AC 2011-1412: AN INTERNATIONAL COMPARISON OF ENGINEERING PROGRAMS IN THEIR EMPHASES AND PROFESSIONAL SKILLS DEVELOPMENT

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Introduction

In the face of grand challenges for engineering[1], several efforts have been undertaken to identify the vision for what we should expect from our undergraduate engineering students. For example, one of the significant reports[2] indicates that our graduates should aspire "*to have the ingenuity of Lillian Gilbreth, the problem solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King, and the curiosity and wonder of our grandchildren*." This statement implies that not only should our graduates be very well equipped with analytical skills, but also master problem solving and professional skills. Indeed, given the near certainty that grand challenges will require complex problem solving skills in multi-disciplinary global settings[2], our graduates will need to develop professional skills to a higher degree than they currently do.

It is unlikely that there will be one good "problem solving and professional skills attainment" recipe for all to follow, given that our historical evolution as institutions of education are different and our identified emphases are shaped by our surroundings (e.g., industrial sectors, socio-economic setting, etc.) and our educational resources. Further, the admission processes, curricula structures and emphases might be different. For example, while in Europe most countries use an entrance exam for placement of students, in the U.S. we opt for a more holistic view, and review application packages which are designed not only to convey test scores but also leadership accomplishments. Also, while in terms of credit hours count, engineering students have about the same level of course engagement, most European students will have a much higher level of engineering courses (~95%) whereas US students will have less (~65%) by the time their degrees are conferred. Then, there could be differences in both the level and mechanisms to impart problem solving and professional skills around the world.

Despite the unavoidable differences we still expect that our engineering graduates will, at some point in their careers, work with their international peers in collaborative settings. Cognizant of this, engineering programs provide opportunities for course level collaborations across multiple countries to provide students with an understanding of working in global engineering teams. Mostly, programs involve design-based problem solving in order to practice professional skills (i.e., teamwork, communication, leadership) in a context. We have not found an extensive quantitative study showing the differences in the way students and faculty members perceive how their program is imparting problem solving and professional skills. We fill this void in the literature by replicating the P2P surveys[3] developed as part of an NSF funded project. With the replication at hand, we extend the study to enable comparison across countries. In this paper, we focus on the replication in Ireland and limit revealing our findings to the problem solving and professional skills attainment perceptions of students.

Literature Review

Engineering programs are required to show their outcomes in professional skills attainment as the EC2000 criteria[4, pgs. 24-25] for program level outcomes focused on these criteria. However, it is not trivial to assess the progress of students on attainment of these skills and there is no consistent and practical approach to assess students' progress targeting these skills. Assessment of ABET learning outcomes, at different stages of students' development, is challenging, but must be done. In fact, prominent engineering education scholars note the importance of assessing professional skills[5-6], and offer potential solutions [7]. In many cases, however, what is offered as an assessment method requires significant faculty involvement and time, or constant supervision by assessment specialists, and hence, has not been adopted due to budget constraints and a lack of faculty buy-in for the long term.

Professional skills necessary for students are well documented for engineering[5, 8]. Assessment rubrics and tools exist in some areas (e.g., teamwork, communications skills) and additional research and experimentation are needed in some other areas (e.g., globalization and creativity). Most existing tools, however, are developed only for individual skills. For leadership skills assessment, student perception surveys[9] and quantification of observed leadership behaviors[10] are among the most widely used. Several instruments have been proposed to assess students' oral and written communication skills[11-14]. Team Diagnostic Survey (TDS) is designed to assess the concepts in the model of team effectiveness proposed by Hackman[15-16], and its development and validation have been well-documented[17]. Rubrics for outcome assessment of student's ability to understand ethical responsibility and resolve ethical dilemmas are proposed for the engineering context[18-20]. Some recent work[21] also addresses the assessment of global awareness skills, particularly in engineering education. Student portfolios have been used to record and assess creative thinking skills[22]. A number of the diagnostic tools and surveys measure students' perceptions of their skills and/or their confidence in using these skills, and not the actual attainment of the relevant learning outcomes. Therefore, they are often perceived by faculty as not having the same rigor and objectivity associated with more traditional assessment tools, such as examination results.

One major problem with these existing assessment tools is that they have been developed based on different frameworks, and hence, the integration of non-consistent assessment tools into an overall program assessment is challenging. Beard et al.[7] suggest that an assessment plan to evaluate curricular efforts to integrate professional skills into programs should include standardized rubrics.

Beyond the studies that focused on assessment of individual skills (e.g., teamwork), a few recent studies proposed more comprehensive assessment tools targeting a larger set of professional skills. For example, Huyk et al.[23] studied engineering students enrolled in multi-disciplinary project team courses to investigate the impact of reflections on the service learning and other project outcomes. Some students completed three written assignments per semester that contained reflective thinking questions. The responses to the questions were coded into three levels of reflective thinking based on the Reflective Judgment Model[24]. Huyk et al. also used a self-assessment tool to assess how each student felt about their accomplishment of the overall program objectives related to communication, teamwork, ethical, and multicultural awareness, and project management. The questionnaires provided a definition of each learning objective, and 10 statements assessing competencies under that domain, with responses on a 5-point scale. A series of hypotheses testing of results indicated that neither service learning projects nor reflection exercises appear to increase students' perceptions of their own performance.

Kranov et al.[25] focused on assessment of professional skills relating to ethical, global, economic, cultural/societal, and environmental issues through the use of an authentic performance task called curricular debrief. Up to eight randomly selected senior year students from each engineering discipline in Washington State University participated in the study. Students were presented with a discipline specific scenario which was meant to measure students' critical thinking skills as well as problem formulation and management expertise through debriefing transcripts, which subsequently were rated by assessment specialists and faculty raters. Due to the labor intensive nature of the assessment, not all the students were provided with an assessment of their learning.

One last recent study pertaining to assessment of a number of professional skills is by Kremer and colleagues[26-27]. In this work, the project team collected electronic portfolio-based data from engineering student subjects who were enrolled in two different courses, and at various stages of their education. A portfolio is a collection of work ("artifacts") that demonstrates certain competencies from which the student has selected a subset to demonstrate growth over time. The portfolio contains a reflection on each artifact as well as an overall reflection on the content of the portfolio [e.g., 28]. One of the most important advantages of portfolios is their potential to engage students in intentional learning, resulting in an increased ability in life-long learning[29-34].

The portfolios were created by students enrolled in a wide range of engineering disciplines to assess their development in effectiveness in teams as a professional skill. One-way analysis of variance studies (ANOVA) and post-hoc tests were utilized to examine differences between the engineering discipline and students' class standing (i.e., first-year to junior). Overall, the analysis indicated that the adopted e-portfolio approach along with rubrics based on Alexander's Model of Domain Learning was effective in assessing student development as captured in their e-portfolios. However, the assessment was time consuming despite the fact that only few skills were targeted in total.

Given the inadequacy of assessing professional skills individually, and the taxing nature of qualitative assessment of a bundle of them[e.g., 25], in this study we employ a quantitative approach to assess the students' perception of their attainment of professional skills and their relevant views on program emphases.

Methodology

As previously stated, this study employed the Prototype to Production (P2P)[35] surveys and extended the data collection to include Ireland. P2P is a three-year (2006-09), National Science Foundation-funded study, which assesses the alignment between undergraduate engineering program goals, curricula, and instruction and the goals of the National Academy of Engineering's recent report entitled, *The Engineer of 2020*: *Visions of Engineering in the New Century*. The "P2P" study investigates the educational experiences of undergraduates in two- and four-year colleges, examining how diverse students (women, low-income, and historically underrepresented students) experience their engineering programs and perceive the engineering profession.

The P2P study's original institutional population was defined as all four-year U.S. engineering schools where the six engineering disciplines (biomedical/ bioengineering, chemical, civil, electrical, industrial, and mechanical) accounted for 70 percent of all baccalaureate engineering degrees awarded in 2007. Because the P2P study was also designed to inform analyses of a closely related set of the six case studies from the P360 study (one of which offered only a baccalaureate-level general engineering program, Harvey Mudd College), the sample was also refined to include institutions offering a general engineering program. A 6x3x2 disproportional stratified random sample of institutions was drawn using the following strata: six discipline levels, three levels of highest degree offered (bachelor's, master's, or doctorate), and two levels of type of control (public or private). The sampling design ensured that the sample institutions are representative of the population with respect to type, mission, and highest degree offered.

The P2P research team completed a series of factor analyses to provide a more compact summary of the individual-item data. The research group adopted principal axes analysis and an Oblimin criterion with Kaiser Normalization rotation. To form a scale, the research teams used only items with rotated factor loadings greater than .40. However, because factors may be correlated, some items may load above .40 on multiple factors. In those cases, items were assigned to a factor based on the magnitude of the loading, the effect of keeping/discarding the item on the scale's reliability, and on professional judgment. Factor scale scores were formed by summing respondents' responses on the component items of a factor and then dividing by the number of items in the scale. Once scales were initially developed, Cronbach's *alpha* was used to evaluate their internal consistency reliability.

The analyses reported below are based on the responses of 5,249 students (a response rate of 16% overall) in 31 colleges of engineering during the 2009 spring and summer terms along with the Irish data. Weights were developed to adjust for response bias (at the campus level) and for differences in institutional response rates. The weighting adjustments produced a nationally representative sample of students with respect to sex, race/ethnicity, class year, and engineering discipline. Missing data were imputed using procedures recommended by Dempster et al.[36] and by Graham[37]. P2P staff imputed all missing data using the Expectation-Maximization (EM) algorithm of the Statistical Package for the Social Sciences (SPSS) software (v.18).

Consequently, the adjusted sample can be considered representative of the population of engineering students (as specified) both on each campus and nationally. During the data collection in Ireland, Dublin Institute of Technology was involved where 256 data points across all engineering disciplines were collected during Fall 2010.

Results and Discussion on Follow-Up Work

The collected data points from Ireland were compared against the P2P (E2020) data, which represent the situation in the US. In this paper, we reveal the data for three classroom experiences pertaining to topics emphasized in the curricula, professional skills and problem solving, and design skills development. In Table 1, below, we first show the comparison of the P2P data to the Irish set. In the table, mean, standard deviation as well as the significance of the differences across means are provided. As it can be observed in the following table, on the four distinct items, Irish data and the P2P data significantly differed, three of which are in the topics in engineering. While Irish students perceived that the ethical issues in the engineering practice are addressed better in their curriculum, the comparisons indicated that the US sample students perceive the inclusion of emerging engineering technologies and how theories are used in engineering practice to a higher extent.

Table 1. The Comparison of P2P and Irish Data on Selected Items (*p < .05 **p < .01 ***p < .001)

	Irish Group (N=256)		E2020 Group (N=5406)		Sig
	Mean	SD	Mean	SD	
TOPICS IN ENG					
Ethical issues in engineering practice.	3.00	.97	2.99	1.12	**
The importance of life-long learning.	3.54	1.04	3.67	1.02	
Examining my beliefs and values and how they affect my ethical decisions.	2.78	1.13	2.62	1.15	
The value of gender, racial/ethnic, or cultural diversity in engineering.	2.68	1.19	2.53	1.16	
Creativity and innovation.	3.72	.99	3.71	1.03	
Current workforce and economic trends (globalization, outsourcing, etc.).	3.21	1.10	3.15	1.10	
Emerging engineering technologies.	3.44	1.18	3.50	1.05	***
How theories are used in engineering practice.	3.63	.98	3.72	1.00	*
PROFESSIONAL SKILLS					
Professional skills (knowing codes and standards, being on time, meeting deadlines, etc.)	3.81	.90	3.59	1.12	**
Written and oral communication skills	3.70	.88	3.74	.92	
Leadership skills	3.36	1.02	3.32	1.09	
Working effectively in teams	3.91	.84	4.02	.89	
Project management skills (budgeting, monitoring progress, managing people, etc.)	3.34	1.06	3.32	1.06	
PROBLEM SOLVING					
Understanding how an engineering solution can be shaped by environ, cultural, econ, and other considerations	3.27	.99	3.00	1.08	
Understanding how non-engineering fields can help solve engineering problems	2.86	1.08	2.60	1.05	
Systems thinking	3.15	1.03	3.23	1.07	
Applying knowledge from other fields to solve an engineering problem	3.05	1.03	2.85	1.07	
Defining a design problem	3.65	.91	3.79	.93	
Generating and evaluating ideas about how to solve an engineering problem	3.70	.84	3.81	.89	

We have also opted to understand how the students' perception changed across the years based on the students' class standing. We reveal this information in Table 2 for the US data. As one can follow in the last column of the table, for all survey items we have found significant shifts across the years. Note also that despite its length we have opted to include Table 2 as it provides the scale items.

Table 2. A Comparison of Data Based on Class Standings

Curricular Emphases on...	E2020 Student Class Standing	N	Mean	Std. Dev.	Sig.
Topics in Engineering - Ethical issues in engineering practice.	Sophomore	1182	2.93	1.09	.000
	Junior	1856	2.79	1.17	
	Senior and Fifth-year or higher	2264	3.19	1.06	
	Total	5303	2.99	1.12	
Topics in Engineering - The importance of life-long learning.	Sophomore	1182	3.69	1.10	.010
	Junior	1856	3.61	.94	
	Senior and Fifth-year or higher	2264	3.71	1.03	
	Total	5303	3.67	1.02	
Topics in Engineering - Examining my beliefs and values and how they affect my ethical decisions.	Sophomore	1182	2.58	1.12	.000
	Junior	1856	2.44	1.12	
	Senior and Fifth-year or higher	2264	2.79	1.16	
	Total	5303	2.62	1.15	
Topics in Engineering - The value of gender, racial/ethnic, or cultural diversity in engineering.	Sophomore	1182	2.50	1.12	.000
	Junior	1856	2.40	1.16	
	Senior and Fifth-year or higher	2264	2.65	1.16	
	Total	5303	2.53	1.16	
Topics in Engineering - Creativity and innovation.	Sophomore	1182	3.81	1.05	.000
	Junior	1856	3.59	1.05	
	Senior and Fifth-year or higher	2264	3.76	.99	
	Total	5303	3.71	1.03	
Topics in Engineering - Current workforce and economic trends (globalization, outsourcing, etc.).	Sophomore	1182	3.20	1.15	.000
	Junior	1856	3.07	1.07	
	Senior and Fifth-year or higher	2264	3.20	1.09	
	Total	5303	3.15	1.10	
Topics in Engineering - Emerging engineering technologies.	Sophomore	1182	3.52	1.12	.016
	Junior	1856	3.44	1.04	
	Senior and Fifth-year or higher	2264	3.53	1.01	
	Total	5303	3.50	1.05	
Topics in Engineering - How theories are used in engineering practice.	Sophomore	1182	3.65	1.04	.000
	Junior	1856	3.58	1.04	
	Senior and Fifth-year or higher	2264	3.87	.93	
	Total	5303	3.72	1.00	
Professional Skills - Professional skills (knowing codes and standards, being on time, meeting deadlines, etc.)	Sophomore	1182	3.60	1.07	.000
	Junior	1856	3.34	1.27	
	Senior and Fifth-year or higher	2264	3.78	.97	
	Total	5303	3.59	1.12	

Table 2 (Continued). A Comparison of Data Based on Class Standings

Curricular Emphases on...	Class Standing	N	Mean	Std. Dev.	Sig.
Professional Skills - Written and oral communication skills	Sophomore	1182	3.55	1.00	.000
	Junior	1856	3.64	.84	
	Senior and Fifth-year or higher	2264	3.92	.90	
	Total	5303	3.74	.92	
Professional Skills - Leadership skills	Sophomore	1182	3.40	1.07	.000
	Junior	1856	3.11	1.17	
	Senior and Fifth-year or higher	2264	3.46	1.00	
	Total	5303	3.32	1.09	
Professional Skills - Working effectively in teams	Sophomore	1182	4.03	.96	.000
	Junior	1856	3.90	.85	
	Senior and Fifth-year or higher	2264	4.10	.88	
	Total	5303	4.02	.89	
Professional Skills - Project management skills (budgeting, monitoring progress, managing people, etc.)	Sophomore	1182	3.32	1.15	.000
	Junior	1856	3.21	.97	
	Senior and Fifth-year or higher	2264	3.41	1.07	
	Total	5303	3.32	1.06	
Problem Solving - Understanding how an engineering solution can be shaped by environ, cultural, econ, and other considerations	Sophomore	1182	3.04	1.02	.000
	Junior	1856	2.79	1.13	
	Senior and Fifth-year or higher	2264	3.15	1.03	
	Total	5303	3.00	1.08	
Problem Solving - Understanding how non-engineering fields can help solve engineering problems	Sophomore	1182	2.68	1.03	.000
	Junior	1856	2.46	1.06	
	Senior and Fifth-year or higher	2264	2.67	1.04	
	Total	5303	2.60	1.05	
Problem Solving - Systems thinking	Sophomore	1182	3.21	1.13	.000
	Junior	1856	3.13	1.06	
	Senior and Fifth-year or higher	2264	3.31	1.04	
	Total	5303	3.23	1.07	
Problem Solving - Applying knowledge from other fields to solve an engineering problem	Sophomore	1182	2.91	1.07	.000
	Junior	1856	2.72	1.11	
	Senior and Fifth-year or higher	2264	2.93	1.02	
	Total	5303	2.85	1.07	
Problem Solving - Defining a design problem	Sophomore	1182	3.59	1.03	.000
	Junior	1856	3.69	.89	
	Senior and Fifth-year or higher	2264	3.97	.87	
	Total	5303	3.79	.93	
Problem Solving - Generating and evaluating ideas about how to solve an engineering problem	Sophomore	1182	3.70	.99	.000
	Junior	1856	3.72	.86	
	Senior and Fifth-year or higher	2264	3.93	.85	
	Total	5303	3.81	.89	

Interestingly, however, similar shifts in the Irish data were not evident with the exception of the item: professional skills (knowing codes and standards, being on time, meeting deadlines, etc.). This requires further investigation to understand its cause. For example, it is possible that the way the engineering curriculum is structured at DIT allows for the above mentioned skills' development in students to be more rapid at the onset with little follow up increments across the years. Such a curriculum design might reflect the higher percentage of engineering courses in Ireland (also across Europe). Conversely, the progression of engineering curriculum upon a foundation of a general education curriculum may not support problem solving and design skills to be grasped at a higher level to start with. As a follow up on this issue, we will further analyze the curriculum programs and include a comparison of the courses across the years for a typical engineering program in the US, and its European equivalent – in this case, the engineering curriculum at DIT.

One other significant limitation of the work presented is that we have not investigated the contexts where professional skills attainment takes place across these educational settings. In an effort to determine the settings that provide a higher likelihood of success for our students to gain these skills efficiently and effectively and by diverse student populations, our follow up work will involve a qualitative study. Specifically, we will study students: 1) who are enrolled in minor programs that are designed to improve professional skills, and 2) who have sustained participation in co-curricular activities. A qualitative study is planned for this.

Overall, we consider our work to be preliminary in nature in terms of identifying differences across the national boundaries. First of all, as a comparison set we have only included one Irish school. Efforts are underway to expand the data set in Ireland to a larger number of schools. Further, although engineering education programs are fairly regulated in Europe, and hence, similar learning outcomes are aimed to be achieved, contextual factors might present differences in different national settings. Accordingly, our current comparison cannot be stretched to be meaningful at a U.S. and E.U. comparison scale, and thus, further data collection in other European countries is needed and planned.

Conclusions

In the paper, we have undertaken a quantitative comparison of student perceptions on program emphases on topics in engineering, professional skills, and problem solving and design skills, as experienced by students in their engineering curricula. Overall, while we find the average US data to be equivalent to the Irish set, we observe a few minor differences. An important point of note is that while a progression in attainment of these skills is evident in the US data, the Irish data do not reflect that, pointing to a potential curriculum structure difference.

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Bibliography

1. National Academy of Engineering. (2008). Grand Challenges for Engineering.
2. National Academy of Engineering. (2004). The Engineer of 2020: Visions of Engineering in the New Century. Washington, DC: The National Academies Press.
3. http://www.ed.psu.edu/educ/e2020/p2p
4. Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2010-2011 Accreditation Cycle, http://www.abet.org (10/31/2009).
5. Shuman, L. J., Besterfield-Sacre, M., McGourty, J. (2005). The ABET 'Professional Skills'—Can They Be Taught? Can they Be Assessed?, Journal of Engineering Education, 94, 41–55.
6. Lohmann, J. R., Rollins, H., Hoey, J.J. (2006). Defining, Developing and Assessing Global Competence in Engineers. European Journal of Engineering Education, 31, 119-131.
7. Beard, D., Schwieger, D., Surendran, K. (2008). Integrating Soft Skills Assessment through University, College, and Programmatic Efforts at an AACSB Accredited Institution. Journal of Information Systems Education, 19, 229.
8. Besterfield-Sacre, M., Shuman, L. J., Wolfe, H., Atman, C. J., McGourty, J., Miller, R. L., Olds, B. M., Rogers, G.M. (2000). Defining the Outcomes: A Framework for EC-2000. IEEE Transactions on Education, 43, 100-10.
9. Gerhart, A., Grunow, M. (2009). Leadership Models and Practices Course: Student Perceptions and Development of Leadership Skills and Incorporation of a New Leadership Course. ASEE Annual Conference, Austin, TX. AC 2009-766.
10. Skipper, C.O., Pe, M., Bell, L.C., Pe, F. (2006). Assessment with 360 Evaluations of Leadership Behavior in Construction Project Managers. Journal of Management in Engineering. 22, 75-80.
11. Cooper, T.H., Anderson, D.H. (1994). Assessing Students' Need for Skills in Communication and Teamwork. Journal of Natural Resources and Life Sciences Education, 23, 18-22.
12. Trenta, L.S., Marmaduke, P.E. (1988). The Leadership Assessment and Development Program. Journal of Staff Development, 9, 32-36.
13. Greenan, J.P. (1985). Generalizable Communications Skills Assessment. User Manual.
14. Boyd, G., and Hassett, M. F. (2000). Developing Critical Writing Skills in Engineering and Technology Students. Journal of Engineering Education, 89, 409-412 and 504-505.
15. Anewalt, K. (2005). Using Peer Review as a Vehicle for Communication Skill Development and Active Learning. Journal of Computing Sciences in Colleges, 21, 155.
16. Hackman, J.R. (1983). A Normative Model of Work Team Effectiveness. Office of Naval Research. Interim Report. A893631.
17. Hackman, J. R.. (1980). Work Redesign and Motivation. Professional Psychology, 11, 445-455.
18. Wageman, R., Hackman, J.R., Lehman, E. (2005). Team Diagnostic Survey: Development of an Instrument. The Journal of Applied Behavioral Science, 41, 373.
19. Shuman, L. J., Clark, R. M., Besterfield-Sacre, M., Yildirim, T.P. (2008). Work in Progress - Ethical Model Eliciting Activities (E-MEA) - Extending the Construct. 38th ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY, p. 2.
20. Sindelar, M., Shuman, L., Besterfield-Sacre, M., Miller, R., Mitcham, C., Olds, B., Pinkus, R.L., Wolfe, H. (2003). Assessing Engineering Students' Abilities to Resolve Ethical Dilemmas. 33rd ASEE/IEEE Frontiers in Education Conference, Session S2A, pp. 2-25.
21. Goldin, I. M., Ashley, K. D., Pinkus, R.L. (2006). Assessing Case Analyses in Bioengineering Ethics Education: Reliability and Training. 9th International Conference on Engineering Education, San Juan, PR. T4A/14-19.
22. Esparragoza, I.E., Friess, A. and Larrondo-Petrie, M. (2008). Developing Assessment Tools for International Experiences in Engineering Education. ASEE Annual Conference. Pittsburgh, PA.
23. Barak, M. and Doppelt, Y. (2000). Using Portfolios To Enhance Creative Thinking. Journal of Technology Studies, 26(2), 16-25.
24. Huyk, M., Bryant, K. and Ferguson, D. (2009). The Impact of Reflections in the Service Learning and Other Undergraduate Team Project Learning. Proceedings of the ASEE Annual Conference. AC 2009-1032.
25. King, P. M., Kitchener, K. S. (1994). Developing Reflective Judgment: Understanding and Promoting Intellectual Growth and Critical Thinking in Adolescents and Adults. Jossey-Bass Higher and Adult Education Series and Jossey-Bass Social and Behavioral Science Series: San Francisco, CA.

26. Kranov, A. A., Hauser, C., Olsen, R.G., Girardeau, L. (2008). A Direct Method for Teaching and Assessing Professional Skills in Engineering Programs. ASEE Global Colloquium on Engineering Education, Singapore. AC 2008-2384.
27. Masters, C., Yin, A., Okudan, G.E., Schuurman, M. (2009). Assessing Growth of Engineering Students Using E-Portfolios: A MDL-Based Approach. ASEE Annual Conference and Exposition, June 14-17, 2009, Austin, TX.
28. Schuurman, M., Okudan, G., Masters, C. and Hunter, S. Enhancing Design Learning by Implementing E-Portfolios, ASEE Annual Conference and Exposition, June 22-25 2008, Pittsburgh, PA.
29. Barrett, H. C. (2007). Researching Electronic Portfolios and Learner Engagement: The REFLECT Initiative. Journal of Adolescent and Adult Literacy, 50(6).
30. Abrami, P.C., Barrett H. (2005). Directions for Research and Development on Electronic Portfolios. Canadian Journal of Learning and Technology, 31(3).
31. Bereiter, C., Scardamalia, M. (1989). Intentional Learning as a Goal of Instruction. In L. B. Resnick (Ed.), Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser, 361-392. Hillsdale, NJ: Lawrence Erlbaum Associates.
32. Fenwick, T.J., Parsons, J. (1999). A Note on Using Portfolios to Assess Learning. Canadian Social Studies, 33(3), 90–92.
33. Foote, C.J. and Vermette, P.J. (2001). Teaching Portfolio 101: Implementing the Teaching Portfolio in Introductory Courses. Journal of Instructional Psychology, 28(1), 31–37.
34. Hillyer, J. and Lye, T. C. (1996). Portfolios and Second Graders' Self-assessment of their Development as Writers. Reading Improvement, 33(3), 148-159.
35. Prototype to Production. http://www.ed.psu.edu/educ/e2020.
36. Dempster, A. P., Laird, N. M. and Rubin, D. B. (1977). Maximum Likelihood from Incomplete Data via the EM Algorithm. Journal of the Royal Statistical Society. Series A. General, 39(1), 1.
37. Graham, J. W. (2009). Missing Data Analysis: Making it Work in the Real World. Annual Review of Psychology, 60(1), 549-576. doi: doi:10.1146/annurev.psych.58.110405.085530.