THE METAKETTLE PROJECT: A JOURNEY TO THE HEART OF HIGHER EDUCATION

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ABSTRACT

Among the ways that universities can advance the participation of women in science and engineering is by adopting integrative pedagogies which set the technical foundations of educational programs within their wider economic, social, cultural, ethical, and personal contexts. This conclusion undergirds the MetaKettle Project, a practical and innovative follow-up to the recent NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region (2004-2009). The MetaKettle Project offers a pragmatic response to a rapidly changing world and an integrative perspective on higher education. Not only a hub for curricular development and pedagogical support but also an arena for transformative educational experiences, the MetaKettle Project brews big picture thinking about engineering and science education. This includes critically reflecting on the "what" and "how" of science and engineering, as well as the dynamic "who" and "why" of the person who aspires to be a scientist or engineer. The MetaKettle Project taps into the motivations and values which students bring to their study and work, including an emerging sense of themselves as citizens engaged in understanding and meeting the complex challenges of our times, both locally and globally. When situated within this larger context, our efforts to promote women in science and engineering expand to enabling change at the university, fostering increased engagement by our students and life-long sustainability for our graduates. Doing so requires re-engaging the "heart" of higher education, as well as its mind.

INTRODUCTION

This paper contends that universities can advance the participation of women in science and engineering by, among other approaches, adopting and developing integrative pedagogies which connect the person who is learning with the problems being solved, the content being learned, and their wider contexts. There are many pedagogies which have integrative elements, including experiential learning, dialogue-based learning, holistic education, service learning, student-centred learning, etc. In one way or another, each of these pedagogies addresses the student as a whole person, and hence not as only a student, but also a citizen, as well as potentially a future employee, employer, entrepreneur, policy maker, etc. The integrative approach is not new—indeed it has been the goal of the educational enterprise since Socrates in ancient Greece. As is the case with many human goals, integrated education can be difficult and elusive to attain. Yet, efforts to seek this goal can lead to highly transformative results, not only in the education of students, but also in their lives, through enhanced understanding, knowledge, efficacy as scientists or engineers, and potential to better meet human motivations, values, and life goals.

The times are right for a focus on pedagogy as a way to advance the participation and well-being of women in science and engineering. There is an emerging sea-change in

science and engineering education (and higher education more generally), due to the convergence of a wide set of drivers for change. Governments, industry, and universities recognize the need for engineers and scientists to exercise leadership in complex projects which require not only technical competence but also demand an understanding of the social, cultural, economic, environmental, or ethical dimensions of the issues (Grasso and Burkins, 2010b). Industry increasingly seeks employees with "T" shaped expertise, i.e. deep expertise in one discipline, together with the ability to collaborate effectively across a breadth of areas (Institute of Electrical and Electronics Engineers, 2010). Professional licensing associations, such as the Canadian Engineering Accreditation Board, now require that university graduates demonstrate their technical and process skills in terms of outcomes-based measurements (Canadian Engineering Accreditation Board, 2010). And, finally, there is a vital and energetic driver coming from students of the millennial generation who are seeking relevance in their education, not just for immediate career opportunities but for consistency with their life aspirations, including a sense of meaning and connection with their inner values and motivations, and with the global community (MacDonald, 2010; Moloney, 2008).

Our home institution, Memorial University, is engaged in the development and implementation of a Teaching and Learning Strategy (Memorial University, 2011a). At Memorial University, we have initiated a pedagogy project, called the MetaKettle Project, as a legacy from the recent (2004-2009) NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region (Rosales and Moloney, 2010).

This paper summarizes and organizes the scholarship which supports our claim that universities can advance the participation of women (and men) in science and engineering by changing the way we educate scientists and engineers. We demonstrate our approach with the MetaKettle Project at Memorial University. To underscore the difference between the conventional approach or status quo of undergraduate education and the approach advocated by the MetaKettle Project, we employ the metaphor of "journey" into the "heart" of higher education.

THE CWSEA, A CHAIR FOR WOMEN IN SCIENCE AND ENGINEERING

Despite many advances over the past 30 years and more, the participation by women continues to lag behind that by men in many fields of science and engineering, in Canada as well as in other countries. For example, the percentage enrolment by women in full-time accredited undergraduate engineering programs in Canada peaked at just over 20% in 2001, and has fallen below 20% since then (Engineers Canada, 2010). Such continuing and surprising under-representation of women was the impetus for the establishment in 1997 of the unique Canadian program of regional Chairs for Women in Science and Engineering by the Natural Sciences and Engineering Research Council of Canada (NSERC). The key mandate for these NSERC Chairs is that each Chair develop, implement, and communicate strategies to raise the level of participation of women in science and engineering as students and professionals (NSERC, 2011).

Over 2004-2009, the NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region (CWSEA) was held at Memorial University in St. John's, Canada. During the five years of its term, the CWSEA developed and conducted a program of activities and research towards fulfilling the NSERC mandate. Worth noting for its importance to the entire CWSEA program and to its legacy in the MetaKettle Project is a key theme which ran through the initiatives and research of the CWSEA. This theme started from the CWSEA vision for the development of the talents of individual women and girls and the realization of their dreams; it grew into an ethos and concern for the whole person who is or who aspires to be a scientist of engineer; it led

to numerous research results and operational elements about the person who is the scientist or engineer, including her motivations and how she thinks and learns.

Among the CWSEA results were a better understanding of the person who is the scientist or engineer, as thinker and agent (Moloney, 2005), and how she (or he) learns, especially abstract course material (Moloney, 2010). Based on Rogoff's (1995) three-plane model of sociocultural activity, we developed the model that a student becomes a scientist or engineer through thinking, feeling, and acting like a scientist or engineer in workshops and courses (Moloney, 2010). Since thinking and acting are always accompanied by feelings based on values, we also investigated the range and significance of the values and motivations of young women, and generated strategies to better meet these values and motivations in presenting them with the possibility of studying and having careers in science or engineering (Moloney, 2008). These results from the CWSEA are carried forward into the MetaKettle Project.

THE METAKETTLE PROJECT: A CWSEA PEDAGOGY LEGACY

Although the CWSEA's mandate was specifically about women, it became clear that many of the lessons we learned about increasing the participation of women in science and engineering could benefit a larger population. The wider significance of CWSEA initiatives and findings together with the specific insights obtained into the person who is the scientist or engineer in her (or his) full human dimensionality (Moloney, 2008) led to a key conclusion that among the ways that universities, together with their community and professional partners, can advance the participation and engagement of women (and men) in science and engineering is by adopting and further developing integrative pedagogies. Further, we recommended that a project consistent with this conclusion be initiated at Memorial University to realize the potential within the conclusion.

The result is a practical and innovative follow-up pedagogy project to the CWSEA, called the MetaKettle Project, which offers a pragmatic response to a rapidly changing world and an integrative perspective on higher education. The activities of the MetaKettle Project seek to engage the motivations and values which students bring to their study and work in engineering, including an emerging sense of themselves as citizens engaged in understanding and meeting the complex challenges of our times, both locally and globally.

When situated within this larger context, the efforts of the CWSEA to promote women in science and engineering is now expanding to the larger goal of enabling change at the university, by adopting a perspective and implementing methods to foster increased engagement in our students and to promote their life-long learning and growth as graduates and throughout their careers. The MetaKettle Project thus becomes one of the most significant outcomes of the NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region, 2004-2009 (CWSEA).

Integrative Pedagogy for Science and Engineering

In this section, we outline the scholarly argument for using a range of pedagogies, or ways of teaching and learning, in science and engineering. In particular, we focus on integrative pedagogies which aim to connect the person who is learning with the material being learned and its wider context, and thus make positive learning experiences and results more likely. Our focus is on university level education, as that is the domain of our expertise and influence; however, we acknowledge the need and applicability of the ideas proposed here for all levels of education.

Science and engineering education researchers and practitioners have started to argue that the traditional or established undergraduate curricula in science and engineering programs do not respond adequately to the needs of the present world, much less to the needs of a future which is expected to be defined by rapid change, increasing complexity, and global consequences (Colgoni and Eyles, 2010; Felder, 2006; Grasso and Burkins, 2010a; Jaschik, 2010; MacDonald, 2010; Moloney, 2010; National Academy of Engineering, 2005; Reeve, 2010; Rugarcia et al, 2000; Sheppard, Pellegrino and Olds, 2008; Somerville at al, 2005; Williams, 2003). For example, engineering programs established since the 1950s have educated students to be specialized within disciplines, many of which are traditionally defined, and to be technical problem-solvers. However, the 21st century context of engineering, as well as much of current engineering practice, points to benefits to be realized when engineers are problem-definers as well as problem-solvers (Grasso and Martinelli, 2010; Somerville et al, 2005), and more significantly, are able to engage in socially responsible and interdisciplinary collaboration (Goldberg, 2010).

Similarly, the scientific enterprise benefits from cross-disciplinary collaboration and from scientific inquiry situated within a wider context which extends beyond the strictly scientific domain (Colgoni and Eyles, 2010). From a civic perspective, our national and global communities need citizens who are scientifically literate at the level of our times and global issues. In addition, governments, industry, and scientific research institutions have begun to acknowledge the benefits when scientists, as well as engineers, are involved in collaborative, multidisciplinary projects (Brint, Marcey and Shaw, 2009). From a pedagogical perspective, science education thus needs to provide experiential opportunities in which the relevance of the science is clear (Jaschik, 2010; MacDonald, 2010). Further, concerns with better engaging students in science can be extended to the sphere of public policy, where experiments in deliberative democracy show promising developments in engaging the public with social and ethical issues in science and technology (Franklin, 1999). In other words, how to think about science in its full context, i.e. historical, economic, philosophical, etc., is proving to be just as important to the future of science as the processes by which scientific inquiry is conducted (*How to Think About Science*, 2009).

In examining the role of the university in narrowing the gaps identified above, we note the statement of Ursula Franklin, eminent Canadian physicist, public scholar and humanitarian, that "the purpose of a university is not only to be a place where knowledge and understanding find a home, but also to provide a bridge for interaction with the larger community." (Franklin, 2006, pg.139). Although Canadian universities strive to provide bridges through interdisciplinary programs and community engagement initiatives, gaps remain between the wider context and aspirations of a 21st century university and the remnants within it of a "cold War curriculum" (Goldberg, 2010). More significantly and positively, we can consider what we stand to gain when our universities' curricula catch up with both the 21st century and our full humanity. This is the challenge that universities face today around the globe, and in a special way due to their focus on objective content, that science and engineering faculties and schools face.

What is needed is a systemic transformation of science and engineering education within the university, with a shift towards frameworks and perspectives that are more holistic or integrative in scope (Grasso and Burkins, 2010b; Colgoni and Eyles, 2010; Somerville et al, 2005). Such a systemic transformation would include not only an integration across the science and engineering disciplines but also greater emphasis on building teams and on teamwork, on the development of more effective

communications skills, on cross-disciplinary dialogue and on dialogue between humans and their objects of study, on increased awareness of the social, political, environmental, commercial and government contexts of engineering and science (Brint, Marcey and Shaw, 2009; IEEE, 2010; Somerville et al, 2005) and on methods to heighten awareness of self (Lonergan, 1993; Moloney, 2010).

Leaders in science and engineering are taking stock. In Canada, the leaders of the engineering profession organized a summit in Montreal in 2009 at which they issued a declaration which recognized that engineers are "enablers of dreams" (Canadian Engineering Leadership Forum, 2010) who play a significant role in society's development. To this end, the Summit participants committed themselves to transforming engineering education and practice in order to foster greater collaboration, a culture of sustainability, and the best quality of life for Canadians (Canadian Engineering Leadership Forum, 2010). In addition, the Canadian Engineering Accreditation Board has recently adopted guidelines which recognize the need for engineers to relate their work to the wider economic, social, health, safety, legal and cultural contexts (Canadian Engineering Accreditation Board, 2010).

Research into and the practice of integrated or holistic science and engineering education are demonstrated in nascent programs: in Canada, the University of Toronto's Leaders of Tomorrow in the Faculty of Applied Science and Engineering (Reeve 2010), McMaster University's iSci Interdisciplinary Science program (Colgoni and Eyles, 2010), and our MetaKettle Project at Memorial University, among others; in the United States, at Smith College (Koshland, 2010), Princeton University (Jaschik, 2010), and Olin College (Somerville et al, 2005), among others. In addition, programs in other disciplines, such as the Undergraduate Semester in Dialogue at Simon Fraser University in Vancouver, Canada (Gunnlaugson and Moore, 2009) demonstrate successful program elements which provide inspiration for programs in science and engineering.

These initiatives are moving beyond the big picture thinking which emerged in the 20th century (for example in systems engineering) towards even more broadly-based education in engineering and science in the 21st century. Such a move represents a profound response to the world, one not narrowly concerned with keeping up with the global marketplace, but cognizant of the need for the solution of highly complex and multidimensional problems, and, behind all these needs, the human desire for meaningful work (Franklin, 2006; Moloney, 2008; Schumacher, 1979).

To counter criticism that this approach is inefficient, unproductive, or too costly, advocates of integrative or holistic education argue that such broad-based education is both attractive and personally empowering for students, and globally-competitive for industry and governments (Grasso and Burkins, 2010b).

In summary, science and engineering education is being challenged to address both the human side and the content or technical side by setting the technical foundations within a wider context that accounts for historical, social, cultural, ecological and personal frameworks. While conventional science and engineering programs do attempt to expose students to these types of opportunities, the established curricula still tend to focus on delivering technical content rather than on integrating other skills throughout. Although science and engineering education will always need to be technically and scientifically rigorous, the development and implementation of holistic or integrated curricula will tend to broaden students' experiences with a range of subjects, and to cultivate the "soft" or process skills of management, communications, creativity and entrepreneurship.

Journey to the Heart of Higher Education in Science and Engineering

In the previous subsection, we outlined the arguments for integrative education in science and engineering, and pointed to approaches which are now being implemented. However, more can be asked of educational programs in science and engineering. We can ask that educational programs help students (and faculty) to cultivate habits of self-awareness and thought which will help them to become not only well-rounded professionals, but also attentive, intelligent, reasonable and responsible human beings (Lonergan, 1993; Palmer, Zajonc and Scribner, 2010; Zajonc, 2006).

It is the latter and more ambitious challenge to which the MetaKettle Project responds. While we are adopting holistic and integrative approaches for their ability to facilitate more effective retention and application of knowledge, we are also attracted by their potential to transform the knower. In contrast to conventional or youth-oriented pedagogical methods, transformative learning is "the essence of adult education" (Mezirow, 1997, p.11), intending the education of autonomous thinkers, who reflect critically both on their own values, beliefs and meanings, and on those of others (Cranton, 2006; Mezirow, 2000). In a similar way, the theoretical and practical approaches which inform holistic or integrative education in science and engineering not only attempt to engage the whole person, but also focus on changing habits of mind and attention, such as exercising flexibility in problem solving, nurturing the creative dimension of thought and fostering a sense of accountability for one's actions (Sheppard, Pellegrino and Olds, 2008; Somerville et al, 2005; Zajonc, 2006).

A key source of inspiration and validation of our approach is found in the work of Zajonc (2006) and of Zajonc with Palmer in (Palmer, Zajonc and Scribner, 2010). The latter 2010 book, titled *The Heart of Higher Education: A Call to Renewal*, is not so much a guide to integrative pedagogies as a philosophical framework to provide coherence for the emerging field of methods in integrative education. This work is not only theoretical but also uses poetry and metaphor to connect to feelings in the reader. Of note is their use of the word "heart" as a central metaphor for their vision of higher education, where "heart" is used with its older meaning, "not just as the seat of the emotions, but as the core place in the human self where all our capacities converge: intellect, senses, emotions, imagination, intuition, will, spirit, soul." (Palmer, Zajonc and Scribner, 2010, p.20) In addition, their philosophical framework is woven together by the everyday word "community," understood in the usual way as the basic human orientation towards being in relationship, with self, with others, with the globe, with a subject of study, etc. The connection between theoretical framework and positive human action becomes explicit in the following statement:

> "We believe that ethical thinking and action are supported by integrative teaching and learning. Compassionate action is fostered in students when they learn not only with the intellect but also with the heart. As I have attempted to show, an epistemology of love bridges the divide between intellect and feelings, between objectivity and participation. Once knowing activates our feelings, we are moved to action." (Palmer, Zajonc and Scribner, 2010, p. 98)

We recognize and value the approach of Palmer, Zajonc and Scribner (2010), as it connects with our past approach of seeking the philosophical ground upon which to build our initiatives (Moloney 2005, 2010). Although more work is still needed to fully work out, explain, and apply the philosophical framework of integrative education for science and engineering, we endorse the approach of Palmer, Zajonc and Scribner (2010), and are intentionally using it in our development of operational programs within the MetaKettle Project at Memorial University.

The MetaKettle Project at Memorial University

The MetaKettle Project (Rosales and Moloney, 2010) was initiated in 2010 as a legacy of the NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region, 2004-2009 (CWSEA). The impetus behind the MetaKettle Project was to build on the work of the CWSEA and to continue to contribute to its mandate of increasing the participation of women in science and engineering. However, by its setting in a co-educational university, the MetaKettle Project extends the CWSEA goals. Thus, the MetaKettle Project aims to increase the diversity of students studying science and engineering, while enhancing the long-term sustainability of graduates over their careers and lives. We are actively working on growing the MetaKettle Project as a centre for curricular development and pedagogical support as well as a cross-disciplinary arena for transformative educational experiences.

The project's name, MetaKettle, comes from the simple, everyday kettle, an enduring design and artefact from antiquity, symbolic of human productivity and ingenuity and of the natural bent of human beings towards discovery. Moreover, kettles are eminently practical for producing the steaming mugs of tea or coffee over which ideas are discussed and relationships formed within a community. While kettles represent the work of science or engineering, i.e. the product of engineering and the content of science, the MetaKettle is the whole in the Kettle, i.e. the person who is the engineer or scientist. Thus, the MetaKettle Project is intent upon brewing big picture thinking about science and engineering education. This includes critically reflecting on the "what" and "how" of engineering and science, as well as the dynamic "who" and "why" of the person who aspires to be an engineer or scientist.

The MetaKettle Project started in 2010 by adopting a conversational strategy similar to that outlined by Palmer, Zajonc and Scribner (2010, Chapter 5) who demonstrate how institutional change can happen from the grassroots up, conversation by conversation. The initial conversations of the MetaKettle Project were about visions and plans, about how to foster community, etc. They have become an ongoing series of conversations, with individuals and small groups, which have grown our network of supporters and participants. We anticipated—and are beginning to see the results—that our smaller conversations would connect with others, and thus contribute to fostering wider change in the University's conversation. Doing so has started us on a journey to the heart of higher education.

In addition, we engage in conversations to further the MetaKettle Project and to lead to its continuance and growth as a well-funded project within the university. We also develop and run operational programming. The MetaKettle Project has a primary focus on dialogue-based education, which we have developed based on the Undergraduate Semester in Dialogue at Simon Fraser University in Vancouver, Canada (Gunnlaugson and Moore, 2009), although with a specific orientation towards what works best for engineering and science (Rosales and Montano, 2011). In addition to our primary orientation towards dialogue education and the development of a dialogue institute, we are assisting the Faculty of Engineering and Applied Science in preparing for the switch to outcomes-based evaluation measures which will be required for accreditation of the engineering programs as of 2013. We are developing module materials on leadership for graduate students, on how to think about science, and on engineering ethics for courses in the engineering profession stream which will be offered in the upcoming academic year, Fall 2011 to Spring 2012. We are collaborating with colleagues in the Faculties of Arts and Education on a research project on creative methods to foster research writing for graduate students in the humanities and in engineering.

We now situate our work within the recently-adopted Teaching and Learning Framework of Memorial University. We contributed to the consultation process which led to the development of the recent Framework documents (Memorial University, 2011a). The MetaKettle Project is identified as a strength of Memorial University, both for its support of educators and for its interdisciplinarity (Memorial University, 2011b).

CONCLUSIONS

The MetaKettle Project offers a pragmatic response to a rapidly changing world and an integrative perspective on higher education for science and engineering. It offers programming which seeks to engage the motivations and values which students bring to their study and work in engineering, including an emerging sense of themselves as citizens engaged in understanding and meeting the complex challenges of our times, both locally and globally. While the MetaKettle Project is a work in progress, with much development and research to be done (as well as fund-raising to make its future more secure), it is a strong outcome from the recent NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region, and contribution to the NSERC mandate, as well as an example of the leading edge of integrative education for university-level science and engineering.

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REFERENCES

Brint, M.E., Marcey, D.J. and Shaw, M.C. eds, 2009. Integrated science: new approaches to education: a virtual roundtable discussion. New York: Springer.

Canadian Engineering Accreditation Board, 2010. *Accreditation criteria and procedures*. [online] Available at: www.engineerscanada.ca/e/files/Accreditation_Criteria_Procedures_2010.pdf [Accessed 25 May 2011]

Canadian Engineering Leadership Forum, 2009. *Leading a Canadian future: The new engineer in society*. Montreal Declaration, National Engineering Summit, Montreal, QC 21 May 2009. [online] Available at: www.engineerscanada.ca/files/pam_e_Summit_Declaration_English_Final.pdf [Accessed 25 May 2011]

Colgoni, A. and Eyles, C., 2010. A new approach to science education for the 21st century. *EDUCAUSE Review*. Jan/Feb 2010, pp.10-11.

Cranton, P., 2006. *Understanding and promoting transformative learning: a guide for educators of adults* Second ed. San Francisco: Jossey-Bass.

Engineers Canada, 2010. Canadian engineers for tomorrow: trends in engineering enrolment and degrees awarded, 2005-2009. Ottawa: Engineers Canada. Available www.engineerscanada.ca/files/w_report_enrolment_eng.pdf [Accessed 23 May 2011]

How to Think About Science, 2009 [Radio broadcast/podcast series] CBC 2009. [online] www.cbc.ca/ideas/episodes/2009/01/02/how-to-think-about-science-part-1---24-listen [Accessed May 25, 2011]

Institute of Electrical and Electronics Engineers (IEEE), 2010. Conference summary. In: *IEEE/IBM Conference on Transforming Engineering Education: Creating*

Interdisciplinary Skills for Complex Environments, Dublin, Ireland 6-9 April 2010. Piscataway, NJ: IEEE.

Felder, R., 2006. Teaching engineering in the 21st century with a 12th century teaching model: how bright is that? *Chemical Engineering Education*, 40 (2), pp.110-113.

Franklin, U., 1999. *The real world of technology* (CBC Massey lectures series) Rev. ed. Toronto: House of Anansi Press.

Franklin, U., 2006. *The Ursula Franklin reader: Pacifism as a map*. Toronto: Between the Lines.

Goldberg, D.E., 2010. The missing basics and other philosophical reflections for the transformation of engineering education. In: D. Grasso and M.B. Burkins, eds., 2010a, pp. 145-158.

Grasso, D. and Burkins, M.B. eds., 2010a. *Holistic engineering education: beyond technology*. New York: Springer.

Grasso, D. and Burkins, M.B., 2010b. Beyond technology: the holistic advantage. In: D. Grasso and M.B. Burkins, eds., 2010a, pp.1-10.

Grasso, D. and Martinelli, D., 2010. Holistic engineering. In: D. Grasso and M.B. Burkins, eds., 2010a, pp.11-15.

Gunnlaugson, O. and Moore, J., 2009. Dialogue education in the post-secondary classroom: reflecting on dialogue processes from two higher education settings in North America. *Journal of Further and Higher Education*, 33 (2), pp.171-181.

Jaschik, S., 2010. News: rethinking science education. *Inside Higher Ed*. Jan 6, 2011. [online] Available www.insidehighered.com/news/2010/01/06/scienceed [Accessed May 25, 2011].

Koshland, C.P., 2010. Liberal arts and engineering. In: D. Grasso and M.B. Burkins, eds., 2010a, pp.53-68.

Lonergan, B.F., 1993. *Topics in education*. R.M. Doran and F.E. Crowe, eds., 1993. Toronto: University of Toronto Press.

MacDonald, M ., 2010. Science that sizzles. *University Affairs*, August-September, 51 (7), pp.16-20. [online] Available www.universityaffairs.ca/science-that-sizzles.aspx [Accessed May 25, 2011].

Memorial University, 2011a. A comprehensive framework for teaching and learning at Memorial University May 10, 2011 [online] Available at: www.mun.ca/vpacademic/TLF_Document_Final.pdf [Accessed 23 May 2011]

Memorial University, 2011b. Appendix C: findings from the consultation process: strengths and suggestions. [online] Available at: www.mun.ca/vpacademic/Appendix_C.pdf [Accessed 23 May 2011]

Mezirow, J., 1997. Transformative learning: theory to practice. *New Directions for Adult and Continuing Education*, Summer, 74, pp.5-12.

Mezirow, J., 2000. Learning to think like an adult: core concepts of transformation theory. In: J. Mezirow, ed. 2000. *Learning as transformation: critical perspectives on a theory in progress*. San Francisco: Jossey-Bass, pp.3-33.

Moloney, C., 2005. The scientist in our midst: who is she? In: *Proceedings of the 13th International Conference of Women Engineers and Scientists (ICWES 13)*, Seoul, Republic of Korea 26-29 August 2005. INWES.

Moloney, C., 2008. Women in science and engineering … maybe. In: *Proceedings of the 14th International Conference of Women Engineers and Scientists (ICWES 14)*, Lille, France 15-19 July 2008. INWES.

Moloney, C., 2010. 'Understanding understanding' across the disciplines: towards strategies for sustainable engineering education for the 21st century. In: *IEEE/IBM Conference on Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Environments*, Dublin, Ireland 6-9 April 2010. Piscataway, NJ: IEEE.

National Academy of Engineering (NAE), 2005. *Educating the engineer of 2020: adapting engineering education to the new century*. Washington, DC: National Academies Press.

NSERC, 2011. Chairs for women in science and engineering program. [online] Available at www.nserc-crsng.gc.ca/Professors-Professeurs/CFS-PCP/CWSE-CFSG_eng.asp [Accessed 23 May 2011]

Palmer, P.J., Zajonc, A. and Scribner, M., 2010. *The heart of higher education: A call to Renewal (Transforming the academy through collegial conversations).* San Francisco: Jossey-Bass.

Reeve, D.W., 2010. There is an urgent need for engineering leadership education. *Engineering Leadership Review*. May 2010, pp.1-6.

Rogoff, B. (1995). Observing sociocultural activity on three planes: participatory appropriation, guided participation, and apprenticeship. In: J.V. Wertsch, P.D. Rio, and A. Alvarez, eds. 1995, *Sociocultural studies of mind*. Cambridge, UK: Cambridge University Press, pp.39-164.

Rosales, J. and Moloney, C., 2010. Big ideas on the boil: an overview of the vision and significance of the MetaKettle Project. [Online], Available at: www.engr.mun.ca/~cmoloney/MK/MetaKettleOverview.pdf [Accessed 23 May 2011]

Rosales, J. and Montano, G., 2011. Experiencing your education: what engineering education can learn from dialogue. In: *Proceedings of 2011 Annual CEEA-ACEG Conference*, St. John's, Canada 6-8 June 2011. Canadian Engineering Education Association (CEEA-ACEG).

Rugarcia, A., Felder, R.M., Woods, D.R., and Stice, J.E., 2000. The future of engineering education. *Chemical Engineering Education.* 34 (1), pp.16-25.

Schumacher, E.F., 1979). *Good work.* New York: Harper and Row.

Sheppard, S.D., Pellegrino, J.W. and Olds, B.M., 2008. On becoming a 21st century engineer (Guest editor's forward). *Journal of Engineering Education*. July, Special Issue on Educating Future Engineers: Who, What, and How, 97 (3), pp.231-234.

Somerville, M. et al., 2005. The Olin curriculum: thinking towards the future. *IEEE Transactions on Education*. Feb, 48 (1), pp.198-205.

Williams, R., 2003. Education for the profession formerly known as engineering. *The Chronicle of Higher Education*. Jan 24, 49 (20), B12.

Zajonc, A., 2006. Cognitive-affective connections in teaching and learning: the relationship between love and knowledge. *Journal of Cognitive Affective Learning*. Fall, 3 (1), pp.1-9.