AC 2008-2918: EMPOWERING ENGINEERING STUDENTS IN THE EDUCATIONAL PROCESS

Daniel Borrelli, McMaster University

Daniel is a fourth year student in the Mechanical Engineering & Management Program at McMaster University in Hamilton, ON. He is also the McMaster Engineering Society Public Relations Chair, a former Vice-President (Education), and has worked with students from engineering societies across Canada. He has served on numerous committees in the Faculty of Engineering and the University, including the ENG1 Operating Committee and Undergraduate Council. Daniel has also been a Teaching Assistant in the Eng1 Program for the last 3 years.

Susan Masten, McMaster University

Susan Masten is the Director of the First Year Engineering program in the Faculty of Engineering at McMaster University, Hamilton, ON. Her responsibilities include supervising staff and instructors in the ENG1 Program, curriculum development, and planning and implementing programs to enhance retention. She is also a Professor in the Department of Civil Engineering and is a registered professional engineer in the State of Michigan. She has her Ph.D. in environmental engineering from Harvard University and is co-author of the textbook, Principles of Environmental Engineering and Science (McGraw-Hill).

Empowering Engineering Students in the Educational Process

Abstract

The educational system in Canada empowers students to become actively involved in the educational process. We will provide numerous examples from our experience at McMaster University, a research-intensive university, located in Hamilton, Ontario. The practices discussed herein are typical of those used at many Canadian universities.

Undergraduate students are actively involved in teaching assistantships, where they accept the responsibility of teaching a tutorial and become intimately involved in the educational process. Students will give up their spare time to help students in need, sometimes voluntarily. Undergrads regularly serve on Faculty committees and provide feedback to administrators, which are always taken seriously and mostly implemented.

Undergraduate engineering schools in Canada are accompanied by successful student-government organizations. These societies provide a wide variety of services to students, through the collection of mandatory membership fees. Student-run executive teams manage million-dollar budgets and maintain financial transparency and accountability through regular meetings and documentation. Business ventures, such as stores, pubs, or coffee houses are popular means of generating additional income to support numerous activities, including engineering design teams, a full-day student-lead design competition, and scholarships for study abroad. In addition, the student-led groups run week-long activities for September orientation. Faculty members take on a collaborative role rather than one of supervisor-subordinate.

Giving students responsibility in and out of the classroom has led to significant participation in the educational process, as well as innovative, responsible, and well-rounded students ready to accept challenges and overcome adversity.

Introduction

McMaster University is a comprehensive research-intensive university located in Hamilton, Ontario. It prides itself on being student-centered and focused on both undergraduate and graduate education. The Faculty of Engineering was founded 50 years ago and has an enrollment of approximately 2,900 undergraduate students and almost 800 graduate students in over 20 programs.

The Educational Model for Engineering 1 Program

The first year engineering program at McMaster University is common for all students. In this year, students are expected to complete 13 courses: Calculus 1 and 2, Linear Algebra, Physics 1 and 2, Engineering Computing, Engineering Graphics, Chemistry 1, Introductory Materials Science, Engineering Professionalism and Ethics, and two complementary study electives.

Engineering Computing, Engineering Graphics, and Professionalism and Ethics are all administered through the Engineering 1 Program.

Although the chemistry, physics, and math courses use a traditional model of professor-led lecture-based courses, the three engineering courses take a different approach where the majority of classroom time is spent in undergraduate student-led tutorials and laboratories. In the Engineering Computing and Professionalism and Ethics courses, students spend one hour per week in professor-led lectures. In Engineering Graphics, each week the students attend two hours of lectures taught by a professor. In Engineering Computing and Engineering Graphics, students spend five hours per week actively engaged in tutorials (i.e., recitations) and laboratories. In Engineering Professionalism and Ethics, active learning principles are used in the two-hour tutorials that the students attend each week.

The approach used in the engineering courses allows some 120 senior undergraduate students to take on the role of teaching assistants, where they accept the responsibility of co-teaching a tutorial or laboratory. Teaching assistants always work in pairs or threes, and as often as possible, experienced teaching assistants are matched with new ones. Unlike in many other courses where teaching assistants simply work problems and review material in tutorials, the teaching assistants in the engineering courses are assigned new material that must be covered for the students to succeed. The TA is given the task of teaching students new material not covered in lecture, and is responsible for answering questions in class and on the web, and marking weekly assignments and providing feedback.

In Engineering Computing, the tutorial teaching assistants are given the script for their presentations (in PowerPoint format) in the weekly meetings they have with the course instructor. The following week, the teaching assistants present this material to the first year students in tutorials. The presentations are designed to allow first-year students time to work through and attempt new material and to ask questions. Laboratories are set up with alternating practice and graded assignments. First-year students are given the opportunity in the first week to master desired concepts, with the teaching assistants serving as facilitators or guides. In the second week, the first-year students are given a problem to solve, which affords them the opportunity to demonstrate mastery of the skills presented in the previous weeks tutorials and laboratories. Lectures are used to reinforce and extend conceptual material. Similar approaches are used in the other first-year engineering courses.

We believe that this approach empowers upper-year teaching assistants firstly by allowing these students to better understand and have "a greater say about the nature and purposes of higher education as a whole"[1] and secondly and more importantly, by fostering critical thinking or metacognition. Metacognition encourages students to challenge their own thinking, along with that of their peers and teachers.[1] In teaching course material, these student teaching assistants must develop their own understanding and knowledge and be able to present it clearly and coherently to others. They change from "passive recipients of information to active controllers of learning".[2] All teaching assistants who responded to a survey (see the Appendix for a summary of the survey results) asking them to reflect upon this role stated that being a teaching assistant has affected their view of the educational process. One teaching assistant wrote, "[t]eaching the same material for some time gives you a better idea of what are the common

pitfalls and misunderstanding that will occur when students are learning the new material and you can develop new skills to make the material that is being taught more easily understood". The weekly meetings between the instructor(s) and the teaching assistants allow for open dialogue and reflection on the teaching and learning process in an attempt to enhance learning.

We believe that this dialogue between instructors and teaching assistants fosters a sense of mutual interdependence in which all are working towards a common goal, or as one teaching assistant wrote, "being a TA has shown me that I am responsible for the education of other students." As a result of this shared responsibility, teaching assistants/students take on roles often not observed in academe. For example, one of the challenges of teaching a course such as Engineering Computing is the highly varied skills of the first-year students. While many students have no computer skills, others are highly experienced. To offer these experienced students challenges, yet ensure that they have mastered the key skills related to algorithm design, several teaching assistants run a Computing Club, now in its second term. Students with strong programming skills self-select into the club, which as one teaching assistant wrote, allows the very experienced students in the course to participate "and really set their creativity loose and engage their intuition and reasoning skills."

The use of active participation in tutorials and laboratories also empowers first-year students as they are no longer expected to be the "open vessel into which professors pour knowledge" as often described by Karl Smith of the University of Minnesota. Students must be actively engaged in laboratories and tutorials and they are empowered by becoming involved in and personally responsible for the learning process[2] to become self-learners.[3]

One of the most important aspects of the approach used in the Engineering 1 Program is that it fosters a learning community and over time, the students and teaching assistants become "co-contributors to a learning community, sharing, supporting, challenging" one another.[4,5] One teaching assistant responded to the survey with the comment, "Everyone works to help everyone else, which establishes its own sense of community. This occurs not only amongst students, but the TA-student relationship as well. I will go out of my way on my own time to talk to students and see what their thoughts are and talk about any issues." Another student noted that a "quick to trip to the Thode [Library] basement is a great illustration of how" students support and help one another.

It is likely that the use of teaching assistants in the first-year program assists in the successful development of learning communities. Wenger[6] notes that successful learning communities need:

1. places of engagement or learning spaces (basement of Thode Library or the Engineering Student Lounge)
2. materials and experiences (learning tasks) with which to build an identity, and
3. methods to make their actions matter (learning partnerships).

The difficulty and intensity of the first year program (13 classes/37 units (credits)) helps build an identity through a common and challenging experience. It is not uncommon to hear comments such as this one, "if it wasn't (sic) for a good TA I would not have gotten the marks that I did, on some occasions not even pass" a course. Teaching assistants make a significant impact on the success of first-year students. Not only do they meet with students in the classroom, but also

assist students in "unpaid review sessions", offering "guidance to first-year students in need", and helping "help them achieve their potential" (as noted by teaching assistant in their responses to the survey). Clearly, these efforts help build an identity and partnerships and foster a learning community, and empower students to become intimately involved in the learning process.

The Role of Student Societies and Faculty Committees on Empowerment

As shown in the student action research literature, the involvement of students in investigating issues, reaching conclusions, and making decisions, is highly beneficial to students, their schools, and their communities.[7] Although most of this research has been conducted with elementary and high school students, the conclusions found are applicable to university students. The benefits include:

1. Building important academic skills
2. Engaging disenfranchised youth
3. Developing responsible leadership
4. Developing empowered civic identity, their connection to civic life
5. Better understanding of the operation of the academic unit.[7,8]

Clearly, by serving as teaching assistants and by actively engaging students in tutorials and laboratories, students and teaching assistants hone important academic (and interpersonal) skills. While we would not describe the average McMaster engineering student as disenfranchised, many first year students do find themselves feeling lost and alone, as the majority are away from home for the first time, many from across the globe. In some cases, teaching assistants serve as peer mentors. As one teaching assistant wrote, "I can relate to them more easily and being in a smaller group setting gives me a chance to connect to them on a more personal level. It gives me strong motivation and desire to see them succeed" and "an opportunity to shape their success, not only in the course [for which I am a teaching assistant], but in general during their first year."

Responsible leadership is nurtured at the majority of engineering schools in Canada, where engineering students form a government separate from the general students' union. Through the collection of mandatory membership fees ($0 to $80 per year), Engineering Societies ("EngSocs") represent students to various forms of academic and local government, and provide services to members. An executive team made up of eight to ten undergraduate students, along with a council (similar to a Board of Directors) and possible full-time staff, guide the society and make day-to-day administrative and financial decisions. Typical engineering societies are not-for-profit and run on a break-even basis, with annual revenues, ranging from $5,000 to almost $300,000, as documented from a recent survey of EngSoc executives. Student governments maintain accountability through a regular series of meetings – biweekly and semi-annually, to inform general members of the activities of and decisions being made by the society. In some cases, engineering general meetings are better attended than those of the students' union, with up to 10-20% of the engineering students in attendance twice a year.

Business ventures, such as stores and pubs, are popular means of generating additional income to support numerous activities and allow students to be more autonomous from the administration and empower their own sense of civic identity. Selling engineering-branded paraphernalia is

standard and students are proud to wear the popular leather jacket of their school, which have become an identifying characteristic of engineering students across Canada.

Design competitions, at the university, regional, or national levels, give students the opportunity to display their knowledge and abilities while under pressure and intense deadlines. With financial assistance from local industry partners, these competitions are organized and run by students through EngSoc sub-committees, and can have complex requirements such as providing housing, meals, and transportation for all participants, as well as designing and running the competition events. At McMaster University, a small group of highly dedicated and motivated students run qualifiers to select students to send to the Ontario Engineering Competition (OEC). These students control all aspects of the competition from securing financial support, setting up and running the competition, selecting judges, to completing all the risk management forms required to allow use of campus facilities. Upon success of student teams at OEC, students move on to the Canadian Engineering Competition (CEC), hosted by the Canadian Federation of Engineering Students (CFES) each year. It was the Innovative Design category of this competition that allowed a group of McMaster students to showcase their 4th year product design class project called the "CPR Glove". The students received the second place award at the 2007 CEC and now have started a business venture and are currently testing the prototype for wide-scale manufacturing. In May and November 2007 respectively, Popular Science[9] and TIME Magazine[10] selected the glove as one of the best inventions of the year. In both cases, it was the only Canadian invention.

Fourth-year electrical and biomedical engineering students Corey Centen and Nilesh Patel developed the CPR Glove, which measures the frequency and depth of compressions being administered during CPR and outputs the data to a digital display.[11]

Engineering societies regularly give back to the community in the form of charitable work, scholarships and bursaries. A popular charity event held across Canada is knows as "CANtraption", an event where students compete to collect the most amount of canned food, and then are judged on building the largest and most elaborate life-sized model using the cans. 10,600 kilograms of food was collected by University of Western Ontario engineers in April 2007.[12] Feats of strength are showcased annually when engineering students pull a transit bus, airplanes, or series of cars by hand in support of charity. For the last 18 years, McMaster Engineering students have organized city leaders, alumni, and incoming first year students to pull an accordion style transit bus in downtown Hamilton for 4 kilometres as a part of Orientation Week. In the last three years, over $6,000 has been donated to the Cystic Fibrosis

Foundation in Hamilton, and the group has received media attention on the internet, television, and local newspapers. EngSocs support students through bursaries based on financial need, or offer scholarships to high school design competitions or study-abroad programs at university. For example, the McMaster Engineering Society offers $2,500 in scholarships to undergraduate engineering students traveling overseas as part of the Engineering Study Abroad Program.

Orientation Week is another unique way Canadian engineering students take a leadership role. During Orientation Week, upper year students welcome their incoming colleagues to the university, and engage them in a week-long series of activities to foster interaction and team-building skills. At McMaster University, two undergraduate engineering students coordinate the progress of a twelve-member committee for planning purposes. An additional 130 upper-year engineering students are selected by this committee as Orientation Week volunteers, providing a 1:6 ratio of upper-year students to new engineering students. Volunteers are trained to meet with students in small groups and help adjust them to their new community. Budgets of up to $40,000 are spent on activities and equipment to run a successful Orientation Week.

With engineering societies, faculty members take on a collaborative role rather than one of supervisor-subordinate. Most EngSoc executives who responded to our recent survey called themselves “completely autonomous” when asked about the way their society functions with respect to engineering administration. Student groups regularly inform the administration of happenings in the society, but hesitate to let them take a leading role in the development or implementation of the events. A student from Queen’s University in Kingston, Ontario mentioned that, “we have a lot of autonomy. The Dean is given monthly updates from the President. Our faculty supports our activities and rarely takes control." A student from Carleton University in Ottawa, Ontario stated that, “as long as we are responsible, the Faculty doesn't try to talk to us or pressure us to change our policies or practice.” This approach leaves student groups to function within their own democracy, which leads to increased participation, builds a sense of civic pride, and brings together responsible leaders who care about the development and longevity of the engineering society.

Conclusions

Giving students responsibility in and out of the classroom has led to significant participation in the educational process, as well as innovative, responsible, and well-rounded students ready to accept challenges and overcome adversity.

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Appendix

Table 1. Demographic Data from the survey of teaching assistants (TA)

Course	How long have you served as a TA (yrs)?	Approximately how many hours do you work as TA each week?	How connected do you feel to Engineering as a profession?
1C03	4	5	4
1C03	3	7	5
1P03	<0.5	5	4
1D04	0.5 at Mac	6	3
1P03	<0.5	2	2
1C03	3	5	2
1C03	1	Yes	5
1C03	1.5	5	4
1D04	3	4	5
1D04	1.5	5	5
1C03	<1	4	4
1C03	<1	2	3
1C03	4	5.5	1
1D04	1.5	2.5	4
1C03	7	0.5	4
1P03	0.2	4	3
1C03	4.0	5.5	3

Table 2A. TA Survey results to the question, "The abstracts states that, "Undergraduate students are also actively involved in teaching assistantships, where they accept the responsibility of teaching a tutorial and become intimately involved in the educational process." Do you believe this to be true? Please explain why or why not."

Are you actively involved in the educational process?	**Comments**
Yes	Teaching 1st year students help to develop an appreciation for the art of teaching and the education process.
Yes	A lot of the learning in the laboratory comes from one on one interaction with the TA. Student development is achieved through feedback in the work completed.
Yes	It is the essence of what a good TA should be, someone who sees first year students as themselves a few years ago and want to help them achieve their potential and to be to them as our favorite TA's were to us. I can honestly think of a couple of classes where if it wasn't for a good TA I would not have gotten the marks that I did, on some occasions not even pass them.
For some, yes	Some of them look at it more as a source of some income. But anyways when you teach you do 'accept the responsibility of teaching a tutorial and become intimately involved in the educational process.'
No	As for "undergraduate students" being actively involved, this statement only applies to a select few of the hundreds of students in Engineering.
Yes	Yes as there is material covered in labs/tutorials that is not covered in the lecture process.
Yes	The best way of learning something is teaching and being a TA is a great involvement in learning process. Being a TA is not only about marks, but also it is about accepting the responsibility of a job. It is not like a class in which student can show up late. The title of TA simply means others are counting on you.
Yes	Because of the structure of Eng 1 tutorials and labs, we are an extension of the professor's lectures, and must help the students apply the new knowledge to assignments.
Yes	Especially in 1D04, where the tutorials and labs are run by TAs

Are you actively involved in the educational process?	Comments
Yes	I absolutely believe this to be true, especially with ENG1D04. In this class, most of the course material is presented in tutorial and students spend two hours in tutorial for each hour of lecture. It's almost impossible to not become very closely connected to your students' educations when you become a TA. As their peer I can relate to them more easily and being in a smaller group setting gives me a chance to connect to them on a more personal level and really gives me a strong motivation and desire to see them succeed. Being in such close contact with the students really gives me an opportunity to help shape their success, not only in this course but in general during their first year.
	No answer
Yes	Yes, I believe the student TAs *should* become intimately involved in the educational process, although I think this depends upon the individual. I have found I learn best in the classroom when I enjoy both the subject and the teacher. I enjoy the teacher best when he/she teaches according to the needs of the students, and to know their needs involves initiation and active engagement on the part of the teacher.
Yes	Yes because we help students visualize and understand why certain concepts are important in industry. Also, you know that you are involved in the educational process when you see the progression of students in your section.
Yes	Yes, since we are able to see the educational process from multiple angles
Yes	Undergraduate students make good TAs, as they can be the closest to students taking the course. Therefore students can relate to them and be comfortable asking them questions about the course. This improves the teaching process and runs it smoothly.
Yes	TAs learn to know the students in their classes and are a big help in the learning process.
Yes	The opportunities are not abundant, however, I know students can apply for positions in 1D04, 1C03, and 1P03.

Table 2B. TA Survey results to the question, “Has being a TA affected your view of the educational process? Please explain.”

Has your view of the educational process changed?	**Explain**
Yes	Being a TA has made me appreciate the time and effort that has to be put into running a class as well as get a better understanding of the administrative work that goes on behind the scenes.
Yes	It has enlightened me as to how professors and TAs for my own courses view my own work when I submit it.
Too new	
Yes	I don't quite get what you mean by the 'educational process'. You will always learn things better when you teach them. Teaching the same material for some time gives you a better idea of what are the common pitfalls and misunderstanding that will occur when students are going to learn the new material and you can develop new skills to make the material that is being thought more easy to be really understood in depth.
Too new	
Yes	Yes, I recognize the incredible diversity of students enrolling in first year, and have been especially surprised by mature students whom I have TA’d that end up taking the courses with 17 year olds who have in some cases taught at a college level in other countries, the material I am teaching them… it shows how little personal circumstances are taken into account at an undergraduate level and the lack of ability to customize a course when large volumes are encountered
Yes	Since I teach well; everyone think so. Therefore, I always try to learn as deep as possible. I observed that students learn how to plug the numbers into a formula, but if someone asks them why, they can not answer.
Yes	I find I better understand the decisions other professors make, and can better adapt myself to classes in general. I feel a much greater appreciation for the effort involved in constructing a course.
Yes	Being a TA has shown me that I am responsible for the education of other students. However, this has also shown me a large hole in the educational process where incapable TA's detract from another student's education.

Has your view of the educational process changed?	Explain
Yes	Being a TA has certainly affected my view of the educational process. I have always been near the top of my class, so I have found lectures slow-paced and have been frustrated at the efforts my professors would expend to reshape ideas and present them in many ways. Being a TA has made me acutely aware of the diversity in talent and learning styles within each class and has given me a new appreciation for the importance and difficulty of presenting information in a way that will connect to the largest portion of the class.
No	
Yes	I was a TA for a class in high school and have tutored privately; for both instances the subject was math. Yes, my view has been changed from my experience. At first, I found it difficult to understand how a person was struggling with mathematical concepts that I found simple. I have learned that, when teaching, I need to be sensitive to the current level of the students to be effective. I've also seen students lacking confidence in their work, which can debilitate further efforts. Helping them to recognize this, and encouraging them, I have found, increases their learning rate.
Yes	As a student I understand how material presented in a particular way is received, this allows me to teach so that the messages are better received
Yes	Yes, since I am now able to view the process from an educators perspective, and understand the objectives educators have.
Yes	My understanding of what the professor wants from a student has increased. I understand that the TA plays an important role in the teaching process, as he is the link between the professor and the student.
Yes	It gives an outside look at what it is like to be a student and a TA makes me strive to do my best at both.
Yes	Being a TA gives a better perspective of what goes on behind the scenes and has made it easier for me to relate to the common problems incurred in a semester.

Table 2C. TA Survey results to the question, "The abstract states that, 'Students will give spare time to help students in need, sometimes voluntarily.' Is this an accurate reflection of Engineering at McMaster? Please explain."

Help in Need	Explain
Yes	I've held 2 unpaid review sessions while being a TA as well as offered guidance to 1st year students in need.
Yes	Everyone works to help everyone else which establishes its own sense of community. This occurs not only amongst students, but the TA-student relationship as well. I will go out of my way on my own time to talk to students and see what their thoughts are and talk about any issues.
Yes	In my first year I used to hang around the engineering lounge and yes, when I asked upper year students for help, they were often happy to give it an attempt. They often had forgotten the specifics of the courses but they were willing to try. When it comes to my classmates, if someone who I only know in a vague way, but was in one of my classes asked for help, I would be happy to do so, assuming I had time to spare. I have often been stuck on an assignment and wandered around Thode till I found a face I recognized and they were often very willing to help me with what I did not understand.
Yes	You sometimes see that a TA will put extra time to explain something for one of the students. As you would do for a friend.
Yes	Generally yes. A quick trip to Thode Basement is a great illustration of this. Unlike other universities, McMaster does not encourage an environment of excessive competitiveness. From first year we are encouraged to work together through projects and student clubs. Even with individual assignments, it is common knowledge that students will conglomerate at some point and solve problems as a team. Now in ECE, because of academic dishonesty issues and the fact that assignments are generally worth less than 5% of the final mark, many professors now give unmarked optional assignments.
Yes	Students often find and offer help in the Engineering Lounge.
Yes	I am one those students who spent part of my spare time to help my friends. Dr. Elkott suggested to me to apply for TA position after he saw I was helping other students. In all courses, if someone asks me a question, I try to be helpful.
Yes	I find our TAs are very willing to give of their own time to help others, and I have myself been approached by friends who have other friends who need more guidance in the courses I've worked.
Yes	Absolutely, when students have problems they can usually ask most upper year students or peers for help. Generally most people will help if they do not have something urgent to get done themselves.

Help in Need	Explain
?	I think the term “voluntarily” can be kind of ambiguous. If it means “without monetary compensation” then I think that statement is accurate, however, especially in Engineering I think there exists an understanding of reciprocation on almost all the favours offered. I have experienced this myself. I have tutored people and not asked for any money with the understanding that later, if I find myself in need of help, those that I’ve given my time to will come to my aid. I think this flows very naturally out of the mutual respect that exists for one another’s time and abilities.
I hope so	But I personally always try to find the answer myself
It can be	It can be, but not necessarily. With friends, sure this can happen. Between levels or people that don’t normally associate, I do not think this is typical. Avenues, relationships, and motivations need to be present for such.
Yes	- Yes, I came in to help a student on Easter day because it was the only time that could work for him. - I’ve also helped students from other sections who were struggling independently in a lab with the material I have taught
Yes	I have often witnessed students volunteering to help other students studying, this attitude is common among engineering students at McMaster.
Yes	Yes. I feel responsible to spend extra time with students trying to explain all the important aspects of the course, as I believe that the quality of the students’ understanding reflects the proficiency of their TA. Most other TAs at McMaster University feel the same way toward their students, and they try to help them in every way possible.
Yes	Almost always when I need help another student or TA will undoubtedly offer it.
Yes	Although not funded by McMaster, students can take on tutoring positions at their own discretion.