egg breaks after being dropped, you will incur a penalty of 16 points.

Bonus: If your egg survives, you will get a 50 points bonus. This is a motivator to make a good design.

Guidelines:
Be creative and have fun! Good luck!



Egg Drop Score Sheet

Team: _____

Material	Quantity	Cost (points)	Total
Plastic Bag		10	
Rubber Band		2	
Straw		2	
Cotton Ball		2	
White Paper		1	
Construction Paper		4	
Chinese Box		20	
Pre-made Box		20	
Glue		2	
Paper Clips		1	
MATERIALS' COST			
INITIAL POINTS		100	
MATERIALS' COST			
EGG SURVIVAL			
SCORE			

Figure 1: Example of handout and scoring criteria created by undergraduates

3 Description of Activities

With the intent of providing the middle school students a broad view of mechanical engineering, each of the activities selected showcase a different area of mechanical engineering: heat transfer/fluid dynamics, structures/strength of materials and design competition. The process to select the activities for a given event has varied from year to year: (1) faculty has made the selection after requesting the input from the students who proposed the activities and (2) faculty and the officers of the ASME student chapter have made the selection. The process followed for the selection of activities has depended on the timeline and the involvement of the ASME officers. The result of the selection process is that three activities are provided at each event. Table 2 presents the activities selected for the events in the last four years. The actual logistics of the event are outside the scope of this article.

Table 2: Summary of Proposed Projects

Year	Number of Projects Proposed	Activities Selected for the Event	Comment
2008	5	Egg Drop	Many examples online
		Heat Transfer Demonstrations	Based on heat transfer experiments
		Beam Design using cardboard	Idea similar to a class beam project using wood. Undergraduates built a testing stand
2009	3	Egg Drop	Modified from 2008
		Zip Line	Adapted from Design Squad ^{10,11}

		Watercraft	Adapted from Design Squad ^{10,12}
2010	5	Watercraft	Modified from 2009
		Earthquake	Undergraduates built a small shaker table
		Bridge	Using K'NEX
2011	6	Watercraft	Same as 2010
		Trolley	Conceived by undergraduates
		Bridge	Modified from 2010

The day of the event, a handout was provided to each team describing the activity and the task to complete. The Design Squad design model was employed to guide the participants through the activities.¹⁰ A description of each selected activity follows.

1. Egg-Drop Module: Participants must design and build an apparatus with the least amount of materials that will allow an egg to be dropped from a height of about 8 feet without breaking when it hits the floor.
2. Heat Transfer Experiments Demonstrations: Undergraduate students demonstrated three experiments to the participants while allowing them to help setup, run the equipment and take measurements:
 - a. Boiling and Condensation
 - b. Measuring viscosity by falling spheres
 - c. Measuring water flow rate in an open channel
3. Beam Design: Participants must design a beam out of 3' x 3' cardboard that can hold the maximum load on a three point bending.
4. Zip Line: Participants must “design and build something that can carry a Ping-Pong ball from the top of a zip line string to the bottom in four seconds (or less!)”.¹¹
5. Watercraft: Participants must design and build a boat that can hold 25 pennies for at least ten seconds before sinking.¹²
6. Earthquake: Participants must construct a structure that can hold a cup 10 inches above the ground. The structure is taped to a board that is shaken to simulate an earthquake. Failure occurs when the cup sinks below 10 inches.
7. Bridge: Participants must create a bridge out of one K'NEX set that spans a distance of at least 12 inches and is at least 3 inches wide at its skinniest area. The bridge must sit flat and demonstrate that a hot wheels car could cross it.
8. Trolley: Participants must create a trolley out of various materials provided that can hang on a fishing line by itself and propelled by balloons can transport four ping-pong balls twelve feet in the shortest amount of time.

The handouts for the bridge and trolley are presented in Appendixes B and C, respectively. These are two of the three activities employed in 2011 events. The third activity, watercraft, was adapted from Design Squad¹²; only the scoring sheet is presented in Appendix D. The authors can be contacted for additional handouts.

4 Results

To date, this outreach project has served five different middle schools and a total of 331 participants. Table 3 presents the overall demographics and cost of the events. The number of undergraduate students during the event is presented as well; their participation is more than double the number of students enrolled in the course that requires their attendance.

Table 3: Participant Demographics and Cost of the Event

	2008	2009	2010	2011 (March)	2011 (April)
Number of Participants	40	50	62	91	89
Female Representation	17	24	22	52	46
Minority Representation	1	1	4	4	11
Number of ME undergraduates during event	35	35	20	29	30
Number of ME undergraduates enrolled in Machine Elements	15	6	15	15	
ASME DAG Funding	\$1,500	\$1,500	\$1,500	\$3,000	
Total Project Cost	\$1,867.99	\$2,106.95	2,634.91	\$4,698.24	

4.1 Middle School Students' Survey Results

Middle Schools students were surveyed at the end of each event. Based on the survey results presented in Table 4, participants left the event with an increased knowledge of mechanical engineering and 60.7% of all the participants “absolutely” would recommend the event to their friends interested in engineering. The participants stated that the activities were well structured. The survey administered to the participants appears in Appendix E.

In 2008, the egg drop module and the beam design were the most liked activities. In 2009, the egg drop and the watercraft were the most popular. In 2010, the watercraft activity was the most liked; while in 2011, it was the bridge design.

Based on the surveys (refer to Table 4), in 2009, 37 out of 47 (79%) participants said that engineering was fun; 36% of the participants said they would consider becoming an engineer while 53% said they are unsure. Overall, a similar trend has been observed in the other years that there has been a positive impact on the participants' perception of engineering.

The participants were asked to provide a comment regarding the student aids (i.e. undergraduates). The comments were very positive. Participants stated that the students were very nice and well educated, and that they instructed the activities well. They reported that the students were very helpful and very enthusiastic.

Table 4: Selection from the 2008-2011 Survey Results

	2008	2009	2010	2011 (March)	2011 (April)
In a scale from 1-5, how much did you know about engineering <u>before</u> participating in the ME Day? (1 being nothing and 5 being the most, please circle one)					
1 – Nothing	2(5.2%)	4(8.5%)	3(4.7%)	3(3.3%)	7(8%)
2	22(56.4%)	24(51%)	23(35.9%)	23(25.3%)	13(15%)
3	6(15.4%)	12(25.5%)	32(50%)	33(36.3%)	33(37%)
4	8(20.5%)	7(15%)	3(4.7%)	21(23.1%)	25(28%)
5 – A lot more	1(2.5%)		3(4.7%)	11(12%)	11(12%)
In a scale from 1-5, how much did you know about engineering <u>after</u> participating in the ME Day? (1 being nothing and 5 being the most, please circle one)					
1 – Nothing			2(3%)	8(9%)	7(8%)
2	3(7%)			3(3%)	3(3.3%)
3	24(62%)	4(8%)		10(11%)	10(11.2%)
4	12(31%)	29(62%)	28(44%)	36(40%)	36(40.4%)
5 – A lot more		14(30%)	34(53%)	34(37%)	33(37.1%)
Would you recommend this event to other students interested Engineering?					
1 – Never					
2		2(4%)	1(2%)	7(8%)	7(8%)
3	1(2.5%)	1(2%)	3(5%)	23(25%)	23(26%)
4	10(25%)	10(22%)	22(34%)	20(22%)	10(11%)
5 – Absolutely	29(72.5%)	33(72%)	38(59%)	41(45%)	49(55%)
Were the activities well structured?					
1 - Not really					
2			1(2%)	1(1%)	1(1%)
3	1(2.5%)	5(11%)	3(5%)	6(7%)	6(7%)
4	17(42.5%)	19(40%)	22(34%)	35(38%)	33(37%)
5 – Excellent	22(56%)	23(49%)	38(59%)	49(54%)	49(55%)
Do you think engineering is fun?					
Yes	33(82%)	37(79%)	40(62%)	57(63%)	55(62%)
No		1(2%)	4(7%)	11(12%)	11(12%)
Not Sure	7(18%)	9(19%)	20 (31%)	23(25%)	23(26%)
Would you consider becoming an engineer?					
Yes	18(45%)	17(36%)	14(22%)	45(49%)	41(46%)
No	1(2.5%)	5(11%)	13(20%)	17(19%)	19(21%)
Not Sure	21(52.5%)	25(53%)	37(58%)	29(32%)	29(33%)

4.2 Undergraduate Students Perspective

Mechanical engineering students enrolled in Machine Elements are required to submit a reflection, 300 words minimum, to assess the event, its purpose and the process. Students have

provided constructive comments that have allowed faculty modify the event and the activities offered. For example, based on the undergraduates' comments, the zip line activity was eliminated; students stated that the majority of the middle school students could not achieve the goal creating a level of frustration. Additionally, based on the undergraduate reflections, it appears that they understand the overall goal of the project: inspire the participants, without overlooking the benefits that this type of activity provides to their own personal and professional development. This has been observed in several of the reflections submitted. A couple of excerpts that attest to this statement follow.

Reflection 1:

"The first item that can be reflected upon is how this activity provided a learning experience for the college students themselves. It may seem like this day is mainly for the younger students, but it is prepared for mostly by college students. This allowed students an opportunity to understand how organization for an event is done. It also gave a reason for them to unleash their creativity and think of an activity that uses the basic principles of mechanical engineering. Therefore, this day showed a way for students to use their education to help the education of younger students."

Reflection 2:

"It was a good feeling to see the students succeed at the task they were assigned."

Reflection 3:

"...this day showed the older college students what is needed to teach engineering concepts in a fun activity that both old and young students would enjoy."

5 Lessons Learned and Challenges

The activities ran smoothly. From the surveys, it is clear that the participants enjoy the activities and that they learned about engineering.

The most challenging part of the organization of this event was recruiting the students. This has been a learning experience. Middle schools schedule their activities months in advance and for a high attendance, advertising/recruitment must start early. The Admissions Office has been very helpful in coordinating the recruitment in the last two years. This seems to be the most efficient way to advertise and recruit the students.

Creating a sense of ownership in the undergraduate students proposing activities is important. By ensuring that one or two of the activities proposed each single year are adopted for the event, a sense of ownership is ensured and the undergraduate students are more willing to participate.

Overall, the Mechanical Engineering Day has been a success. Undergraduate students enjoyed teaching middle school students. The middle school students learned about engineering; and 69.6% of all the participants think, according to the survey, that engineering is fun. Additionally, a 39.6% of the middle school students stated that they could consider engineering as a possible career.

6 Acknowledgements

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7 References

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Appendix A: Guidelines Project Proposals

ME335: Machine Elements
Dr. K. M. Vernaza

Spring 2011

MECHANICAL ENGINEERING DAY Group Project 1

Assigned: February 15, 2011
Activity Due: March 10, 2011 by 5 p.m.
Mechanical Engineering Day: March 18, 2011 and April 15, 2011

As part of service learning activities (already required on the Core of Discovery), Mechanical Engineering Students will host a Mechanical Engineering Day. We have secured funds through the ASME Diversity Action Grant for two events this spring semester: March 18, 2011 and April 8, 2011 (tentatively).

The first event will take place on March 18, 2011. You will need to sign up for a minimum of two hours for each event. This is in addition to the time preparing the assignment. The tentative agenda for the event is attached. The activities have been divided as follows:

Activity	Faculty Mentor	Type of Activity
Mentor for Juniors	Vernaza	Structures/strength/machine elements

Project:

In groups of 3 you will design/select a 50-minutes activity that showcases Structure, Strength of materials, or Machine Elements in Mechanical Engineering. The idea is that the middle school students (6-8 graders) that attend can do a hands-on experience that you will guide them through. We do not expect to have more than 90 students (maximum). If that is the case, they will be separated in groups of three, so each session will have a maximum of 30 students (refer to Agenda). Note: You cannot propose any of the activities performed in the last two Engineering Days (refer to Angel for details).

Things to address in your project:

1. With the time constraint, what should be the size of the groups to make sure that they will finish in time?
2. What will be the grading or scoring criteria? Create a scoring sheet.
3. Description of Activity: Prepare the handout that you will give the participants explaining the activity.
4. List of materials that will be needed. You have a budget of \$350.00 to buy all the materials needed for all three sessions of your activity. A budget must be created.
5. You should try the activity before submitting it. Keep the receipts for any expenses, you will reimburse them.
6. There are several websites that you can look into for guidance: Girls Scout website, Design Squad website, Pbs website, ASEE website.

Selection of the activity

Once all the possible activities are in (there will be five from your end and a couple that we will propose), the activity that will be used will be selected.

What to hand in on March 10, 2011 (if you want to take time during the break to work on this, you can let the instructor know.)

1. Description of selected activity with instructions.
2. How is the activity going to run: number of students working together, time for activity (i.e. 5 minutes to explain, 30 minutes to construct/built, 10 minutes to test, etc.)
3. List of materials with prices and possible purchase location. Budget.
4. Contest criteria – A winner must be selected
5. Any necessary information.

Note: One of the submitted projects will be selected for the March 18th ME Day.

March 11, 2011 – March 17, 2011

You will be assigned certain tasks to accomplish to prepare for Engineering Day. You will run the activity that day (classes permitting).

March 18, 2011

During Mechanical Engineering Day you are expected to run the activity and participate. If you have classes and permission is not obtained to be excused, you should attend them.

March 25, 2011

Individual assessment/reflection of activity is due.

Grading

Criteria	Percentage	Explanation
Report	60%	Description of activity addressing all the above mentioned items.
Participation	30%	Preparation for the event
		Participation during Mechanical Engineering Day.
Assessment of Activity	10%	Guidelines to be provided

Appendix B: Bridge Design Handout



Mechanical Engineering Day – Bridge Design | 2011



Objective

Your objective is to create a bridge out of k'nex that meets the criteria listed below:

- It must **span** a distance of at least **12 inches**.
- The bridge must **sit flat** and at least demonstrate that a hot wheels car could cross it. This means no major gaps on driving surface.
- It must be at least two layers high. No flat plates are allowed
- It must be at least **3 inches wide** at skinniest area.



Methods

- You are only allowed to use the pieces provided in the box your team is given. NO SHARING OF PIECES between groups.
- You will have **10 minutes** to **design** your bridge.
- **25 minutes** for **construction**.
- **15 minutes** for **testing**.

Testing

- The bridge will be tested by suspending weights under the bridge at the center.
- Weights will be added incrementally with a new weight added holding steady for **3 seconds**.

Judging

- Your performance is determined by the ratio of the weight held to weight of bridge.
- This means you should design to **hold maximum weight** with the **lightest bridge**.

TEAM

Weight of Bridge (g)	
Weight Held by Bridge (kg)	
SCORE (Weight Held / Weight Bridge)	

Appendix C: Trolley Activity Handout



Trolley | **2011**



Objective

Your objective is to create a trolley out of various materials provided that:

- It must **hang on the fishing line** by itself.
- It must be **propelled by balloons**.
- It must be based on the **base** provided.



Methods

- You will have **10 minutes** to **design** your trolley.
- **30 minutes** for **construction**.
- **15 minutes** for **testing**.

Testing

- The trolley will be tested by blowing up any propulsion balloons, placing it at one end of the line, and releasing it.

Judging

- The **faster** the **trolley** makes it across the line the better.
- The trolley **must** carry **four** (4) ping-pong balls.

TEAM MEMBERS

Time Across (How fast did it move?)			
Distance (How many inches traveled?)			
People (Did it hold four balls?)	Yes / No	Yes / No	Yes / No
Materials Costs: Paper Clip (3 points) Binder Clip (5 points) Straw (3 Points) Pipe Cleaner (5 Points) Tape – Either kind (6" – 10 points) Balloons (Big – 20, Small – 10 Points)			
SCORE (Distance*5) - (Materials + Time)			

Appendix D: Watercraft Score Sheet. Activity adapted from Design Squad.



Watercraft Score Sheet

Team: _____

Material	Quantity	Cost (points)	Total
Paper Cup		20	
6" Duck Tape		10	
Straw (2)		5	
Plastic Wrap (1")		5	
Paper Towel (1 sheet)		5	
MATERIALS' COST			

INITIAL POINTS	100
MATERIALS' COST	
FIRST 50 PENNIES HELD (+25)	
1 POINT FOR EVERY EXTRA PENNY	
SCORE	

Appendix E: Participant Survey for Effectiveness



PARTICIPANT SURVEY

Mechanical Engineering Day 2011

Name: (Optional) _____

1. In a scale from 1-5, how much did you know about engineering **before** participating in the ME Day? (1 being nothing and 5 being the most, please circle one)

1. nothing 2. 3. 4. 5. a lot

2. In a scale from 1-5, how much did you know about engineering **after** participating in the ME Engineering Day? (1 being nothing and 5 being the most, please circle one)

1. nothing 2. 3. 4. 5. a lot

3. Would you recommend the ME Engineering Day to other students considering Engineering?

1. never 2. 3. 4. 5. absolutely

4. Were the activities well structured? (1 being the worst and 5 being the best, please circle one)

1. not really 2. 3. 4. 5. excellent

5. Please comment on the Introduction to ME Engineering Video: (circle one)

1. disliked 2. 3. 4. 5. loved it

6. Please comment on the following activities: (circle one)

Activity 1: Bridge Design

1. disliked 2. 3. 4. 5. loved it

Activity 2: Trolley

1. disliked 2. 3. 4. 5. loved it

Activity 3: Watercraft

1. disliked 2. 3. 4. 5. loved it

7. Do you think engineering is fun?

- a. Yes
- b. No
- c. Not sure

8. Would you consider becoming an engineer?

- a. Yes
- b. No
- c. Not sure

9. What was most valuable about the Mechanical Engineering Day?

10. What would you like to improve about this Mechanical Engineering Day?

11. Comment on the student aids

12. General comments:
