AC 2009-1276: ASSESSING GROWTH OF ENGINEERING STUDENTS USING E-PORTFOLIOS: A MDL-BASED APPROACH

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Abstract

Overall premise of the work presented is to study the potential of e-portfolios as a viable mechanism for student reflection and assessment of growth on attributes that are part of becoming a World Class Engineer. These attributes relate to becoming: 1) Aware of the World, 2) Solidly Grounded, 3) Technically Broad, 4) Innovative, 5) Effective in Team Operations, and 6) Effective in Leadership Positions.

Our project team has collected data from engineering student subjects who were enrolled in two different courses, and at various stages of their education. These portfolios were created by students intending to major in a wide range of engineering disciplines. One-way ANOVAs and post-hoc tests were utilized to examine differences between the engineering discipline and students' class standing (i.e., first-year students, sophomores, juniors, and seniors). Overall, our analysis indicates that our rubrics based on Alexander's Model of Domain Learning (MDL) [2-4] are effective in assessing student development as captured in their e-portfolios.

Introduction and Background

E-portfolio development is a pedagogical tool that is promising as a means for promoting active learning. Portfolios are based on constructivist theory, which supports the principles of student-centered instruction and encourages instructional practice that fosters active learner involvement. Although portfolios have only recently become popular across academic disciplines, the fields of Arts and Education have used this practice to showcase students' work for some time. Consistent with the recent interest in the use of portfolios, in ABET criterion 3, portfolios are mentioned as one way to document and assess student outcomes [1].

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 (see for example reference 6).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 [7-12]. Portfolios are expected to have a positive effect on attitudinal, motivational, affective, and professional outcomes [13.] These may include increased self-confidence, increased awareness of professional identity, more positive attitudes toward profession, improved career-decision self-efficacy, and increased ability to build a network of professionals. DiBiase[13] described many other potential benefits of e-portfolios including an increased learning effectiveness for students, the opportunity for faculty to leverage student motivation and align objectives and evaluation strategies, and the opportunity for a university to respond to calls for greater accountability and outcomes-based accreditation. While students gather evidence of their own learning, ideally they will go through the steps described in previous work by Francis, Malder, and Stark[5], starting with questioning and organizing, and ending with adapting.

E-portfolio construction contributes to students' development and internalization of active learning processes. Because these processes are needed to support life-long learning, portfolios have the potential to contribute to professional development well beyond the college years. With the current generation of students being greatly influenced by information technology [14] —reflected in, for example, an overwhelming interest in Facebook [15], and the ease with which e-portfolios can be shared among various constituents as compared to paper portfolios, e-portfolios offer students a great learning opportunity that can guide them in becoming engaged learners. In this study we wanted to leverage these advantages and use e-portfolios as a formative assessment technique that would simultaneously promote student learning and allow for the on-going assessment of a set of student outcomes our College intends for our graduates.

The Accreditation Board for Engineering and Technology (ABET) expects institutions to have detailed student learning objectives in place that are consistent with the institutions' mission and with ABET's criteria [16]. With the assistance of an external board made up of a broad cross section of industry leaders, The Pennsylvania State (Penn State) University's College of Engineering has developed a set of attributes that address the inclusion of the new demands for professional skills[17]. Along these same lines, the Penn State College of Engineering strategic plan includes the mission to prepare students to become World Class Engineers (WCE) who are Aware of the World, Solidly Grounded in Fundamentals of their chosen engineering discipline, Technically Broad with respect to their knowledge in various engineering disciplines, Innovative, Effective in Teams, and Successful as Leaders.

Our research team evaluated e-portfolios for evidence that students are developing on selected WCE attributes, namely Solidly Grounded and Effective in Teams. We chose these two WCE attributes, because they were most applicable to the courses in which e-portfolios were required. We could not assess all six attributes because of time constraints.

As part of developing an assessment tool for the e-portfolio content, we have established three criteria. First, in order for the assessment tools to be sensitive to the development of professional engineers, these tools must evaluate the attributes that comprise the World Class engineers. Second, the tools must be grounded in a recognized model of development. Third, because the intent is for e-portfolios to be used over time, the assessment techniques must be able to detect change. To meet these three criteria, we developed an assessment technique that synthesized a model of domain learning with the attributes of the World Class Engineer.

Rubric Development

Alexander's Model of Domain Learning (MDL) [2] was used as the theoretical framework that structured and guided evaluation of these three attributes. In MDL, students develop through the three stages of acclimation, competency, and, finally, proficiency (Table 1).

Within each stage, a developmental shift is seen along three dimensions: knowledge, strategic processing, and interest. Alexander proposed in her model that all three dimensions interact to influence learning in a particular academic domain. Over time, for example, reliance on domain-general strategies gives way to more powerful domain-specific strategies; interest shifts from situational to topic; and powerful, principle-driven domain knowledge supports learning and problem solving. In MDL, evidence of development is obtained when students show shifts along the three dimensions toward expertise. Accordingly, MDL lends itself to longitudinal measurement because it was developed to describe change over time. Thus, it has been chosen as our theoretical framework while several such frameworks exist (e.g., Five-Stage Model of Adult Skill Acquisition[18]).

Table 1: Alexander's (1997, 2003) Model of Domain Learning

Levels of Expertise	**Characteristic**		
	Knowledge	**Interest**	**Strategic Processing**
Acclimation	Low domain knowledge. May have high knowledge in certain topics.	Interest is more situational than personal.	More likely to depend on surface features to learn.
Competence	Knowledge becomes more organized around abstract concepts.	Situational interest is likely to be the motivation to learn as personal interest develops.	Surface-level process strategies are less likely utilized as deep-level processing strategies become more developed (i.e., forward reaching transfer).
Proficiency/ Expert	Highly-organized knowledge structure, where person is well-versed in evaluating the validity and merit of new knowledge in the field.	Personal interest drives the person to become a problem finder in the field.	Mainly uses deep-level strategic processing.

We developed assessment rubrics grounded in both the World Class Engineer and the MDL by setting these frameworks against one another in a single matrix. Specifically, for each of the dimensions of the MDL (domain knowledge, strategies and interests) we developed a matrix with progressive rows that correspond to each of the MDL expertise stages. This matrix can be used to assess each of the World Class Engineer attributes. In our study, each portfolio entry was read to identify evidence related to two World Class Engineer attributes. This evidence was examined to assess the learners' developmental stage based on the rubrics. Specifically, we looked at each relevant segment to locate evidence of students' strategic processing, interest, and domain and topic knowledge. For each of these dimensions, we evaluated this evidence according to Alexander's description of development within each stage (Table 1). The label for the identified stage was entered into the cell that corresponds to both the dimension and the attribute. Thus, for example, a student who showed emerging domain-specific strategies for learning about teamwork would be identified as falling within the competency stage for the strategies used to become Effective in Teams. Patterns of change over time should reveal the emerging expertise of participating students.

Data Collection and Methods

Our project team has collected data from engineering student subjects who were enrolled in two different courses, and at various stages of their education. The first course, first year Introduction to Engineering Design (EDSGN 100), is mandatory for most engineering majors. The second course, sophomore level strength of materials (E MCH 213), while required by slightly fewer majors, is taken by a majority of engineering students at Penn State. The data collection was executed in two different stages: 1) the pilot run, and 2) the comprehensive run. For the pilot run, an e-portfolio template was prepared, and implemented in two EDSGN 100 class sections during the Spring 2007 semester. Implementation difficulties were noted, and the e-portfolio template was accordingly improved. Our experience and accomplishments were reported in reference 19. The comprehensive run implemented an e-portfolio assignment in 6 sections of EMCH 213. In addition, a set of guidelines for students was prepared to allow for students to complete their e-portfolios in a way conducive for growth detection over time. This data collection was completed during the Spring 2008 semester.

Evidence displayed in an e-portfolio for each WCE attribute was evaluated on the following three components: knowledge, strategies, and interest [2-4]. Points were awarded depending on whether the evidence met the requirements of a certain level (A = acclimation, C = competence, P = proficiency). See Table 2 below for the rubrics.

Knowledge, strategies, and interest were evaluated for each of the two WCE attributes. Students received separate scores for each of three different settings for the evidence described; from their course (EMCH 213), from other classes, and from activities outside of class. Since the assignment was to provide at least one piece of evidence for each of the assigned WCE attributes, we then took the maximum value for knowledge, strategies, and interest for each of the two WCE attributes. This resulted in eighteen scores for each student; three settings (their course, other classes, outside activities), three dimensions (knowledge, strategy and interest), and two WCE attributes (Solid Grounded and Effective in Teams). Using a one-way ANOVA and post-hoc tests (Dunett T3), comparisons were made between engineering disciplines and students' class standing on each of the WCE attributes.

Results

Students were evaluated on their knowledge, strategies, and interest for each attribute utilizing the e-portfolio rubrics developed. The data was analyzed with regard to the student's intended or declared major. A majority of the students in the study were pursuing Architectural, Civil, or Mechanical Engineering degrees. Due to the low number of participating students in the each of the remaining majors, these were collapsed into an "other engineering/discipline" (Table 3). Upon review of Table 3, mechanical engineering students appear to have demonstrated a higher level of proficiency (i.e., higher mean scores) in their knowledge, strategies, and interest for both the Solidly Grounded and effective in teams attributes as compared to the architectural and civil engineering students.

Table 2: Rubrics for assessment of MDL dimensions

Knowledge:		
Level	**Pts. Awarded**	**Description**
A	0	Student does not have an understanding of the characteristic, e.g., does not mention any of the attributes related to the characteristic.
A	1	Provides a good understanding of the characteristic or provides evidence/artifact(s) that suggest a good understanding of the characteristic.
A	2	Provides evidence/artifact(s) and a good understanding of the characteristic but does not connect the two together.
C	3	Articulates the understanding of the characteristic with the provided evidence/artifact(s). Student provides an explanation of how the evidence/artifact(s) demonstrates their mastery of the characteristic. (Note: this can be done in a finer detail, on how well the explanation aligns with the evidence/artifacts).
P	4	Shows the same characteristics as the previous level. Students also articulate their strengths and weaknesses in the characteristic and the implications to them as engineering students. For example, what specific courses will they take to increase knowledge, clubs joined, work experience.
Strategies:		
Level	**Pts. Awarded**	**Description**
A	0	Student does not mention strategies on learning/ obtaining the characteristic.
A	1	Student mentions strategies on learning/ obtaining the characteristic
C	2	Student mentions and explains how the strategies allowed them to accomplish or hinder their ability to learn/ obtain characteristic.
C	3	Same as the level above and student explains how his/her strategies can be improved or provides alternative strategy (-ies) to learning/ obtaining characteristic.
P	4	Same as the level above, but student explains how the new/modified strategy (-ies) may improve the mastery of the characteristic in the future.
Interest:		
Level	**Pts. Awarded**	**Description**
A	0	Student does not appear to be interested in the characteristic at a personal level (e.g., sees no relevance of material learned in the classroom to his/her future as an engineer).
C	2	Student appears causally interested in the material and begins to see some minor connections to the characteristic.
P	4	Student understands the relevance and appears to have shown interest in learning the characteristic at a personal level. For example, I know the importance of learning the laws of thermodynamics as a future engineer in HVAC systems.

A= Acclimation, C=Competence, P=Proficiency.

The one-way ANOVA for all the attributes (Table 4) provides evidence that the disciplines only significantly differ at an alpha of .05 with respect to the knowledge dimension of the WCE attributes. Dunnett T3 post-hoc test (results not shown) shows that architectural engineering students had significantly lower knowledge of the WCE attributes than the "other" engineering disciplines.

Table 3: Engineering Discipline Means for Combined Solidly Grounded and Effective in Teams Attributes

Major	n	Knowledge	Strategies	Interest
Architectural Engineering	67	2.17	1.82	2.13
Civil Engineering	63	2.33	1.97	2.11
Mechanical Engineering	65	2.39	2.11	2.27
Other Engineering/Discipline *	47	2.42	1.89	2.07
Total	**242**	**2.32**	**1.95**	**2.15**

* Other engineering includes agricultural and biological engineering, aerospace engineering, bioengineering, chemical engineering, electrical engineering, engineering science, engineering, industrial engineering, kinesiology, nuclear engineering, and petroleum and natural gas engineering

Table 4: ANOVA Table for Discipline and Attributes

		Sum of Squares	df	Mean Square	F	Sig.
Knowledge	Between Groups	2.230	3	.743	3.432	.018*
	Within Groups	50.468	233	.217		
	Total	52.698	236			
Strategies	Between Groups	2.963	3	.988	2.326	.075
	Within Groups	98.929	233	.425		
	Total	101.892	236			
Interest	Between Groups	1.319	3	.440	1.809	.146
	Within Groups	56.614	233	.243		
	Total	57.932	236			

* Significant at an alpha of .05 or less.

Table 5 provides the mean scores of Solidly Grounded and Effective in Teams (the two WCE attributes) by engineering discipline. From Table 5, the mechanical engineering students appear to demonstrate a higher level of proficiency (i.e., higher mean scores) in their knowledge, strategies, and interest for both the Solidly Grounded and Effective in Teams attributes than the architectural and civil engineering students. The one-way ANOVA on each dimension of each of the two attributes (Table 6 provides evidence that the disciplines only significantly differ at an alpha of .05 on the knowledge of the attribute of Solidly Grounded (p-value = .003 – see grey highlight in Table 6). Dunnett T3 post-hoc test (results not shown) shows that architectural engineering students had a significantly smaller Solidly Grounded score than the other engineering disciplines.

Table 5: Engineering Discipline Means for Solidly Grounded and Effective in Teams Attributes

Major	n	Solidly Grounded Knowledge	Solidly Grounded Strategies	Solidly Grounded Interest	Effective in Teams Knowledge	Effective in Teams Strategies	Effective in Teams Interest
Architectural Engineering	67	2.13	1.73	2.21	2.18	1.88	2.06
Civil Engineering	63	2.38	1.95	2.22	2.27	2.02	2.00
Mechanical Engineering	65	2.42	2.02	2.37	2.35	2.19	2.13
Other Engineering Discipline*	47	2.51	1.87	2.28	2.38	1.94	1.92
Total	**242**	**2.35**	**1.89**	**2.27**	**2.29**	**2.01**	**2.03**

* Other engineering includes agricultural and biological engineering, aerospace engineering, bioengineering, chemical engineering, electrical engineering, engineering science, engineering, industrial engineering, kinesiology, nuclear engineering, and petroleum and natural gas engineering

Table 6: ANOVA Table for Discipline and Attributes

		Sum of Squares	df	Mean Square	F	Sig.
Solidly Grounded Knowledge	Between Groups	4.665	3	1.555	4.734	.003*
	Within Groups	78.177	238	.328		
	Total	82.843	241			
Solidly Grounded Strategies	Between Groups	2.967	3	.989	2.174	.092
	Within Groups	108.240	238	.455		
	Total	111.207	241			
Solidly Grounded Interest	Between Groups	1.035	3	.345	.649	.584
	Within Groups	126.506	238	.532		
	Total	127.541	241			
Effective in Teams Knowledge	Between Groups	1.424	3	.475	1.664	.176
	Within Groups	67.903	238	.285		
	Total	69.326	241			
Effective in Teams Strategies	Between Groups	3.428	3	1.143	1.576	.196
	Within Groups	172.556	238	.725		
	Total	175.983	241			
Effective in Teams Interest	Between Groups	1.324	3	.441	1.682	.171
	Within Groups	62.412	238	.262		
	Total	63.736	241			

* Significant at an alpha of .01

Table 7 provides the mean scores of Solidly Grounded and Effective in Teams by students' semester standing. The results of the one-way ANOVA on both attributes (Table 8) provide evidence that students did not differ significantly based on their semester standing. However, these results highlight a limitation in the design, as the majority of the students in the study were in their fifth semester at the institution (67%).

Figure 1 provides a plot of the attribute means by students' semester standings, which does provide insight on possible trends. For example, students' Solidly Grounded knowledge and interest appears to increase in proficiency as their semester standing increases, while their strategies (i.e., their ability to learn new material) appears to decrease. For the Effective in Teams attribute, students' proficiency appears to increase in their knowledge and strategies for this skill as they progress through their college education. Students' interest though remains relatively constant.

Table 7: Semester Standing Means for Solidly Grounded and Effective in Teams Attributes

Semester Standing	n	Solidly Grounded Knowledge	Solidly Grounded Strategies	Solidly Grounded Interest	Effective in Teams Knowledge	Effective in Teams Strategies	Effective in Teams Interest
3	1	3.00	3.00	4.00	3.00	3.00	2.00
4	13	2.46	2.00	2.00	2.31	1.85	2.15
5	164	2.30	1.87	2.27	2.28	2.01	2.05
6	35	2.34	2.03	2.23	2.32	2.03	2.00
7	21	2.52	1.67	2.33	2.18	1.86	1.91
8	6	2.67	2.17	2.33	2.50	2.50	2.00
GR	2	2.50	1.50	3.00	2.00	2.50	2.00
Total	**242**	**2.35**	**1.89**	**2.27**	**2.29**	**2.01**	**2.03**

Table 8: ANOVA Table for Discipline and Attributes

		Sum of Squares	df	Mean Square	F	Sig.
Solidly Grounded Knowledge	Between Groups	2.248	5	.450	1.314	.259
	Within Groups	80.048	234	.342		
	Total	82.296	239			
Solidly Grounded Strategies	Between Groups	3.613	5	.723	1.584	.165
	Within Groups	106.782	234	.456		
	Total	110.396	239			
Solidly Grounded Interest	Between Groups	4.096	5	.819	1.593	.163
	Within Groups	120.367	234	.514		
	Total	124.463	239			
Effective in Teams Knowledge	Between Groups	1.082	5	.216	.744	.591
	Within Groups	68.081	234	.291		
	Total	69.162	239			
Effective in Teams Strategies	Between Groups	3.248	5	.650	.885	.492
	Within Groups	171.748	234	.734		
	Total	174.996	239			
Effective in Teams Interest	Between Groups	.613	5	.123	.455	.810
	Within Groups	63.120	234	.270		
	Total	63.733	239			

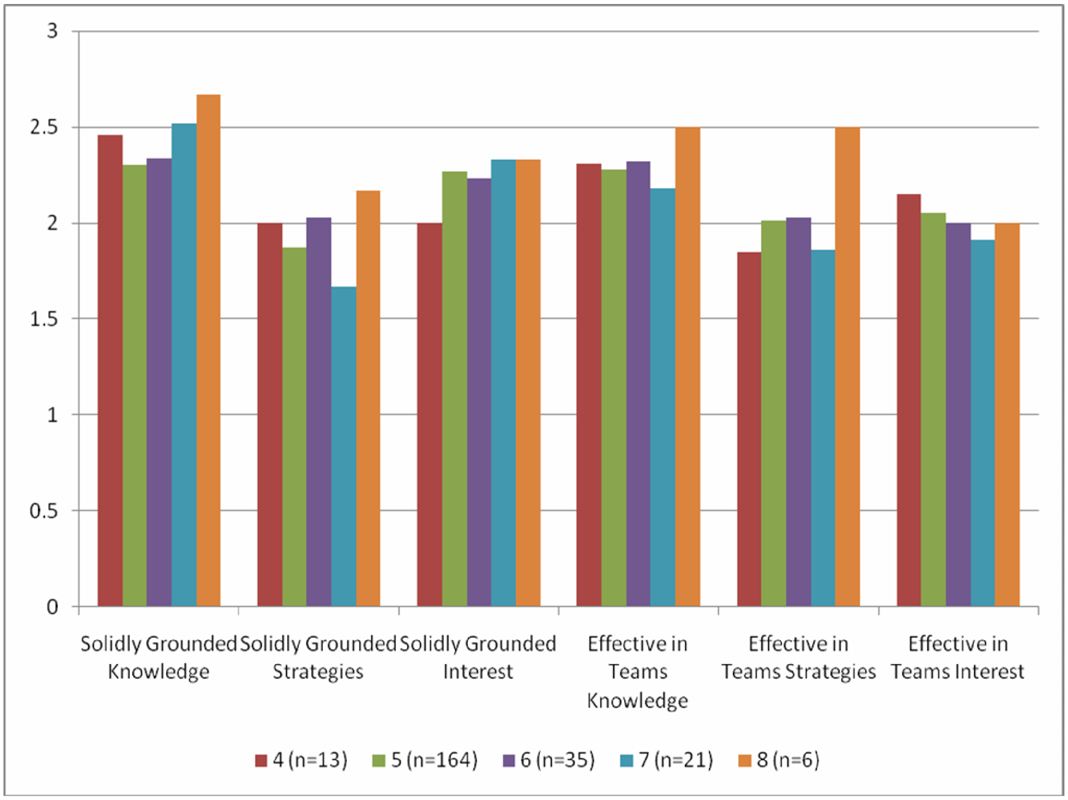

Figure 1: Plots of the Attribute Means by Students' Semester Standing

Conclusions

Overall, our analysis indicates that our proposed adoption of MDL and relevant implementation to collect evidence of learning and development on selected World Class Engineer attributes has merit. Using the developed assessment rubrics, we are able to easily assess current level of learning and detect differences over time. For the reported results, the assessments were completed by a graduate student. For future use, we would like to make the assessment rubrics available to students so that students not only benefit from actively organizing and demonstrating their learning as captured in e-portfolios, but would also be able to self-assess their development over time.

References

1. ABET (2007). *Criteria for Accrediting Engineering Programs*. http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2007-08%20EAC%20Criteria%2011-15-06.pdf, retrieved September 10, 2007.
2. Alexander, P. A., Jetton, T. L. and Kulikowich, J. M. (1995). Interrelationship of Knowledge, Interest, and Recall: Assessing a Model of Domain Learning. *Journal of Educational Psychology*, 87, 559-575.
3. Alexander, P. A. (1997). Mapping the Multidimensional Nature of Domain Learning: The Interplay of Cognitive, Motivational, and Strategic Forces. *Advances in Motivation and Achievement*. M. L. Maehr and P. R. Pintrich. Greenwich, CT, JAI Press. 10, 213-250.

4. Alexander, P. A. (2003). The Development of Expertise: The Journey from Acclimation to Proficiency. *Educational Researcher* 32(8), 10-14.
5. Francis, M. C., Mulder, T. and Stark, J. S. (1995). Intentional Learning: A Process of Learning to Learn in the Accounting Curriculum. Sarasota, Fl: Accounting Education Change Commission and the American Accounting Association. http://aaahq.org/aecc/intent/cover.htm , retrieved March 2009.
6. Barrett, H. C. (2006) Researching Electronic Portfolios and Learner Engagement: The REFLECT Initiative. *Journal of Adolescent and Adult Literacy*. (in press) Retrieved 8 August, 2006, from http://electronicportfolios.com/portfolios.html#pubs.
7. Abrami, P.C. and Barrett H. (2005). Directions for Research and Development on Electronic Portfolios. *Canadian Journal of Learning and Technology*, 31, 3. Retrieved August 8, 2006, from http://www.cjlt.ca/content/vol31.3/abrami.html.
8. Bereiter, C. and 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.
9. Fenwick, T.J. and Parsons, J. (1999). A Note on Using Portfolios to Assess Learning. *Canadian Social Studies*, 33(3), 90–92.
10. 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.
11. Hillyer, J. and Lye, T. C. (1996). Portfolios and Second Graders' Self-assessment of their Development as Writers. *Reading Improvement*, 133, 148-159
12. Wade, A. and Abrami, P.C. (2005). An Electronic Portfolio for Learning. *Canadian Journal of Learning and Technology*, this issue. Retrieved August 9, 2006, from http://www.cjlt.ca/content/vol31.3/wade.html
13. DiBiase, D. (2002). Using e-Portfolios at Penn State to Enhance Student Learning, https://www.e-education.psu.edu/files/e-port_report.pdf, retrieved March 2009.
14. Oblinger, D. (2003). Boomers, Gen-Xers, and Millennials. Understanding the New Students. *Educause Review*,July/August, 37 - 47. Retrieved March 2009 from http://www.educause.edu/ir/library/pdf/ERM0342.pdf.
15. Rover, D. T. (2006). The Academic Bookself: Closing the Distance. *Journal of Engineering Education*, 95, 2, 175-176.
16. National Academy of Engineering. (2004). The Engineer of 2020: Visions of Engineering in the New Century. Retrieved August 8, 2006, from http://www.nap.edu/catalog/10999.html
17. Leonhard Center for the Enhancement of Engineering Education. (2008). Retrieved March 2009 from http://www.engr.psu.edu/ProspectiveStudents/.
18. Dreyfus, S.E. (2004). The Five-Stage Model of Adult Skill Acquisition, Bulletin of Science Technology Society, 24, 177.
19. Schuurman, M. Masters, C., Van Meter, P. and Okudan, G.E. (2008) Enhancing Design Learning By Implementing Electronic Portfolios, ASEE Annual Conference and Exposition, June 22-25 2008, Pittsburgh, PA.

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