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Hands-On Activity for First-Year Engineering Students

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Hands-On Activity for First-Year Engineering Students

Abstract

This Complete Evidence-based Practice paper describes a hands-on activity for first-year engineering students. It is intended to expose them to real engineered equipment, to give them experience working with tools, to enhance their teamwork skills, to have them take measurements in one set of units and then convert them to another, to have them draw hand sketches, to have them carry out some simple engineering calculations, and to have them write a basic set of instructions.

This paper describes an activity designed for first-year engineering students to learn how some common devices work. In this activity, students work in teams to take apart various devices and then put them back together again. Example devices include a: carburetor, compressor, single-cylinder engine, vacuum cleaner, and printer. Most of these devices are fairly complicated, have many parts, and yet are reasonably inexpensive. The selected devices do not have to be new and do not actually have to work although it would be preferred if they did, so students can demonstrate they successfully reassembled them. Note that this is not a project, where students research, analyze, design, and build something. While projects are very valuable in the development of good engineers, freshmen engineering students need intimate exposure to typical equipment designed by engineers.

Introduction

It was not uncommon in years past for first-year engineering students to have significant hands-on experience related to engineering, prior to starting college. For example, some worked on machinery used on a farm, while others worked on their cars or motorcycles [1]. Today, many first-year students typically have little hands-on experience related to engineering [2]. Many have never used common tools before and do not know how common devices, such as car engines, actually work. Stephen Belkoff, an engineering professor at Johns Hopkins, noted the lack of practical skills for incoming freshmen, “These are all A students, and it took two days to build a shelf from Home Depot and get it @$$-backwards” [3]. While they are generally very computer savvy, incoming freshmen have little experience with engineered equipment. Students do get experience with equipment in a variety of labs and in their capstone projects during the course of their college careers, but neither of these may be with actual equipment used in industry or in everyday life.

A common complaint from industry regarding new engineering graduates is their lack of hands-on practice [4], particularly with actual equipment. This may be due in part to the general lack of actual engineering experience for engineering faculty [5]. Ralston and Cox write, “Leaders in U.S. engineering education point to increased ‘real world’ skills as crucial for meeting the challenges of engineering in the future” [6].

Experience plays a central role in the learning process [7] and therefore is an important part of the engineering curriculum. Kolb writes, “Knowledge results from the combination of grasping and transforming experience. Grasping experience refers to the process of taking in information, and transforming experience is how individuals interpret and act on that information” [8]. A deserved criticism from industry, where most students go after graduation, is that most university engineering programs do not incorporate enough hands-on activities (experience) with actual equipment. This is referred to as “practical intelligence” [9]. U.S. undergraduate engineering education has a heavy emphasis on theory with much less emphasis on practical applications [10].

Wankat and Oreovicz write, “Despite almost universal agreement on the importance of design and laboratory work, there is a tendency to cut these programs since they are expensive, messy, hard to teach, time-consuming, and not connected to the university’s other mission – research” [11]. Laboratories play an essential role for engineering students to gain experience in the practice of engineering [12]. Feisel and Rosa identified three types of engineering labs: development, research, and educational. The activity described here would be considered to be an educational lab.

Engineering students generally find hands-on activities to be enjoyable [13]. That seemed to be the case for most students in the class where the activity described here was implemented (see Figure 1). Research has shown that engineering students feel like they learn more when they find exercises to be more engaging [14], which is an important aspect of the activity described here.

Figure 1. Students working on single-cylinder engine.

This activity is part of a 3-credit introductory course required for all engineering students entitled “Engineering Innovation and Problem Solving” (ENGR 1103) which consists of 2 hours of lecture and 2 hours of lab each week of a 15-week semester. The activity described here is only one part of the lab portion of the course. The major part of the lab section of the course is dedicated to an integrated drone project where students modify commercially available drones to deliver supplies such as food and medicine in a developing country. The class can have up to 36 students. This activity satisfies the course objective “Students will be able to take apart and re-assemble common engineered devices.”

For each lab session of up to 20 students, there were four sets of hand tools which included Philips and flat-head screwdrivers, an extensive set of English and metric socket wrenches (as part of a Craftsman 230 piece Mechanic Tool Set), Allen and adjustable wrenches, and various types of pliers among other tools. Each set of tools also included a digital caliper and a tape measure, both of which included English and metric units. No power tools were provided, nor were needed.

Activity Description

An activity has been developed for first-year engineering students to expose them to: actual engineering equipment, common tools (e.g., screwdrivers and wrenches), working on teams, taking measurements in one set of units and converting them to another, making simple engineering calculations, drawing hand sketches, and developing a written procedure.

Goldberg and Somerville describe engineering as a "team sport" [15] that requires interaction and collaboration to be effective. Engineering students that actively and collaboratively learn generally perform better and retain information longer [16]. In a landmark study funded by the Carnegie Foundation for the Advancement of Teaching, researchers found that learning to work collaboratively in labs is a critical skill for engineering students [17]. Stone and McAdams believe that hands-on engineering education activities can be unwieldy for individual students, but are well-suited for groups [18]. Pusca et al. believe that engineering labs in particular should be hands-on [19].

In the activity discussed here, students select what teams they will work on which usually changes for each device. Every student in a group is required to do something during disassembly and reassembly of a device. It is preferred if each group has at least one student experienced using tools and taking things apart and reassembling them, although not necessarily for the particular device being disassembled and reassembled.

The devices used here were selected because they met the following criteria:

- Common engineered devices familiar to students
- Easy/convenient to obtain
- Relatively low cost
- No special, expensive, or power tools needed
- Small enough for one student to lift without any special equipment

For example, the Volkswagen carburetors were obtained for free from a junkyard by a student in the class who rebuilds VWs.

The quality of the hand sketches varied widely. Some students attempted to generate 3D drawings while most others confined their drawings to 2D. Final drawings in industry are done in CAD but it is not uncommon for engineers to hand sketch parts for technicians, machinists, and draftspersons. Few attempts were made by the students to name the parts, which was not a requirement for the assignment. Since no exploded view drawings were provided by the manufacturers, the actual part names were generally unknown.

Students selected which areas and volumes they would calculate for a particular device. No formulas were provided for these calculations, so students would get some experience making them. They also selected the primary measurement units (English or metric) that would be used for measuring dimensions and reporting areas and volumes. The only issues noted for these calculations were some errors in converting between units.

Ideally, the activity is done in sessions that are more than an hour long to give students sufficient time to get a device and appropriate tools, disassemble the device, reassemble the device, and put the device and tools back where they came from. Depending on the length of each session, students may not complete the activity for a device in a single session and may have to continue the activity in another session. The devices are on metal carts (Harbor Freight, $106 each) which makes it easy to bring them out and put them back again after the activity is completed. Depending on the specific devices chosen, it is very possible that none of the students will have experience taking them apart and putting them back together again. Therefore, even students with significant previous hands-on experience still learn from the activity. Those who are experienced generally lead their groups which helps develop their leadership skills.

The activities in a particular lab session were at the discretion of the students. They worked on the drone project portion of the lab with a team designated by the instructor in some sessions and with a team of their choice on the lab activity described here. They were given this flexibility because they were sometimes waiting on parts and equipment for their drones, in which case they worked on the activity described here to fill in the gaps.

For best effectiveness, it is recommended there are enough appropriate tools available so students do not have to wait to use them. Each student does their own short report for each device. The report requires the student to give a brief description of the device which could be from an internet search. Integrated into the report template (see Appendix) are some general safety instructions and a generic procedure for the activity. Students were required to wear safety glasses during the activity. Since taking a device apart is usually easier than putting it back together again, students are required to develop a set of instructions for how to reassemble the device. They are also required to sketch a minimum number of significantly complicated parts (e.g., not screws or bolts) including dimensions in both English and metric units. This gives them experience with making measurements and unit conversions in the two most common systems. They are also required to make some area and volume calculations related to something in or on the device. An example would be the surface area of a piston and the volume of a cylinder in an engine. Note that this activity is different than other activities such as making something out of Lego pieces [20] which is not an actual engineering device.

Examples

For this course, students had to complete a lab report for 4 of the following 5 devices: carburetor, compressor, single-cylinder engine, printer, and vacuum cleaner. For this type of activity, it is recommended that familiar devices are used to demonstrate the complex engineering involved in everyday devices [21]. Five Volkswagen carburetors (see Figure 2) were obtained at no cost from a local repair shop specializing in VWs. Two compressors (see Figure 3; $160 each) and two single-cylinder engines (see Figure 4; $130) were purchased from Harbor Freight. Two inexpensive printers (see Figure 5; $40 each) were obtained from Staples and two vacuum cleaners (see Figure 6; $59 each) were purchased from Walmart. There was a sufficient quantity of devices that no groups had to wait for equipment. Each group generally had 4 – 6 students.

Figure 2. Volkswagen carburetor.

Figure 3. Fortress 1 gal. compressor.

Figure 4. Predator 3 hp, 79 cc engine.

Figure 5. HP 2734e printer.

Figure 6. Bissel Powerforce Helix vacuum cleaner.

Results

Students were required to disassemble and reassemble 4 of the 5 available devices and complete their own lab report. All devices were successfully reassembled. No data were collected on how long it took to disassemble and then reassemble each device. The relative value of each section of the report is shown on the template in the Appendix, where there were 36 total points available for each device. There were 27 mechanical and 8 electrical engineering students who received grades in the class. Each student was graded individually on this activity where teamwork did not factor into the grade.

The grades for and number of students disassembling and reassembling each device are shown in Table 1. Note that the vacuum cleaner was the most popular device (all but one student selected that device) and the engine the least popular (21/35 selected), presumably because the vacuum was assumed to be the simplest device and the engine the most complicated.

Table 1. Grades for each device.

	Carburetor	Compressor	Engine	Printer	Vacuum Cleaner	Overall
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Median	96.9%	90.6%	84.4%	93.8%	90.6%	92.2%
Average	90.6%	84.1%	82.8%	85.0%	83.8%	83.9%
Minimum	40.6%	43.8%	59.4%	34.4%	34.4%	41.4%
# Completing	26	27	21	25	34	35

The cumulative scores for all 4 devices for a given student ranged from 41.4 to 100%. The lowest average scores were for the engine which was the most complicated device. The highest scores were for the carburetor which was relatively simple. Note that grading was not very strict since this is a first-year introductory course designed in part to motivate students to continue in engineering since retention is an ongoing problem in engineering education [22]. All students who started this course successfully completed it, with most students getting an A or B and 2 students getting a C for the class.

Although not a specific objective of this activity, it was observed that students often had to use problem-solving skills to reassemble the more complicated devices. No assembly instructions were provided with the devices since they came assembled and they were not specifically designed for users to take them apart and put them back together again. One particular incident highlighted this problem-solving. One of the groups disassembled the engine which has a pull-string mechanism to start it, similar to gas-powered lawnmowers. A team took that mechanism apart but was initially unable to reassemble it properly. One student on the team took it upon himself to reassemble that mechanism which took him well over an hour to do. He remarked how satisfying it was to finally get it working again.

Student Feedback

The last part of the lab report asks students the following questions:

1. Did you know how this device worked before this lab?
2. List any tools you used for the first time during this lab.
3. What did you learn from this lab?
4. What suggestions do you have to improve the lab?

The results for the first question are summarized in Figure 7. About half of the students knew how a carburetor, compressor, and engine worked before the lab. Most students knew generally how a printer works and all knew how a vacuum cleaner works (not the details but the general function).

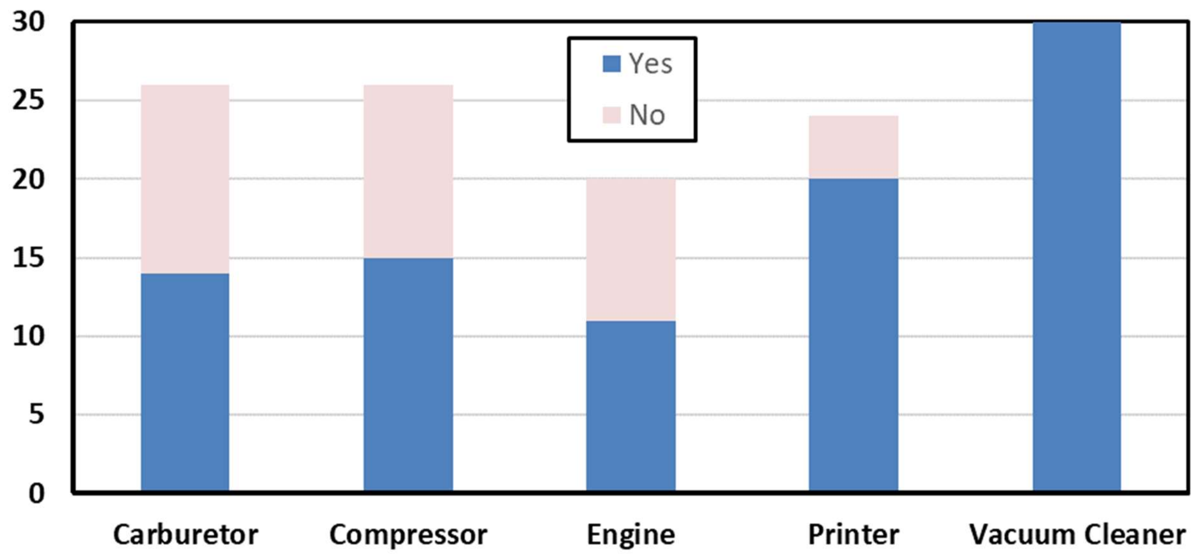

Figure 7. Student responses (yes or no) to whether they knew how a particular device worked before the lab.

Figure 8 shows that two-thirds of the students reporting did use at least one tool for the first time and approximately two-thirds of those using a tool for the first time used more than one new tool. Table 2 shows which tools were used for the first time and how many students used each tool for the first time. The most common answers were screwdrivers and wrenches with pliers being the tool least used for the first time.

Table 2. New tools used.

	Allen Wrench	Digital Caliper	Pliers	Screwdriver	Starbit Screwdriver	Tape Measure	Wrench	Total
Count	2	5	1	16	3	5	13	45
%	4.4	11.1	2.2	35.6	6.7	11.1	28.9	100.0

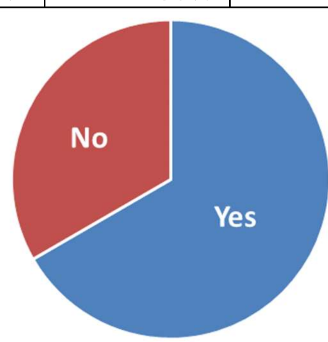

Figure 8. Students using any type of tool for the first time.

The most common answer by far for the third question was that students learned the detailed operation of a particular device. Table 3 shows that some students were surprised by how simple some devices are, while others were surprised by how complicated some devices are.

Table 3. Number of students who found a particular device simpler or more complicated than expected.

	Carburetor	Compressor	Engine	Printer	Vacuum Cleaner
Simpler than expected	1	2	1	1	2
More complicated than expected	0	0	2	3	0

Some common responses to the fourth question included: more discussion of the device before working with them and more space and time to work on the devices.

A voluntary and anonymous survey was given to the students at the end of the course about some of the major assignments, one of which was the activity discussed here. Students were asked to rate the activity and provide any feedback. There were 16 responses for the activity. The results are shown in Figure 9. Note that some students did not realize there were questions on the back of the survey to be completed, which is where this question was located. This helps explain the lower response rate for the questions on the back of the survey as 21 students completed the front page of the survey.

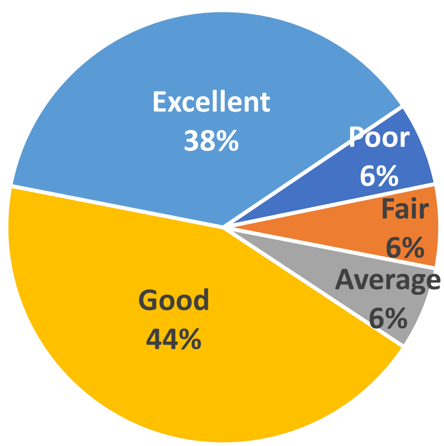

Figure 9. Survey results on the equipment disassembly/reassembly activity (based on 16 responses).

Some selected comments included:

- “Very interesting overall. I enjoyed looking at internal mechanisms, but I didn't like the time management.”
- “Great way to learn how to use tools and parts. Also dealing w/equipment that is new.”
- “By far my favorite part of the class; perhaps we could have started earlier in the semester.”
- “I really did like being able to take apart and put the equipment back together! Maybe some guidance on names of parts, but doing research on things helped!”

The main complaints regarded not starting this activity until approximately the midpoint of the semester when the idea was conceived after observing that many students were not very familiar with common tools and that an activity was needed to fill in while waiting for parts for the drone project. In future labs, the activity described here will be started at the beginning of the course and will be woven throughout the labs. More devices may be added as well.

Conclusions and Recommendations

As might be expected, there were some challenges for students putting some of the devices back together again. In future labs, it may be useful to collect data on how long it takes to disassemble and reassemble each device. It was encouraging to see students with little if any experience with tools to actively and enthusiastically engage in the activity. Those students with significant experience acted as mentors for their groups and willingly helped their less-experienced colleagues. The activity is very flexible and can be done with various size groups and at various times during a course. The number and type of different devices are completely up to the instructor.

There is an upfront investment in tools and devices, but these can be used many times in future labs with very little additional expense. While not required, four tool cabinets (Craftsman model 1000 top and bottom, $149 for each set) were purchased to contain the hand tools. The hand tools cost approximately $300/set. The total cost of the devices previously described was approximately $780. Then the total cost of the tools, cabinets, carts, and devices was approximately $3,000. The only expenses in future labs will be repairing or replacing any damaged devices, replacing any broken or missing tools, and potentially adding new devices. Note that no devices had to be repaired or replaced after the first semester incorporating this activity. It may also be possible to get some of the devices at little or no cost from junk yards, secondhand stores, garage sales, and flea markets.

The number of devices for each student to disassemble and re-assemble depends on the device's complexity and the time available. The carburetor, printer, and vacuum cleaner can generally be completed in a two-hour lab session. The compressor and engine took approximately three hours each. The time also varies depending on when in the course students work on a particular device. It takes them longer at the beginning of the course than at the end when they have become more proficient at disassembling and reassembling devices. Ideally, students would start with simpler devices and work up to more complicated devices, but this would require many more units of each device.

A suggested improvement for future labs will be to limit the number of students in a group to make sure students get enough time to work on a given device. This will either mean getting more devices or having more sessions available for this activity. Other improvements for future labs are to provide basic safety training beyond what is given in the lab report template and training on the specific devices before disassembling and reassembling them.

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Appendix

Lab Report Template

Last Name: ______________________________ First Name: ______________________________

Date: ______________________

Circle Equipment Investigated:

carburetor compressor engine printer vacuum cleaner

Background Information -write a brief description of the purpose of this equipment (e.g., the purpose of a hair dryer is to dry hair). Use the internet as appropriate – make sure to reference your sources if you use any (1 pt).

Safety Precautions

If the device is electrical, it should not be plugged in while disassembling & reassembling it. Be careful of sharp objects/edges. If you do not know how to use a tool make sure to ask. Do not lift anything that is too heavy. Do not do anything you consider unsafe. Ask for help if you need it.

Experimental Procedure

1. See if the device runs properly before you take it apart.
2. Identify what the front, top, right, left, back, and bottom of the device is in words so someone reading your description knows the orientation before you describe how you are taking it apart. (1 pt)

3. Create a set of instructions for how to take the equipment apart in a way someone else could repeat your procedure including the type and size of the tool used such as an 18 mm box wrench.
4. As the device is being disassembled, select at least 5 different parts to measure and sketch.
    a. For each part, sketch the part and label what it is if you know.
    b. Measure all the dimensions of the part and list these on your drawing in both metric and English units to the proper number of significant figures.
    c. Calculate the area or volume if possible, listing units in both metric and English units in the proper number of significant figures.
5. Reassemble the device.
6. Create a set of instructions for how to reassemble the device in a way someone else could repeat the steps.
7. Test the device to see if it works after it is reassembled.

Sketch 4 <u>substantial</u> parts – not screws, nuts, springs, etc.; include both English & Metric Dimensions. (4 pts each)

Part name/description:____________________________	Part name/description:____________________________
Part name/description:____________________________	Part name/description:____________________________

Make an area calculation for a part or assembly on this equipment using both English & metric units. For example, you could calculate surface area for a part on the printer. (4 pts)

Make a volume calculation for a part or assembly on this equipment using both English & metric units. For example, you could calculate the volume inside an engine cylinder. (4 pts)

Re-Assembly Instructions – give step by step (use as many steps as necessary). (4 pts)

1.

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Follow-up Questions

1. Did you know how this device worked before this lab? (1 pt)

2. List any tools you used for the first time during this lab. (1 pt)

3. What did you learn from this lab? (2 pts)

4. What suggestions do you have to improve this lab? (2 pts)

Total Score: ________ / 36