Global Competence: Technology Innovation and Sustainability – The experience of a Trans-Atlantic concurrent Master's degree project

Dyrenfurth, M.J. [1]
Professor
Department of Technology Leadership and Innovation
Purdue University, West Lafayette, Indiana, United States of America

Barnes, J.L.
Professor
James Madison University
Harrisonburg, Virginia, United States of America

Conference Topic: The Global Engineer

1 INTRODUCTION

This paper overviews a partnership of the Dublin Institute of Technology (Ireland), the Universitat Politècnica de Cataluña (Spain), and Purdue University (USA) offering a concurrent Master's degree program that focuses on a specific set of competencies that the principals would argue are among those needed by a globally competent engineer and/or engineering technologist in today's and tomorrow's world. The key points presented herein are derived from this EU Atlantis–FIPSE funded project implementing a program focusing on Sustainability, Technology and Innovation.

In an unpublished white paper, the author characterized the demands facing current and future engineering and technology graduates with the following quotation:

Tomorrow's world, which will be the environment both housing and being shaped by our graduates, will be characterized by ever increasing global interconnectedness and also by increasingly complex problems. Such a demanding future highlights the need for technology-degreed graduates well versed in technology systems, innovation, and leadership advantaged with the capability of understanding the international dimensions of both the problems they address and the solutions they will generate and implement. Consequently, TLI graduates will need to possess sophisticated understandings of, and capability with, the global/international dimensions of technology, leadership and innovation. [1]

To the end of providing detail as to the nature of such global competencies, this paper presents a combination of traditional academic planning, a conventional scholarly literature review and an academically unconventional approach, namely crowd-sourcing. The latter deserves some further explanation. Specifically, the project's leadership team took the position that, even though they have invested considerable planning effort and reasoned judgment pertaining to the design of the program, never-the-less there was a strong possibility that the program's students and the graduate faculty engaged in guiding their master's program, might actually be well positioned to augment significantly the best efforts of the project team.

In short, the participating faculty and students' multiple perspectives as to what competencies might be important for their projected international careers were deemed to be valuable in terms of framing each student's formal plan of studies. Their choice of courses, as guided by their faculty advisors from three countries, was taken as an indicator of their perception of important competencies. Furthermore,

[1] Dyrenfurth, M.J.

the authors of this paper consider the thesis topics evolved by these students and their major professors as also being indicative of what they deemed important to their futures.

2 REVIEW OF SELECTED LITERATURE

The paper's context is set against a backdrop of relevant literature pertaining to the emerging consensus for global competence as it relates to engineering and technology. We begin by highlighting the growing mass and nature of professional engineering and technology master's programs as documented by the USA's National Research Council's *Science Professionals: Master's Education for a Competitive World* [2] and other relevant literature. The authors of the present paper would argue that necessarily competent professional in today's globalized world would necessarily also possess at least a core set of global competencies.

The meaning of global competence certainly varies depending on the answer to the question, competence for what. In the engineering and technology fields this can refer to practicing engineers/technologists, engineering/technology managers, and engineering/technology faculty/researchers. In short it is clear that there is no singular answer to the matter of global competence.

It is also important to note that competency models differentiate between general personal characteristics, specific engineering/technology competencies, global competencies and most importantly, the intersection of the latter as shown in Figure 1.

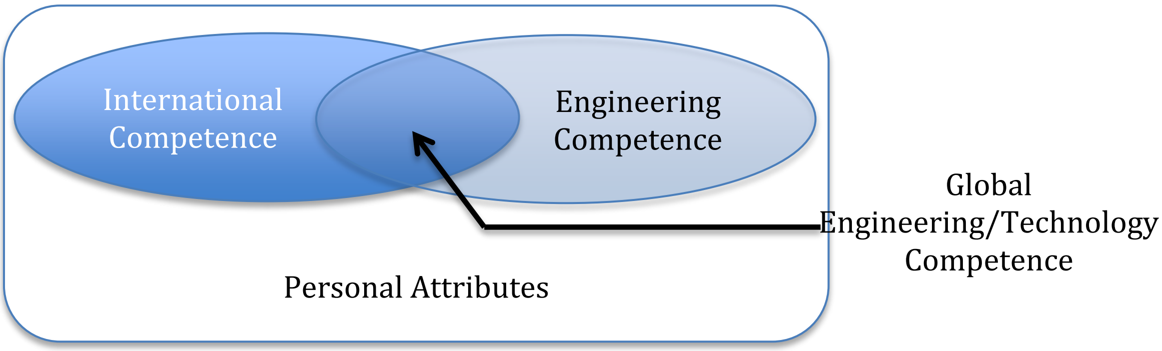

Figure 1. Model for Global Engineering/Technology Competence

With respect to the faculty/researcher role of engineering/technologists Jesiek, Haller & Thompson [3] have compiled a most insightful document that highlights many of the key competencies related to globalization. Similarly, Nasr [4] in *Towards a converged and global set of competencies for graduates of engineering programs in a globalization-governed world* has also compiled a useful synthesis with perhaps a more internationally comprehensive scope. These authors and others have generated more extensive reviews of the literature than what this paper's size restrictions permit but it is an important document for researchers desiring such detail.

Perhaps one of the more useful overarching categorizations of globalization competencies is presented by Jesiek et al. [5] They identified and cited the USA's National Research Council's four main groups of such competencies:

(1) language and cultural skills, (2) teamwork and group dynamics skills, (3) knowledge of the business and engineering cultures of counterpart countries, and (4) knowledge of international variations in engineering education and practice. [6]

The authors of this present SEFI paper wish to point out that the methods for achieving global competence represent an entirely different concern than the actual attempt to stipulate what competencies are required in order to be globally competent. In short, the latter is target acquisition and the former is developing a means to reach the target. While both are critically important, the focus of this paper is on target acquisition, i.e., the nature of global competence.

It would be too strong to suggest that there exists a consensus as to any specific set of globalization engineering/technologist competencies – at least on the basis of this review. But, does seem valid to suggest that our various professions and thought leaders are certainly moving in that direction. For example, Gustafson & Gottlieb [7] refer to a preliminary study establishing eight global competences for engineers:

1. Understanding of global cultural diversities and their impact on engineering decisions
2. Ability to deal with ethical issues arising from cultural or national differences
3. Proficiency in a second langualge
4. Ability to communicatee across cultural and linguistic boundaries
5. Proficiency in working in an ethnically and culturally diverse team
6. Understanding the connectedness of the world and the workings of the global economy
7. Understanding of the international aspects of engineering topics (such as supply chain management, intellectual property, liability and risk, market and product design considerations, and business practices)
8. Familiarity with the history, government, and economic system of several target countries.

It is worth noting, however, that the concern raised earlier by Johnson, Lenartowicz, and Apud's [8] work remains valid. The observed that based upon a 28 year spanning review of business journals, there were few articles that documented <u>specifics about the actual competencies</u> [emphases added], and knowledge that constitute global competence.

3 PROJECT DESCRIPTION

The authors and their colleagues at the Dublin Institute of Technology (DIT), Universidad Politècnica de Cataluña (UPC), and Purdue University (PU) conceptualized and were awarded a four-year European-United States Atlantis grant by the Fund for the Improvement of Postsecondary Education (FIPSE, USA) and the Education, Audiovisual and Culture Executive Agency (EACEA, EU) to facilitate master-level students to concurrently receive both a US and European master's degree. The project's degree focused uniquely on the intersection of Technology – Globalization – Innovation and Sustainability for their Sustainability, Technology, and Innovation Dual Master's Degree (STIMS). But, all programs need to be detailed in order to become implementable and this required the team to consider what the target competencies were to be. Subsequently program's path to the attainment of the desired outcomes was operationalized by means of plans of study, one of which is presented in Figure 2.

The project's goals, curricula, and student-developed competencies are reflected in the program's plan of studies, the students' actual course taking experience, and their theses so far. To this end, the actual course taking experience, at each of the three collaborating institutions, was analyzed by means of transcript analysis. This is relevant because it represents the judgments, on both sides of the Atlantic, of multiple faculty advisors and students as to their perceptions of what skills are needed for success in our increasingly globalized world.

Barnes Technologies International LLC (BTILLC) evaluated the STIMS Program using a mixed methods (qualitative and quantitative) process-outcomes and decisions-oriented evaluation model. More specifically, BTILLC assessed among other factors, program context documentation, curriculum alignment, language and cultural development, and sustainability. BTILLC's program evaluation model [8], [9] consisted of an integrated approach employing Stufflebeam's Context, Input, Process and Product Evaluation Model (CIPP) [10], [11], Kirkpatrick's Four Levels of Evaluation Model (reactions, learning, transfer, and results) [12], and Wilder's Collaboration Inventory Factors (environment, membership characteristics, process and structure, communication, purpose, and resources) (Mattessich, Murray-Close, & Monsey [13]; to conduct a third party program evaluation.

The CIPP Model provided a comprehensive approach to evaluating programs, projects, personnel, products, institutions and systems. This evaluation approach is built on the assumption that anything that can be evaluated can be successfully evaluated at various stages of its development, context, input, process, and product. Simply put, the CIPP Model focuses on "What needs to be done?", "How should it be done?", "Is it being done?", and "Did it succeed?" The findings and results of the mixed methods assessment provided recommendations to the principal investigators for how well the program's goals and objectives have been met and what adjustments must be made to fill in gaps.

Atlantis Concurent/Dual Master's Degree in
Sustainability, Technology and Innovation

Plan of Study 1, UPC Admission Student, Autumn Start, UPC & Purdue Award (120 ECTS credits, 63 credit hours)			
Sem 1, UPC Autumn	Sem 2, DIT Spring	Sem 3, Purdue Autumn	Sem 4, Purdue Spring
Core Modules/Courses	**Core Modules/Courses***	**Core Modules/Courses**	
Environmental and Ecological Economics	MECH 9002 Innovation and Knowledge Management	TECH 646 Analysis of Research in Industry and Technology	TECH 621 Building a Philosophy of Technology
Systems Thinking and Complexity	or REEN 2215 Renewable Energy Technologies	STAT 501 Experimental Statistics I	
Ecology and Natural Resource Mgmt.			
Human Sustainable Development	Irish Cultural Studies		
Urban Ecology and Land Use Planning	English (If required)	English (If required)	English (If required)
Culture, Technology and Innovation	Joint Directed Project (Engagement in directed project can start at the start of this semester)	Joint Directed Project (Engagement in directed project must start no later than the start of this semester)	Joint Directed Project (Must be completed by the end of this semester)
Elective Modules/Courses (No elective modules in this semester)	**Elective Modules/Courses** (3 of the following if English not required. 2 of the following, if English is required)	**Elective Modules/Courses** (3 of the following if English not required. 1 of the following, if English is required) (1 and no more than 1 elective must be selected from the cultural courses listed)	
English support (if required)	Whichever module above is not selected as core can be considered when choosing an elective.	IT 507 Measurement & Evaluation in Industry & Technology	
	ENER 1702 Energy Supply	IT 590 Special Problems in Industrial Technology	
	MECH 9010 Applied Surface Engineering	IT 623 Contemporary Industrial Technology Problems	
	SSPL 9055 Sustainable Construction	IT 668 Administering Technical Programs	
	SSPL 9030 Env. Design & Mgmt.	ECET 581C Efficient Energy Systems	
	BITE 2216 Biomass Technology/Biofuels	CIT 550 Organizational Impact of Information Technology	
	CBEM 1404 Artificial Intelligence	CIT 551 Information Technology Economics	
	MECH 9000 Advanced Dynamics	Culture courses, e.g. HIST 58400, SOC 51400, SOC 51500, SOC 52000	
	CBEM 1415 Computer Aided Design and Eng.	English courses, e.g. ENGL 62100, ENGL 62000, ENGL 10600	
	ADEN 2211 Advanced Energy Systems		
	ENCO 1104 Energy Conversion and Use		
	MECH 9013 Computational Fluid Dynamics		
	MECH 9014 Heat and Mass Transfer		
	CBEM 1412 Engineering Systems Simulations		
	Other suitable electives	Other suitable electives	

Notes: Awards on completion: UPC MSc (Sustainability) and Purdue University MSc (Technology).
* Students must take Irish Cultural Studies and one other core module listed.

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH · DIT · PURDUE UNIVERSITY · Bilateral Cooperation with Industrialised Countries · EACEA Education, Audiovisual & Culture Executive Agency

FIPSE The contents of these pages were developed under an EU-U.S. Atlantis grant (P116J090064) from the Fund for the Improvement of Postsecondary Education, (FIPSE), U.S. Department of Education. However, those contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government.

Attention: This action has received funding from the European Community through its EACEA agency. Sole responsibility lies with the author, and the EACEA and the European Commission are not responsible for any use that may be made of the information contained herein.

Figure 2. Sample Plan of Study

4 GLOBAL COMPETENCIES

Given the preceding work by the project team, and in concert with the findings of our review of the literature, we conceptualized the following set of competencies as being critical to the anticipated globalization demands facing our graduates:

- Cultural sensitivity to differences in values, norms and mores of other societies and skills in interacting effectively with peoples of other cultures, personal and corporate value systems
- Ability to operate effectively across different time zones and capability with distance communication mechanisms such as video conferencing
- Technology collaboration competence such as file sharing and joint/simultaneous editing
- Fluency in multiple languages
- Project management capabilities appropriate to varying cultural values of time and procedure
- Awareness and an understanding of the implications of varying technological systems and standards, e.g., metric vs. customary measurement, positioning of graphic objects in three dimensional space, electrical standards and the like.
- Acquiring and maintaining internationally required work permits, passports, visas etc.
- Understanding of the various national approaches to qualification frameworks, i.e., classification of varying positions along a nation's technological human resource spectrum
- Comparative ethics
- World and regional geographic awareness of countries and climates as relating to technology
- Understanding of different (national) legal interfaces and interactions with technology
- Effective consideration of international aspects when engaged in technological problem solving
- Awareness, accessing and interpreting international information sources and international agencies such as ISO, OECD, ILO, UNESCO, the World Bank, and the like
- An ability to communicate, network and collaborate with international professionals in business, industry, academe, and the public sector and across cultural and linguistic boundaries
- An open, non-judgmental mindset appreciative and respectful of other cultural perspectives
- Ability to be flexible and adapt to unfamiliar international contexts

Then, when we analyzed the actual plans of study designed by more than 35 members of the program's international cohort, we identified the most frequently taken courses and their frequencies as shown in Table 1 on the following page. To further assess student and faculty perceptions we analyzed all course titles and generated the frequency driven keywords shown in Figure 3. Clearly they identified numerous specific technologies as important to their future. Similarly important were the skills of:

- Analysis
- Application
- Development (as in R&D)
- Sustainability
- Language
- Statistics
- Experimentation
- Management
- Systems

Figure 3 Course Title Word Cloud

Table 1. Most Frequently Taken Courses

Experimental Statistics I STAT 50100 PU	38
Analysis Research Industry & Technology TECH 64600 PU	30
Spanish language (any, from PU or elsewhere	27
Technology from a Global Perspective MET 52700 3 PU	15
Energy Supply ENER 1702 2.5 Tr DIT	11
Energy Conserving Building Retrofit BCM 58100 3 PU	11
Sustainable Construction & Development BCM 58100 3 PU	9
Sustainability & Global Entrepreneurship BCM 58100 3 PU	9
Management Projects MGMT 69000 2 PU	8
Innovation & Knowledge Management MECH 9002 3 Tr DIT	8
Culture Technology & Innovation CTI 001 3 Tr 10 UPC	7
Applied Sustainability-Kenya BCM 58100 3 PU	7
Principles & Management of Six Sigma TECH 58100 3 PU	6
Efficient Energy Systems ECET 58100 3 PU	6
Power Systems & Smart Grid IE 59000 3 PU	5
Industrial Ecology & Life Cycle Analysis EE 43000 3 PU	5
Ecological Principles Building BIOL 59500 2 PU	5
Technological Innovation TECH 62100 3 PU	4
Solar Decathlon Planning BCM 58100 3 PU	4
Science & Technology in 20th Century HIST 35000 3 PU	4
Renewable & Alternative Energy Systems MECH 9016 3 Tr DIT	4
Ecology & Management of Natural Resources ENRM 001 3 Tr 9 UPC	4
Applied Optimization MET 50300 3 PU	4
Urban and Regional Development Technology 001 3 Tr UPC	3
Technology and Policy TECH 62100 3 PU	3
Gender & Leadership ENE 59500 3 PU	3
Green Building Information Management TECH 58100 3 PU	3
Wind Energy for Electricity Supply DIT 2.5	2
Construction Research Fundamentals BCM 58100 1 PU	2
Research Seminar BCM 58100 1 PU	2
Environmental & Ecological Econ EEE 001 3 Tr UPC	2
Technology Realization Workshop TECH 58100 2 PU	2
Technology Innovation & Culture IT 59000 3 PU	2
Social Internet TECH 63700 3 PU	2
Technology for Sustainable Human Development TDHS 001 3 Tr UPC	2
Technology for Sustainable Human Develop TSHD 48053 3 Tr UPC	2
Political Sociology SOC 53000 3 PU	2
Society & Sustainable Development. SSPL 9062 5 Tr DIT	2
Sustainable Human Development DHS 002 3 Tr 10 UPC	2
Smart Grid Seminar CNIT 58100 3 PU	2
Exploring Research Solar Panels BCM 59000 3 PU	2
Biometric Usability IT 54000 3 PU	2
Quality & Productivity in Industry & Technology AT 50800 3 PU	2
Principles of Personal & Professional Management Practice OLS 58100 3 PU	2
Energy Technology & Applications TECH 62100 PU	2
Renewable Energy Technologies REEN 2215 3 Tr DIT	2
Global Supply Chain Management IT 53500 3 PU	2
Irish Cultural Studies 5 DIT	2
Biomass Technology Biofuels BITE 2216 3 Tr DIT	2
Data Warehousing CNIT 55900 3 PU	2

Systemic Thinking & Complexity SC 002 3 Tr UPC	3		Energy Conversion &Use ENCO 1104 2.5 Tr DIT	2
Special Problems in Industrial Technology IT 59000 3 PU	3		Entrepreneurship for Engineers ENTR 1950 3 Tr DIT	2
Project Management for Industry & Technology IT 57100 3 PU	3		Environmental Design & Management SSPL 9030 3 Tr DIT	2
Organizational Impact of Information Technology CNIT 55000 3 PU	3		Communication with Public AGRY 59700 1 PU	2
Measurement and Evaluation in Industry and Technology IT 50700 3 PU	3			

Because the above table only presented the most frequently taken courses that our student cohort had taken we also chose to do a content analysis of the titles of all the theses completed so far. The results of this analysis are presented in a word cloud provided in Figure 4. Again the key competencies related to analysis, sustainability, design, innovation and systems emerged with considerable frequency. Similarly, the focus on specific technologies also reappeared as exemplified by the terms energy, building/construction, environmental, electrical, management, and power in addition to the international dimensions naturally emphasizing Ireland, Spain, Europe and the USA.

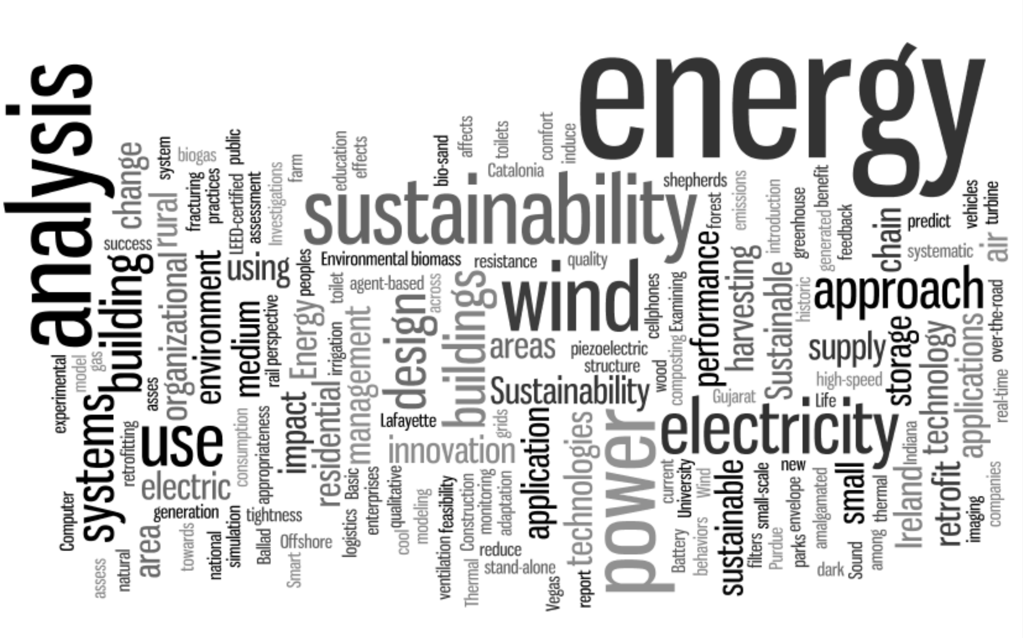

Figure 4. Thesis Title Word Cloud

5 SUMMARY

Among the lessons the partners have learned by experience with collaborative exchange and concurrent degree programs is the criticality of selecting the right partners and then interacting extensively enough, at each other's site, to build significant understanding, rapport and trust. Central to this understanding is in-depth cognizance of each other's vocabulary, course content and divergent ways of describing target outcomes, credit and grade equivalencies, and instructional culture. This collaboration has led us to agree that the competencies identified in section four of this paper are critically important – but, we also recognized that there are invariably multiple ways to develop such competencies, i.e., there is no singular approach that will work for all!

6 REFERENCES

[1] Dyrenfurth, M. (2014), Systematic Globalization of the TLI degree experience: Transformative Implementation of Globalization - Developing Global Competence in Tomorrow's Technology Leaders. Unpublished position paper. West Lafayette, IN: Purdue University, College of Technology, Department of Technology Leadership and Innovation.

[2] National Research Council. *Science Professionals: Master's Education for a Competitive World*. Washington, DC: The National Academies Press, 2008.

[3] Jesiek, B.K., Haller, Y., & Thompson, J. (2014), Developing Globally Competent Engineering Researchers: Outcomes-Based Instructional and Assessment Strategies from the IREE 2010 China Research Abroad Program. *Advances in Engineering Education*, Vol. 4 No. 1.

[4] Nasr, K.J. (2014, March), Towards a converged and global set of competencies for graduates of engineering programs in a globalization-governed world. In Alameddine, A.M. (ED.) Impact of Globalization on Engineering Education, *Journal IDEAS*, *18*

[5] Jesiek, B.K., Zhu, Q., Woo, S.E., Thompson, J., and Mazzurco, A. (2014), Global Engineering Competency in Context: Situations and Behaviors," *Online Journal for Global Engineering Education*: Vol. 8: No. 1, Article 1. Available at: http://digitalcommons.uri.edu/ojgee/vol8/iss1/1

[6] National Research Council. (1999), *Engineering Education Tasks for the New Century: Japanese and U.S. Perspectives*. Washington, DC: National Academy Press.

[7] Gustafson, R.J., and Gottlieb, E.E. (2013), What global competencies do engineers need? Presentation at Internationalizing Engineering: Research on Global Competencies, Why, What and How, the AIEA 29th Annual Meeting, February 18-20, 2013, New Orleans, USA. Columbus, OH: The Ohio State University

[8] Barnes, J. and Barnes, S. (2010). *BTILLC Integrated Program Evaluation Model for FIPSE Atlantis Programs*. Harrisonburg: BTILLC.

[9] Barnes, J., Barnes, S., Dyrenfurth, M., Herrick, R., McHale, D., Schmidt-Walter, H., and Seybert, T. (2010), *Mixed methods used to measure the impact of FIPSE exchange student programs*. Radford University: http://www.radford.edu/~vera/

[10] Stufflebeam, D. (2002), *CIPP evaluation checklist: A tool for applying the fifth installment of the CIPP model to assess long-term enterprises*. Retrieved from http://www.wmich.edu/evalctr/checklists/cippchecklist.htm

[11] Stufflebeam, D. (2004), The 21st Century CIPP Model: Origins, Development, and Use. In M. Akin (Ed.). *Evaluation roots: Tracing theorists' views and thoughts* (pp.245-266). Thousand Oaks, CA: Sage.

[12] Kirkpatrick, D. (1996), Great ideas revisited. *Training & Development*, Vol. 50, No. 2, 54-60, 227-240.

[13] Mattessich, P. W., Murray-Close, M, and Monsey, B.R. (2001), *Collaboration: What makes it work* (2nd ed.). St. Paul, MN: Fieldstone Alliance.