LEGO Builds Bridge for Communication and Teamwork

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Introduction

It is well recognized that engineering graduates require communication and teamwork skills in order to succeed in the workplace. Unfortunately, the traditional model of lecture/tutorial/lab for discrete subjects emphasizes reliance on the instructor for the delivery of facts and well-established principles rather than teaching students what engineers really do – design, revise and test solutions while analyzing and synthesizing the best available data and theories. Thus, the Canadian Engineering Accreditation Board (CEAB) and the American Accreditation Board for Engineering and Technology (ABET) both stipulate that every student must have real world, team-oriented, open-ended design experiences before graduation[1,2].

Mount Royal College instructors believe that students should be exposed in their first year to a design class that incorporates elements of team work, communication skills and creative problem solving so that they begin to develop these skills in parallel with their technical knowledge. Engineering Communications and Design I and II (ENGR 1251 and 1253) are two such courses. The communications component includes oral, written as well as visual communication skills, with a strong emphasis on sketching, which has been shown to have a positive impact on the engineering design process and quality of the designed solution[3]. Developed in conjunction with similar courses at the University of Calgary, the Engineering Design and Communication courses span the entire first year and are taught by a team of interdisciplinary instructors. Students spend only 1 hour per week in lecture, and 4.5 hours per week in labs where activities are mostly team-oriented. Students are assessed with equal weight on visual communication skills (technical drawing and sketching), oral and written communication skills (presentations, report writing as well as grammar and organization) and design (team project design performance, analysis and quality).

However, most entering students in science and engineering believe there are unique answers to any problem, expect their instructors to know what those answer are, and expect their task to be memorizing and repeating those answers on tests[4-7]. Requiring students to take a course which emphasizes communication, teamwork and design often yields resentment and generates complaints such as "I went into engineering so I didn't have to write and/or draw" and "If I had a teammember like this at a real job, he/she would be fired". Explaining to students that what they practice in the course will be exactly what most of them will do as professionals can help to overcome some student resistance[8]. In addition, active learning has been shown to be an extremely effective way to improve student attitudes, increase motivation to learn and to improve critical thinking skills[8-11]. Therefore, we find it useful to start the first semester with a team activity that helps to demonstrate the need for development of communication skills.

The purpose of this paper is to describe one of the opening activities in our first-year design course which was developed to be a fun, team-building activity, but also to defuse students' resistance to teamwork and development of communication skills.

Activity

Students are divided randomly into groups of five. Each group is given a mechanical device made from the LEGO Dacta series, with all groups in the same class receiving the same device. The devices include a ferris wheel, scale, u-joint, scissor jack, pump jack and water wheel (see Figure 1 for examples).

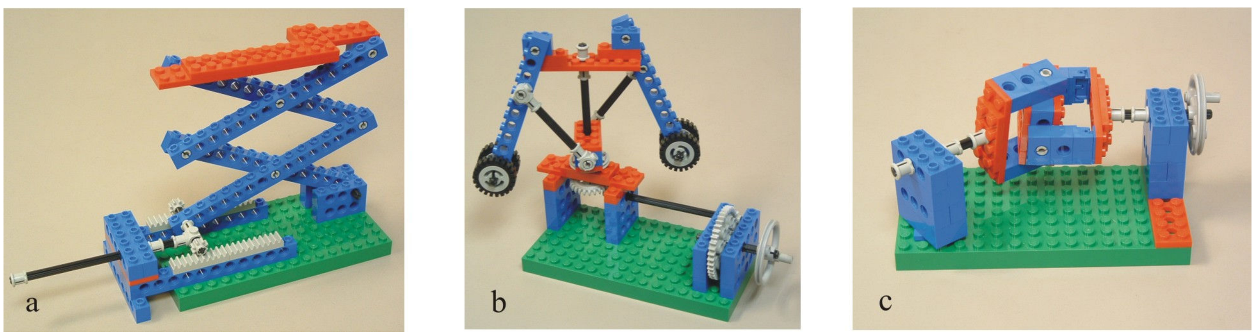


Figure 1. Examples of LEGO Dacta mechanisms: (a) scissor jack, (b) ferris wheel and (c) u-joint.

For the first 30 minutes, students are asked to draw a representive sketch of the mechanism in their sketchbooks. They are instructed to avoid capturing all the detail of each individual bump on the LEGO pieces; however, they have not yet received any sketching instruction.

Next, the teams are asked to take an hour to "prepare instructions that allow another team to build the mechanism." The instructors deliberately do not explicitly mention whether the instructions should be written or visual, and if students ask for clarification they are only told to do whatever they think will make the instructions the most effective. At the end of the hour, each team must provide the instructor with one copy of the instructions along with the disassembled mechanism.

After completing their task, teams are given a set of instructions for a different device, prepared by a group in another class, accompanied by the disassembled mechanism. They are given up to 30 minutes to attempt to build the new mechanism and to evaluate the instructions (Table 1).

Table 1. LEGO instructions peer evaluation criteria (maximum score: 30 points).

Standard	Description	Value
Excellent	The written and graphical instructions clearly describe how to build the LEGO mechanism	30
Good	The instructions allow the building of the LEGO mechanism with a minimal amount of interpretation	25
Satisfactory	Instructions result in at least 2 interpretations in building the mechanism	20
Poor	Instructions contain mistakes, and/ or the final object cannot be completed or is unknown	15
Missing	No instructions have been included	0

Having evaluated a peer group's set of instructions, the students next become actively involved in an instructor-initiated class discussion about what elements are necessary for good instructions. Typical suggestions include:

- Use pictures rather than long descriptions whenever possible.
- Be short, simple and concise.
- Name pieces and/or groups of pieces.
- Use a logical order.
- Do not repeat information.
- Be clean and neat in presentation of both text and drawings.
- Label figures.
- Include a picture of the finished product.

An instructor also provides a short lecture to introduce some basic, simple rules for grammar, punctuation, spelling and style in technical writing. A list of requirements includes:

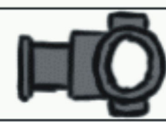
- Use words accurately.
- Call an object by the same name throughout a document.
- Use the active voice.
- Keep tenses simple and consistent.
- Use parallelism in lists.
- Use conditional clauses before result clauses.
- Keep pronoun antecedents clear.
- In instructions, use the imperative.

Results

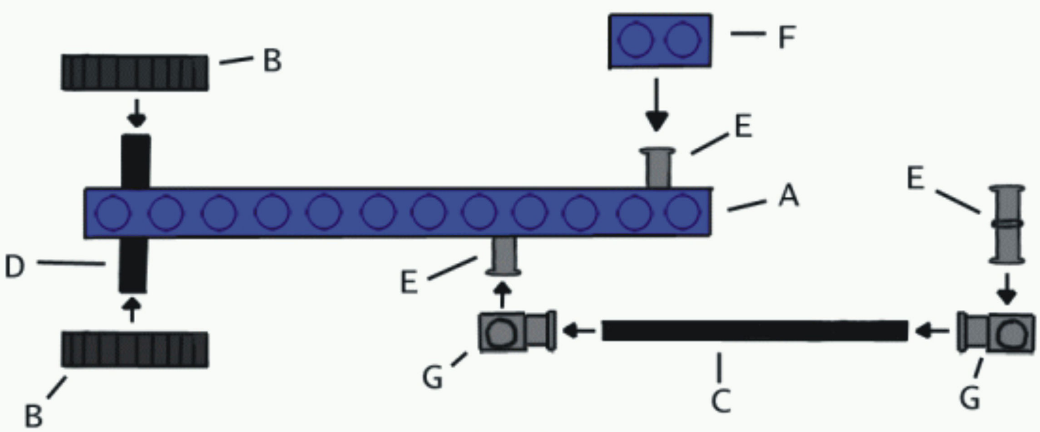
The opportunity to evaluate each other's work reinforces the need for effective written and visual communication. In fact, many groups do not even consider using drawings at all in their first attempt at preparing a set of instructions. At the end of class, students receive their own instructions back along with their peer evaluations, and are given until the following week to improve and resubmit the instructions. The improved set is marked by the instructor, using criteria from the above lists.

Critiquing other groups' instructions helps improve the students' own self-critiquing skills and consequently improves their instructions. The second attempt results in clear, concise and more accurate text as well as more logical organization and better drawings. Most improved instructions include a list of parts where each piece is clearly named. One group's description of the first step in building the ferris wheel is shown below (Figure 2):

Piece 1 & 2 (Build Twice)

Materials			
Reference Letter	Quantity	Description	Picture (If necessary)
A	1	12 x 1 x 3 with holes	
B	2	Tires	
C	1	6 length axle	
D	1	4 length axle	
E	3	Connection joints	
F	1	2 x 1 x 3 with holes	
G	2	Closed axle end piece	

Instructions



Top View

Figure 2. Step one in an improved set of ferris-wheel instructions.

Discussion

The LEGO instructions activity is the first in a series of applied and iterative learning opportunities in the first engineering design course. Not only is it useful for introducing students to the concepts of effective teamwork and communication in engineering, but it also teaches students to start thinking critically about their own work. Because the students discover their own mistakes in comparison to their class norms, the lessons become part of the deep structure of their class experience as their first introduction to a career in engineering.

Kurfiss[12] examined a wide range of successful courses devoted to teaching critical thinking, and derived eight principles for designing a course to support critical thinking. The instructions activity is novel and extremely useful, as it incorporates five of the eight principles in a short assignment at the beginning of the students' careers in engineering:

- Both the instructor and peers are resources in developing critical thinking skills, as students receive guidance in evaluating their peers' and their own work.
- The problem (in this case, preparing instructions) is used as the point of entry into the subject of successful teamwork and written communication, and thus provides increased motivation for sustained learning.
- The activity challenges students to think critically on their own first, then provides appropriate support by facilitating discussions on technical writing and effective instructions.
- The problem is activity-centered rather than text and lecture centered.
- Students are required to formulate their thoughts in writing.
- Students collaborate in small groups to learn, and they begin to understand that several heads are better than one as they begin to bounce ideas off one another.

In addition, the instructions activity helps students learn the benefit of making links from knowledge in one "discrete" area to another. For example, most students have seen LEGO or IKEA instructions before, which use drawings very effectively. However, many groups ignored their own experience that a combination of sketches and words are highly effective, and initially prepared text-only instructions. After the critique and discussion period, many students make comments such as "I have seen instructions with pictures before, I don't know why I didn't think to do that!" Another goal of the first-year design courses and the LEGO instructions activity is to encourage students to consider other subjects such as statics, dynamics, mathematics or their own experiences as information that is not meant simply to be used in those courses but is also meant to be incorporated into their set of analysis tools to be used to attack their engineering problems. We dare to hope that by the time they participate in a capstone design project, they will be able to negotiate the minefields of team work and communication skillfully.

Bibliography

1. Canadian Engineering Accreditation Board (CEAB) (2003) Accreditation Criteria and Procedures, <http://www.ccpe.ca/e/files/report_ceab.pdf>, accessed January 1, 2005.

2. Accreditation Board for Engineering and Technology (ABET) Criteria for accrediting engineering programs, < http://www.abet.org/images/Criteria/E001%2004-05%20EAC%20Criteria%2011-20-03.pdf>, accessed January 1, 2005.

3. Schutze, M., Sachse, P., Romer, A. (2003) Support value of sketching in the design process. *Research in Engineering Design* **14(2)**, 89-97.

4. Jehng, J., Johnson, S.D., Anderson, R.C. (1993) Schooling and Students' Epistemological Beliefs about Learning, *Contemporary Educational Psychology*, **18(1)**, 23-35.

5. Pavelich, M.J., Moore, W.S. (1996) Measuring the Effect of Experiential Education Using the Perry Model, *Journal of Engineering Education*, **85(4)**, 287-292.

6. Paulsen, M.B., Wells, C.T. (1998) Domain Differences in the Epistemological Beliefs of College Students, *Research in Higher Education*, **39(4)**, 365-384.

7. Wise, J., Lee, S.H., Litzinger, T.A., Marra, R.M., Palmer, B. (2004) A Report on a Four-Year Longitudinal Study of Intellectual Development of Engineering Undergraduates, *Journal of Adult Development*, **11(2)**, 103-110.

8. Felder, R.M., Brent, R. (2004) The Intellectual Development of Science and Engineering Students. Part 2: Teaching to Promote Growth, *Journal of Engineering Education*, **93(4)**, 279-291.

9. Hake, R.R. (1998) Interactive Engagement vs. Traditional Methods: A Six-thousand Student Survey of Mechanics Test Data for Introductory Physics Courses, *American Journal of Physics,* **66**, 64-74.

10. Terenzini, P.T., Cabrera, A.F., Colbeck, J.M.P., Bjorklund, S.A. (2001) Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains, *Journal of Engineering Education*, **90(1)**, 123-130.

11. Prince, M. (2004) Does Active Learning Work? A Review of the Research, *Journal of Engineering Education*, **93(3)**, 223-230.

12. Kurfiss, J.G. (1988) Critical Thinking: Theory, Research, Practice and Possibilities. *ASHE-ERIC Higher Education Report No. 2. Washington, D.C.: ERIC Clearinghouse on Higher Education and the Association for the Study of Higher Education*.

Biographies

JANICE MILLER-YOUNG is a P.Eng. with a background in mechanical engineering and a PhD in biomechanics. She has worked in the oil industry, has consulted for sports equipment companies and academics on biomechanics research, and has been teaching engineering design for three years. She also incorporates writing-across-the-curriculum and inquiry-based learning concepts in more traditional courses such as statics and dynamics.

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CAROL JEFFERIES has a PhD in metallurgical engineering. She coordinates and teaches a variety of first-year engineering courses at Mount Royal College and helped develop the current engineering design and communication courses. She is the engineering advisor for the program.