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Beyond the Calculations: Educating Engineers for Society

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Abstract: The problems facing civil engineers in the 21st century are increasing in complexity, requiring that they be approached in a non-traditional way. In order to be successfully equipped to solve the problems of the future, students need a broader base of skills from which to draw from. Current engineering education is heavily focused on teaching students knowledge and problem solving skills based on current engineering problems. This type of education has historically worked well, but it is unclear how well it will work in the future. The Engineering and Society Program at McMaster University successfully integrates interdisciplinary studies, Inquiry based learning, and sustainability education into an undergraduate engineering program for students in all engineering disciplines. The only program of its kind in North America, the Engineering and Society Program offers students Inquiry based classes that provide historical, social, and political context to their engineering studies while also allowing students to take classes from fields outside of engineering to expand their education. This structure allows students to explore the complex systems in which the engineering profession must operate. This paper will investigate the supporting theory on implementing these ideas into engineering education, perform a case study of the McMaster Engineering and Society Program, and consider the potential for transferring the core elements of this type of program into Civil Engineering curriculum at other universities.

1 Introduction

We live in a rapidly changing world—the politics, environment, economics, and social structures of today are vastly different than those of 30 years ago, and those of the future are unlikely to resemble those of today. It is clear that Civil Engineers need to be educated in such a way that prepares them for the world they will face in the future rather than the world that exists today. The National Academy of Engineering (2004 cited in Zhou 2012) outlined nine essential attributes necessary for future engineers: "strong analytical skills, practical ingenuity, creativity, communication, mastery of the principles of business and management, leadership, sense of professionalism, high ethical standards, and life-long learners". Traditional engineering education does little to foster these characteristics in students while maintaining a heavy focus on mathematics, science, and the technical knowledge of engineering.

Evidence indicates a strong desire among students for changes in engineering education. Students are often frustrated with the lack of options to take elective courses (Hudspith 2001), and alumni have expressed the desire for broader education including more economics, social, and environmental content (Hanning et al. 2012). Also, engineering schools often have a high attrition rate (Felder 2012) and student dissatisfaction is a likely contributing factor. While students are showing dissatisfaction with traditional engineering education, there is some evidence that modified engineering programs can actively engage students. Aurandt and Butler (2011) found that students who completed a sustainable engineering class were very enthusiastic to be learning the social and economic implications of their engineering work and they were excited by the chance to apply it. Programs including an emphasis on the broader societal context of technical material have been associated with increased motivation and self-satisfaction in students (Du and Kolmos 2009). Including sustainability or other social context in engineering education has been found to attract and retain female students better than traditional engineering programs (Wolcott et al. 2011, Du and Kolmos 2009, Hudspith 2001).

Engineering employers are also interested in changing engineering education. Industry representatives have expressed the desire for engineering graduates to have a better understanding of sustainability for use in their careers (Hanning et al. 2012, Bhandari et al. 2011). Employers often complain that new engineering graduates lack many of the skills desired in the work place: critical thinking and analysis, communication skills, and collaboration skills (Felder 2012, Richter and Paretti 2009). It has become well known in both education and cognitive science research that an education structured around traditional lectures and assignments will not develop these skills in students (Felder 2012), indicating that an alternative education model is becoming increasingly necessary for engineers.

A new approach to engineering education is clearly required, and the Engineering and Society (E&S) program at McMaster University offers an example of an established program that enhances traditional engineering education by focusing on sustainability, incorporating interdisciplinary teaching, and practicing Inquiry-based learning. Following a brief description of the E&S program, this paper will review current literature with respect to the benefits of sustainability, interdisciplinary, and Inquiry education; detail how E&S fulfills these educational criteria; and explore ideas of how Civil Engineering education can incorporate these concepts; followed by a discussion and conclusions.

2 The Engineering and Society Program

McMaster University's E&S program started in 1991 as a unique program in North America offering students the opportunity to expand their education while completing a traditional engineering degree in any of McMaster's engineering disciplines (Hudspith 2001). Students who elect to study in the E&S program complete five years of undergraduate studies instead of the typical four years, taking a set of seven core E&S courses and six to eight elective courses in addition to the full engineering curriculum. The core courses provide students with a basic understanding of culture, history and sustainability as it relates to engineering, while the elective courses allow students to add breadth to their education in a subject area of their own choosing (Churchill and Baetz 2009, Hudspith 2001). Electives can be used to study a single subject area or to explore a multidisciplinary theme designed by the student (Hudspith 2001). The program has typically attracted students from every engineering discipline at McMaster, and has approximately double the percentage of female students as in general engineering studies (Churchill and Baetz 2009, Hudspith 2001).

3 Literature Review

3.1 Sustainability Education

There is a widely acknowledged need for engineers to gain an understanding of sustainability and how it relates to their role as an engineer during their education (Kevern 2011, Kennedy et al. 2009). Sustainability can be defined as the ability to meet the needs of the present without compromising the ability for future generations to do the same (United Nations General Assembly 1987), and includes three main components—environmental, social, and economic responsibility (United Nations General Assembly 2005). The concepts of sustainability relate to all areas of specialization within Civil Engineering and represent an active field of academic research, but these ideas are not necessarily being taught to students through their courses. A 2007 review of the undergraduate program at the University of Toronto found that students felt that the sustainability content was insufficient (Kennedy et al. 2009). It is important for students to be exposed to the ideas of sustainability and be trained in how to implement them into their engineering designs. Students who are exposed to the ideas of sustainability during their education take this knowledge with them into the workplace and apply it as they work (Hanning et al. 2012, Dvorak et al. 2011). Bielefeldt (2011) found that after taking a course that included sustainability content, students applied the knowledge to their other assignments even when not required to do so.

There are many examples of engineering education being adapted to include sustainability material through adding to existing classes, creating new sustainability focused classes, and implementing cross-disciplinary sustainable engineering courses (Bielefeldt 2011). The most common forms of this are first-year introductory courses or senior design courses designed to introduce sustainability concepts and applications. Some specific examples include a course developed by Iowa State University where international development provided the basis for sustainability education (Bhandari et al. 2011). Kevern (2011) discusses a graduate course on green building design that used LEED ratings and credit areas to introduce concepts of sustainability and included assignments designed to introduce topics such as the Triple Bottom Line. The University of Toronto has made numerous changes to their curriculum to better incorporate sustainability throughout the curriculum including sustainability focused courses during each year of study and adding examples of sustainable practices in existing technical courses (Kennedy et al. 2009). Another example is illustrated by Aurandt and Butler (2011) who describe an organic compound nomenclature course where students used the Environmental Protection Agency's Toxics Release Inventory as the basis for learning the material. At the end of the course the vast majority of students indicated that learning the material in this way aided their understanding and identification of chemical compound functional groups. All these examples illustrate how including discussions of the broader impacts of a technology in a technical class can make the material much more relevant to students (Frize 2005). Specifically linking course content to sustainability can make it significantly more interesting to students which will result in better understanding, increased learning, and better retention of the material.

3.2 Interdisciplinary Studies

Problems facing engineers into the future are becoming increasingly complex. From a review of relevant literature, Mishra (2011) concludes that discipline-specific knowledge and skills are no longer adequate training to prepare engineers to solve the multidisciplinary problems they will face during their careers. Interdisciplinary education introduces students to the perspectives, skills, and knowledge of multiple academic disciplines and encourages them to integrate these ideas into their work. Exposure to interdisciplinary education helps students to address questions, problems, and ideas that are greater than the scope of any single discipline. Through the expansion of one's academic background it is possible to better acknowledge the strengths and weaknesses of each disciplinary perspective and reconsider one's own assumptions, prejudices, and understanding (Lattuca and Knight 2010, Richter and Paretti 2009).

Interdisciplinary studies have been seen in two distinct ways in engineering education: bringing together students from different engineering disciplines, and bringing knowledge and ideas into engineering from non-engineering disciplines such as the arts or social sciences. The most common way to bring students together from multiple engineering disciplines is through an interdisciplinary capstone design project course through which students must work in interdisciplinary teams (Borrego et al. 2010). Frize (2005) gives examples of bringing gender studies and history content into technical engineering courses during discussions of some of the social implications of engineering. Another example is when the course content is considered to be multidisciplinary such as the Environmentally Conscious Design and Manufacturing course discussed by Aurandt and Butler (2011) where different sections of the course are taught by professors from different faculties such as liberal studies, mechanical engineering, chemistry, industrial engineering, and business.

Simply presenting students with material from various disciplines is not sufficient to train them in interdisciplinary thinking. Students have often been trained to view each of their classes as a standalone subject, meaning students do not always think to transfer knowledge or skills between courses. Survey results show that students face challenges making broad connections between their different classroom experiences (Richter and Paretti 2009). Professors play a key role as they can help students to see the connections between different courses, and students can apply these ideas to build their own links between other course concepts (Borrego et al. 2010, Lattuca and Knight 2010). There are numerous possibilities for including interdisciplinary studies into engineering education. Each alternative has its own academic and organizational strengths and weaknesses, but all provide students with the opportunity to expand their education beyond the narrow technical focus of traditional engineering education.

3.3 Inquiry-based Learning

Inquiry-based learning describes a learning process where students explore (and learn to ask) questions through investigation. Instructors can guide students through the process as they learn to be able to conduct it more independently (Quinn and Albano 2008, Churchill and Baetz 2009). Inquiry is an example of inductive teaching—rather than presenting theories and methods then showing applications, instructors start with application questions (or problems) and teach (or help students learn) the material in context (Felder 2012). The process allows for topics to be explored that are complex and often have no specific "right" answer (Churchill and Baetz 2009). Instructors create an open-minded environment that encourages students to question assumptions and learn to critically assess all materials (Justice et al. 2009). Teaching through inductive methods like Inquiry has been found to promote better understanding of the material and academic skills development among students more than traditional teaching methods (Abdal-Haqq 1998, Hudspith and Jenkins 2001, Justice et al. 2007a, 2007b, and 2009 all cited in Justice et al. 2009 and Prince and Felder 2006 cited in Felder 2012). Many of the skills gained through inquiry-based education will serve students well beyond their classes into their careers: critical thinking, question formulation, evidence gathering and analysis, conclusion generation and evaluation, and communication skills (Lee 2004 cited in Churchill and Baetz 2009, Hudspith 2001, Justice et al. 2009)

McMaster University began introducing Inquiry into the undergraduate curriculum in 1979 when the Arts and Science Program was developed as an Inquiry-based program. Since then, two other Inquiry-based programs have been developed: the E&S program (started in 1991) and the Bachelor of Health Science (started in 2000). Numerous courses at McMaster are also taught using Inquiry as part of the course (Justice et al. 2009). Inquiry can be implemented into laboratory courses allowing students to genuinely explore concepts instead of simply performing prescribed steps in a set experiment (Buch and Wolff 2000, Flora and Cooper 2005 both cited in Quinn and Albano 2008). Inquiry can also be used to allow students to explore concepts in independent study projects that replace traditional essays, papers, or projects (Justice et al. 2009). Typically used as a type of project or assignment, Inquiry provides students with the opportunity to explore their course material in ways that are not possible with traditional methods.

4 The Engineering and Society Curriculum

4.1 Sustainability Education

Sustainability is a common theme throughout the E&S curriculum. The theme of sustainable society is introduced in the first year of the E&S program (the second year of university for the students) and is maintained throughout the program (Hudspith 2001). There is a large emphasis put on the social aspects of sustainability along with environmental concerns (Churchill and Baetz 2009). Three of the E&S courses focus primarily on sustainability content. The first Inquiry class (taken in students' second year) serves as an introduction to the principles of sustainable society. The second class that focuses on sustainability (taken in students' fourth year) covers preventative engineering. The third class is a design project class in the final year of the program which has a sustainable design focus.

Through these courses, students are exposed to concepts such as (but not limited to) sustainable cities, water resources, land use, transportation, air quality, green buildings, green chemistry, and the regulatory and policy instruments related to these topics. Through assigned projects in these courses, students apply the knowledge they are gaining regarding sustainability to real world problems where they must consider the environmental and societal impacts of their suggested designs. Sustainability concepts are introduced early in the program, and are reinforced in subsequent courses allowing students to engage with and consider the material in meaningful ways.

4.2 Interdisciplinary Studies

Interdisciplinarity is accomplished in three ways in the E&S program. The program itself is made up of students from the various engineering disciplines at McMaster so students work within interdisciplinary groups in the core E&S courses. Secondly, these core courses draw upon numerous academic fields to cover the large scope of content covered in the courses. The third way of incorporating interdiciplinarity is through the focus electives that students take to broaden their personal education.

In E&S courses students often work in teams with their classmates who are from different engineering disciplines. This culminates in a formal interdisciplinary design project in the final year where students are formally expected to draw upon knowledge from their specific engineering disciplines for use in the project. In this final design course, material on working in interdisciplinary teams is specifically covered to help students work in cohesive teams (Churchill and Baetz 2009).

Through the core E&S courses, students are challenged to consider relevant issues from differing perspectives (Hudspith 2001). Due to the content and nature of the E&S courses, they draw from the traditions and knowledge of many different disciplines to cover the material. A course on the history of technology (taken in students' second year) introduces students to historical ideas as well as an understanding of the social context of historic technologies. A course on the culture of technology (taken in students' third year) takes a multidisciplinary look at intersections between technology and society. An Inquiry class focused on technology, public policy, and development (taken in students' fourth year) covers economic, social, cultural, and political issues associated with international development.

A large component of the E&S program is the focus electives students take. Students take between six and eight half-year courses in a subject area of their choice. The program director must approve the student's elective plan before they start the program and electives are required to be from a single subject area or centred around a defined theme. Through these electives it is possible for students to earn an official minor in their degree. Subject areas in which students have chosen to obtain a minor in include Drama, English, Religious Studies, Russian, French, Japanese, Environmental Science, Biology, Political Science, History, Linguistics, Geography, or in interdisciplinary programs such as Globalization and the Human Condition. Many students have also designed their own thematic focus (Hudspith 2001). There is no formal requirement for students to bring elective knowledge into their classes, but information, interests, and skills are often incorporated into their E&S classes, if not their engineering classes as well.

4.3 Inquiry-based Learning

Inquiry-based learning is included in both formal and informal ways in the E&S program. Formally, the E&S program includes three core courses that are based around Inquiry (taken by students in their second, fourth, and fifth years), and Inquiry projects are often completed as an element of the course work in other core courses. Inquiry is taught as the beginning of the design process where problems can be defined and understood before a solution is attempted (Hudspith 2001, Justice et al. 2009). The structure, content, and design of E&S courses reinforce the concepts and ideals of Inquiry-based learning through actively engaging the questioning and analysis of the course material. Through this set of courses Inquiry skills are introduced, reinforced, and developed over several years (Justice et al. 2009).

Informally, instructors employ active and diverse teaching methods in the E&S core courses bringing elements of Inquiry—student lead direction, active participation, and question asking—into the classroom. The E&S program encourages instructors to use a variety of methods of teaching in the courses (Churchill and Baetz 2009). All of the core courses use diverse approaches to cover course content: discussions, multimedia, presentations, field trips, independent reading of books or articles, and student led exercises, among others. Students tend to be very engaged with the material and are very active in participating in class discussions and activities.

5 Applications for Civil Engineering Education

5.1 Sustainability Education

The environmental aspects of sustainability are increasingly being included in Civil Engineering education, but there is still little coverage of the social and economic aspects (Carew and Mitchell 2002, Azapagic et al. 2005 both cited in Mishra 2011; Hanning et al. 2012). Kennedy et al. (2009) show that it is possible to adapt Civil Engineering curriculum to have a stronger focus on sustainability. Instead of being an innovative educational practice, the incorporation of sustainability ideas into Civil Engineering curriculum is becoming a necessity to ensure the relevance and competitiveness of the programming.

Aurandt and Butler (2011) suggest that sustainability can be incorporated into the curriculum either by adding specialized sustainability content into existing classes or through the development of a senior sustainability course. At the University of Toronto a combination of the two approaches was used to significantly increase the sustainability content in the curriculum (Kennedy et al. 2009). There are many examples of upper year technical elective courses focused on sustainability topics, but inclusion as a senior technical elective limits the chance students have to further explore the concepts of sustainability during their education and not all Civil Engineering students will elect to take such a course (Bielefeldt 2011). These challenges can be overcome by offering a sustainability course earlier in the students' education and by making it a mandatory component of their education. Consideration will need to be given to how to best engage students in a mandatory sustainability course. The E&S program greatly benefits from the fact that students elect to be in it and are therefore much more likely to actively engage in the material than those who are taking a mandatory class (Churchill and Baetz 2009). It is possible to overcome potential student disinterest with a well-designed course that links the sustainability content to specific applications in Civil Engineering. Having a professor that the students respect teach this type of course may help students to take the course seriously. The sustainability information from a specialized course would need to be reinforced (or at least acknowledged) in subsequent technical courses for there to be maximum potential for the students to retain the information and be able to apply it in the future.

The addition of sustainability content into all (or most) of the technical courses required for Civil Engineering students will expose them to sustainability content integrated into their studies. By integrating sustainability knowledge into their technical classes it will be easier for students to incorporate the knowledge into their engineering work even when they are not explicitly told to do so. Students will also be able to build their understanding of sustainability over the years they are in university allowing them to better engage with the topic. While not all professors are specialists in matters of sustainability, it is possible to easily add topics of interest or ways of thinking sustainably into course content. Aurandt and Butler (2011) show that sustainability concepts can be added to a course without compromising course content or the original objectives. All areas of Civil Engineering include specialized topics that incorporate environmental, social, or economic sustainability considerations and they can easily be covered during a course. Baetz and Korol (1991) offer a detailed list of possible topics that can be covered in Civil Engineering courses, and current research literature includes many different topics relating to sustainability in every field of Civil Engineering providing ideas and material for professors. Covering sustainability topics in this way, throughout the curriculum, will allow students to see how the concepts of sustainability integrate into every aspect of the field (Baetz and Korol 1991). Introducing sustainable applications of course content may even encourage students to become more engaged with technical material that they may have previously found to be tedious. When including sustainability material in technical courses care would need to be taken such that students saw the content as an integrated part of the course and not a "throw away" topic rushed in at the end of the term.

The inclusion of social and economic sustainability needs special consideration. Most examples of sustainability in engineering education focus heavily on the environmental aspects with only minimal considerations of social and economic aspects even though both these concepts are significantly relevant to many Civil Engineering specialities. Concepts such as The Triple Bottom Line approach can be used to introduce these concepts in an applied manner. Baetz and Korol (1991) suggest using the engineering economics course requirement to teach students about economic aspects of sustainability by using specialized economic topics focused on social and environmental aspects of economics to teach students the required economics topics. Social sustainability content will need to be explicitly covered in courses as well as expected as part of student design projects.

5.2 Interdisciplinary Studies

The world of Civil Engineering does not exist in a vacuum. Students need to be aware of not only ideas from other academic disciplines, but also of how to work well with individuals who have different perspectives. Civil Engineering programs often have a very narrow focus in order to cover all of the required technical material in the time frame of a standard undergraduate degree. Exposing students to other ideas in elective courses is an important option for broadening students' perspectives. One option for broadening sutents' education without changing the content of technical classes is to allow students to take more electives as part of their degree. This could be accomplished through summer studies, or by spacing out their degree over an extra year similar to how it is done at McMaster for both the E&S and Engineering and Management Programs. Students would need guidance as to how to do this such that they can complete pre-requisite classes in order. A significant effort would need to be undertaken to promote the benefits of doing this to students. Another option would be to simply aid students in using the elective course spaces available to them in a standard engineering program more wisely. Students are often limited in what courses they can take as electives due to scheduling conflicts, prerequisite requirements for the electives, as well as the course load burden in engineering. Students could be given academic direction and administrative support to help them take courses of interest during their studies.

Another possibility is to borrow from the E&S model and create interdisciplinary courses for Civil Engineering students to take instead of electives. There are many interactions between Civil Engineering specialties and other academic fields (for example psychology and transportation planning, or public policy and water/wastewater treatment) and these courses could be designed to introduce fields of study that complement Civil Engineering studies. Due to the specific design of these complementary classes, the skills students learn will be readily transferable, and the course content will give students added insight into the technical material they study. If possible, professors or other guest speakers who specialize in the topics being covered should be the ones presenting the material as opposed to Civil Engineering professors to further increase the interdiciplinarity of the experience in these classes for students. An objective of the course could be to discuss how the ideas being presented interact with Civil Engineering principles to guide students into interdisciplinary thinking as opposed to the elective model where they need to make all the connections between the material themselves. Even if entire classes focused on interdisciplinary ideas cannot be taken, acknowledging ideas and influences from other disciplines in Civil Engineering classes will help students to develop respect for other disciplines.

Engineers need to learn how to work constructively in interdisciplinary teams. Many universities have interdisciplinary design projects bringing students together from all the engineering departments to work on projects together. Churchill and Baetz (2009) describe how this type of experience was incorporated into the E&S program. Coordinating with other departments might not always be possible especially in the short to medium term, but it is possible to create a similar experience for students within Civil Engineering. Civil Engineering is made up of quite a few different areas of specialization—structural, water, transportation, geotechnical, municipal, waste management, etc—and by having students act as specialists, each for a specific area of Civil Engineering, an interdisciplinary experience could be created within the department. Students could work on a project that drew from the various fields with each student bringing the skills and knowledge of a specialization area. While this would not be a true interdisciplinary experience for students it would help them to develop the mindset and skills required to work in true interdisciplinary teams. Professors would need to closely guide students through this process to ensure that student teams function in an interdisciplinary nature throughout the entire project.

5.3 Inquiry-based Learning

There are numerous ways in which Inquiry-based learning can be incorporated into Civil Engineering education. Students would benefit from completing Inquiry-based projects. It would allow them to explore new, interesting, or simply alternative ideas related to their course material that they would not be exposed to otherwise. It could also allow students to explore concepts related to engineering practice such as risk management, policy standards, and media coverage of engineering topics. Additionally, these Inquiry-based projects would provide a good platform for students to explore social considerations related to transportation, project management, waste treatment, and other Civil Engineering topics.

In the E&S program, the Inquiry process is framed as being the beginning of the design process. This would be a convenient method for incorporating Inquiry into the engineering curriculum, as students could explore the topic of a design project through Inquiry-style research either before beginning the design aspect, or in some classes this could be done in place of the formal design project. While traditional design projects are seen to be like professional engineering tasks, it is important to remember that students are still learning and developing ideas, so tasks that encourage creativity, learning, and engagement with the material are just as important as those that mimic the working world.

Developing an entire Inquiry-based curriculum or having students do full Inquiry projects may be impractical for many Civil Engineering programs. Even if this is the case, some of the ideas and benefits of Inquiry can be captured by implementing active learning practices within classes. Active Learning processes engage students in classroom activities allowing them to actively engage with the material in ways that are not possible through traditional lectures. Common examples include Think-Pair-Share (where students work independently, come together in pairs, and then share their results with the class), or Jigsaws (where students teach each other material in small groups) (Felder, 2012). These activities can be very short (only a couple minutes) or last entire class periods (Borrego et al. 2010). Active Learning can also be encouraged through the type of homework and assignment problems that are assigned for classes. Problems that are open-ended, have multiple solutions, or are intentionally poorly defined can encourage students to think more broadly about the material they are studying. Students need to be encouraged to be creative in their problem solving methods to allow for innovation and new ideas (Felder, 1988). Felder (2012) acknowledges that it can take some time for both instructors and students to grow accustomed to these sorts of activities so it is important to try them multiple times.

Another way to incorporate the benefits of Inquiry-style learning is to engage students in discussions during lecture time to encourage questioning of concepts. All of the E&S classes include a small portion of course marks for in-class participation to encourage student involvement in class discussions and activities. Marks are often not enough to encourage active participation, as a non-judgemental learning environment also must be created for students to feel comfortable participating. Since many Civil Engineering courses are quite large, seminar-style discussions may be impractical, but new technologies offer some possibilities for bringing an element of student participation into large classes even if they will never truly replace live discussions. Clickers (or the clicker Smartphone application) can be used especially as part of a Think-Pair-Share type activity to bring the class back together, or social media sites such as Twitter can be used to compile (through the use of specified hashtags) what students are thinking, interested in, or learning from a lecture in real time. These are the current technological options, but as common technologies change and evolve others might also provide useful classroom applications. The goal is not the focus on the technology used, but to focus on how a technology might provide a tool to enable students to be better engaged with the material in their courses.

6 Discussion

When adding breadth to engineering education, it is important to carefully guide students in making the links between the various aspects of the curriculum. While some students will do this naturally, others will struggle with this process. Felder (2012) acknowledges that many students have been trained to view classes as being self-contained so they will have trouble transferring knowledge and skills between classes without explicit guidance in this area. The E&S program at McMaster has been criticized for this, as some students struggle to make connections between their focus electives, E&S courses, and technical courses (Marzoughi, 2007). Instructors can promote the integration of these ideas by requiring students to reflect on how electives and other non-technical components of their education interact with the technical aspects of their work. Students could be required to write short pieces reflecting on how the skills and knowledge they gain through their elective courses will make them better engineers. This could be completed in a course or as a general departmental requirement for academic year completion.

McMaster used its experience and expertise with Inquiry-based learning to form the basis for its E&S program. Other institutions can make use of other active educational ideas such as problem-based learning if they find it to be more suitable. By building on institutional expertise, not only will there be better support for academic changes but the changes will create less of a drain on instructor resources as they are already familiar with the tools. This will make the transition to less traditional educational practices go more smoothly for both instructors and students.

While implementing any of these ideas will benefit students, it is clear in the E&S program that there is synergy between the three components. Inquiry provides a good basis for teaching students the concepts and practices of sustainability, and interdisciplinary studies enhance students' abilities to understand complexities within the material they are studying. Being provided with knowledge of sustainability, being exposed to various perspectives, and being allowed to ask questions provides students with the educational base necessary to be an innovative engineer.

7 Conclusions

The field of engineering is evolving as society evolves, and engineering education needs to evolve to keep pace with these changes. Implementing change in engineering education can be challenging. University departments have limited resources, and change is not always simple or straightforward. The E&S program at McMaster University provides one concept for broadening the education of engineering students by integrating sustainable education, interdisciplinary studies, and Inquiry-based learning into traditional engineering studies. While the exact model of the program will not suit all institutions the three main ideas of the program are important elements of engineering education that can be introduced directly into Civil Engineering courses and programs. While no one knows exactly what the future will bring, an education designed to encourage critical thinking and the development of broad skills will prepare the Civil Engineers of tomorrow for anything.

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