The Impacts of Project Based Learning on Self-Directed Learning and Professional Skill Attainment

A Comparison of Project Based Learning to Traditional Engineering Education

Bart Johnson
Itasca Community College
Grand Rapids, Minnesota, U.S.
bart.johnson@itascacc.edu

Crystal Smith
Itasca Community College
Grand Rapids, Minnesota, U.S.
Crystal.Smith@itascacc.edu

Ron Ulseth
Iron Range Engineering
Virginia, Minnesota, U.S.
Ron.Ulseth@ire.mnscu.edu

Derek Fox
Itasca Community College
Grand Rapids, Minnesota, U.S.
Derek.Fox@itascacc.edu

***Abstract*— Based upon a successful implementation of an upper-division project based learning (PBL) curriculum, an integrated first/second year PBL experience was designed and implemented. The integrated courses were physics 1, statics, design, and professionalism. The curriculum has been delivered from 2012 to 2015. This work in progress paper describes the design process, the trajectory of the program as it continuously improved, data collection methods, and initial results. Two of the members of this research team were members of the team that adapted the Aalborg (Denmark) model of PBL to an upper division 100% PBL curriculum. The model evolved into an ABET accredited program that is based on the solution of complex industry problems for the last four semesters of a bachelors degree. The results were used as the basis for the design of this lower division PBL program. The lower division program evolved from 2012 to 2015. Upon conclusion of the lower division experience, survey instruments were administered to students. Tools specific to self-directed learning and professional development were employed. The instruments are the Motivated Strategies for Learning Questionnaire (MSLQ) and professional development and professional expectations instruments designed by the authors of this paper.**

Keywords*— *Self-Directed Learning, Evaluation, Project Based Learning, Professional Skills and Abilities

I. Introduction

In recent years Project Based Learning (PBL) has continued to emerge as a pedagogical model in engineering education [1]. PBL implementations exist on a continuum from one course in a traditional engineering program to fully integrated PBL curricula [2]. One of the motivations to implement PBL is an increased development of professional outcomes by student participants [3].

For over a decade, there have been numerous calls for a transformation in engineering education [4,5,6,7,8]. In response to these calls, a Midwestern community college and a Midwestern university collaborated to develop a two-year, upper-division, completely integrated PBL model of engineering education [9]. The program has 75 graduates to date and has earned ABET-EAC accreditation. The community college developers of this upper-division program adapted the curricular model used in the 3rd/4th year PBL curriculum into a portion of the 1st/2nd year engineering education at the community college. This paper analyzes the adaptation/implementation and provides initial results of the impact this PBL engineering program has had on the student attainment of professional outcomes in comparison to students in traditional engineering programs.

II. Background

In 2009, a new upper-division only undergraduate project based learning (PBL) engineering program was developed and implemented as an adaptation of the Aalborg model [10]. The developers of this PBL model sought to address the alignment gap between the outcomes desired for engineering graduates and those attained by graduates of traditional engineering programs [9]. It was designed to address the three interrelated domains of professional, technical, and design competence [11]. Design projects became the central theme upon which design learning, technical learning, and professional learning took place [12].

Each semester, these upper-division students select engineering projects from industry clients. Working on teams, with a faculty mentor as a guide, students complete the design process from an initial scoping to final deliverable. They acquire skills in engineering design, practice ideation, manage resources, and produce products. Integral to the design is the acquisition of technical knowledge required to complete the design. Faculty members scaffold the self-directed learning skills students will need upon graduation to independently acquire the technical competence they will need as practicing engineers [11]. The third domain of professionalism is highly integrated into the design work. Specifically targeted are written communication, verbal communication, project management, entrepreneurialism, lifelong learning, professional responsibility, personal marketing, and inclusivity [12]. Students, working with faculty, characterize

978-1-4799-8454-1/15/$31.00 ©2015 IEEE

their initial competence level in each area on a scale from deficient to exemplary [12].

In 1967, Carl Rogers, a highly regarded psychologist, wrote "The only man who is educated is the man who has learned how to learn" [13]. Acquiring this skill is an outcome of an engineering education, arguably one of the most important. The recruiter for the PBL bachelors program previously described often engages potential students with this commentary:

"I'd like you to visualize your first day of work after graduation. Let me tell you two things that are not going to happen on that day… two things your new boss isn't going to say. First, he won't say "*Greetings John, welcome to ABC Engineering, we are glad you are here. I would like to introduce you to Dr. Jill, we have hired her to be your professor. When you need to learn something new, Dr. Jill will be here to teach it to you*." The second thing he is not going to say is *"Here are some text books. Each week, your job is to do the problems at the end of each chapter. If you get them correct, we will issue you a paycheck. At the end of each month we will give you some written exams. Your performance on the written exams will determine the amount of your bonus."*

This story resonates with the students. To this point in their engineering education, nearly all of their learning has been one-directional from an instructor and nearly all of their performance has been through the completion of closed-ended chapter problems and written exams. They know this is what they neither expect nor want as the duties in their profession and they struggle with this misalignment of activities during college with expectations after college.

Lifelong learning, self-directed learning, continuous professional learning, self-regulated learning, and being metacognitive are all terms used, often interchangeably, to address the outcome expected of new graduates. A summary is that new engineering graduates are expected to be able to acquire new knowledge efficiently and effectively and be able to use it to solve complex, ill-defined, problems quite different than those at the end of a chapter in a textbook.

Originally developed in the 1990's by a team led by Pintrich [14] the Motivated Strategies for Learning Questionnaire (MSLQ) is an 81 item survey that addresses both motivation (intrinsic & extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning & performance, and test anxiety) and learning strategies (rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time/study environmental management, effort regulation, peer learning, and help seeking). Pintrich's group completed reliability and validation testing at the time of the MSLQ's development. The MSLQ was originally developed for addressing course specific motivations and learning strategies [14]. It was modified by removing course specific questions and reducing it down to 44 questions. Rotgans and Schmidt showed the modified MSLQ to be reliable and validated for general curricular use [15]. The MSLQ has four relevant subscales. They are self-efficacy, intrinsic motivation, cognitive strategy use, and self-regulation.

A pair of 2005 studies by Shuman [16] and Loui [17] focused on the ineffectiveness of the traditional lecture format for teaching the ABET professional skills and argued that a modern engineering education should focus on active and cooperative learning approaches. The Loui study identified that students primarily learn about professionalism from relatives and co-workers who are engineers and rarely from their technical courses and proposed that engineering education should have a focus of "socializing students to become professional engineers".

A promising approach for developing the professional competencies is a curricular focus on professional identity formation. Ibarra and Barbulescu [18] identified professional identity as an important factor in the student adaption to the workplace. Sheppard, et. al. [5] describes professional identity in terms of standards of the professional community, "to serve the public with specialized knowledge and skills through commitment to the field's public purposes and ethical standards'. Eliot and Turns [19] define it as the "personal identification with the duties, responsibilities, and knowledge associated with a professional role"; developed through a social process where students are connecting expectations with their own needs, wants, and attitude.

Thorton and Nardi [20] proposed that professional role identification is a four-stage developmental process where individuals go from having idealized perceptions of the professional role to a more personalized role aligned with their own values and goals: 1) Anticipatory Stage: Individuals start with a highly idealized understanding of the role of the professional, which is often incomplete; 2) Formal Stage: Individuals undergo a formal learning experience with the purpose of learning the duties, responsibilities, and knowledge for a professional role; 3) Informal Stage: Individual encounters the unofficial or informal expectations associated with the professional role which that may align or contradict the formal expectations; and 4) Personal Stage: Individual begins internalizing the professional role expectation and attempts to align or adapt it with their values and goals.

The development of the PBL model in this study focused on creating for students their professional identify as engineers with the purpose for their acquiring professional competencies. In the development process, three core curricular foci emerged: 1) the recognition of the social nature of engineering education and the importance of students developing their professional identity as an engineer; 2) the importance for the learning to be embedded in professional practice [21]; 3) the potential a PBL curriculum has to support the first two foci [1]. This model is reflected in Figure 1.

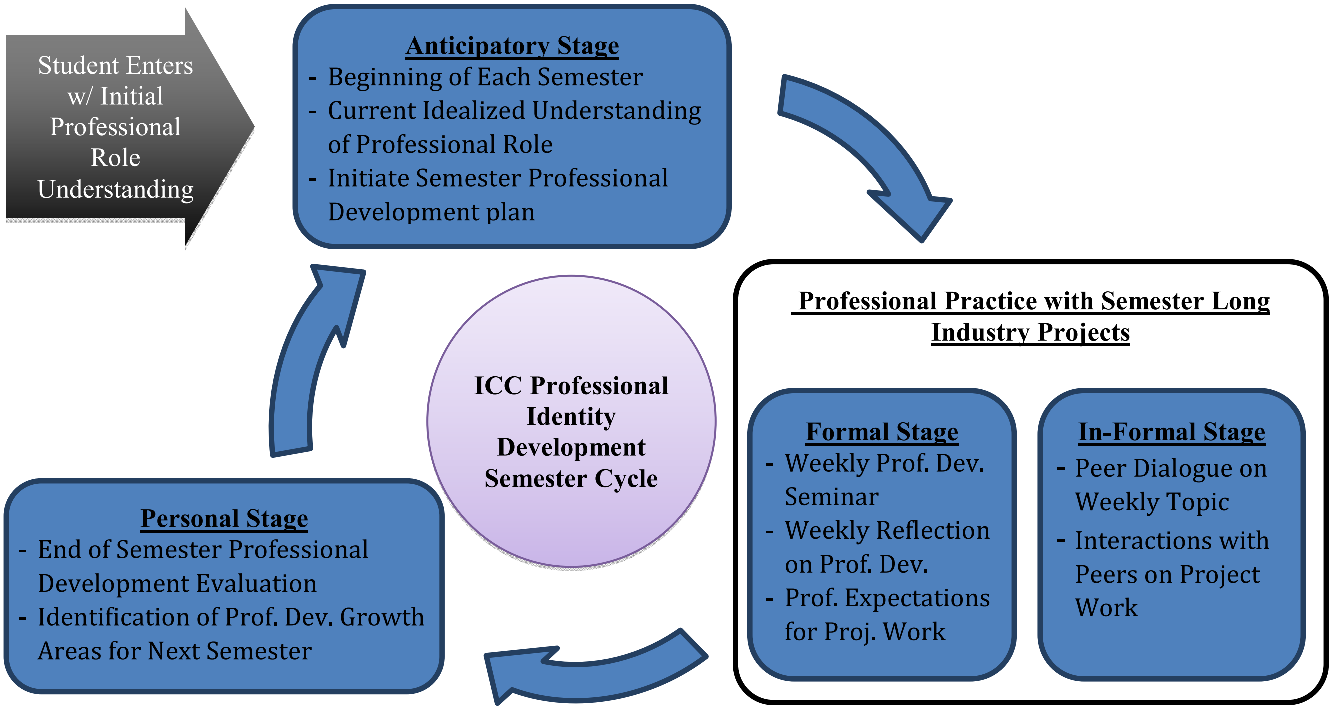

Figure 1. PBL Professional Identity Development Semester Cycle

Currently there are limited well-established resources for assessing student attainment of professional skills [16]. As part of the quantitative study, two instruments were developed to evaluate the professional growth of students in the PBL model as compared to students studying in a more traditional model.

The first, **Individual Professional Development Instrument,** focuses on the professional abilities of the individual. It is 1-5 Likert-scale survey tool, based on the ABET student outcomes [22], that evaluates a set of 19 professional expectations. Students self-identify the importance they place on a professional development topic and their current level of performance.

The second, **Team Professional Development Instrument,** identifies students' beliefs on the importance of professional development and their current performance level within the context of functioning as a member of a team. It is a 1-5 Likert-scale survey tool based upon the TIDEE professional development work of Denny Davis and Steve Beyerlien [23]. Results for both instruments are discussed in section V.

III. Development of the Project Based Learning (PBL) Engineering Education Model

As the successes of the upper division PBL program began to emerge, so did the belief that many of the successes could also be achieved in lower division. The first adaptation came from the perspective that engineering education flows through the integration of the three domains of design learning, technical learning, and professional learning. For nearly ten years, the community college program had focused on these three domains. It was done through the separate instruction of technical knowledge in traditional courses and in a combined engineering professionalism and design course for each of the 4 semesters of lower division. This separation however, did not promote the use of technical knowledge in design, nor the integration of all three as being the *act of engineering*. Further, there was a sense across all instructors that students lacked the ability to transfer technical knowledge from any one learning experience into another.

PBL as a pedagogy provided the opportunity to gain this integration and transfer, while the successes in the upper-division program were indicating these outcomes were possible.

The model implementation built off of the existing 4-semester design sequence [21]. Students start the fall in a cohort with a six-credit design focused introduction to engineering and engineering graphics course pairing. In the first year of implementation, spring 2012, a group of ~30 students selected in the spring of their freshman year to participate in a nine-credit PBL pairing of engineering physics 1, static mechanics, and a second engineering and professional development course. This "PBL Cohort" met daily to develop the course outcomes for students in engineering physics 1 and static mechanics. This learning took place in the context of students developing these outcomes to support their projects. Professional development was an integral component of the experience. Each week a professional development topic was introduced with the expectation for students to reflect and internalize the skill associated with the topic. The experience followed the model displayed in figure 1. At the core of this experience was the creation of the professional identity of each student. These students moved on in their sophomore year to have an engineering and professional development course each semester. The difference being that students took engineering courses related to their intended engineering discipline and there was not the intentional integrating of the student technical learning with their design and professional learning.

In the second year of development, the spring sophomore semester PBL model was expanded to include all students who met the math prerequisites to be in engineering physics 1. In the second year, there was in increased emphasis of the weekly cycle of professional development dialogue described in figure 1. Since then, the program has adopted this model for all students in the spring of their sophomore year and continues to further develop each semester.

IV. Methods

This in-progress study looks specifically at how students in the lower division project based learning environment develop compared to students in a more traditional program. There are two student groups in this comparative study:

1. **PBL Completers**: Community college students just having completed their second year of engineering including one semester of the PBL program described in this paper as part of the four-semester course sequence. All students who completed the PBL program were asked to complete the instruments. There are three subgroups in the PBL completers, those who participated in the semester PBL program in the springs of 2012, 2013, and 2014. The 2015 group will be evaluated at the end of their sophomore year in the spring of 2016.
2. **Traditional University Student:** University students just having completed their second year of engineering without any PBL experience. A group of students at a Midwestern university were contacted through their professors and asked to complete the instruments.

MSLQ data and the professional development instruments results were analyzed using a two-tailed t-test with $p<0.05$.

V. Results

The greater research question for the implementation of this PBL curriculum is "How do PBL students experience the development of these professional and learning skills?" By comparing PBL students to traditional students, the differences of the experiences can be highlighted. Further qualitative studies can then be designed and implemented to characterize the PBL development experience.

The MSLQ areas studied in this research are self-efficacy, intrinsic value, cognitive strategies, and self-regulation. Students answer on Likert 7-point scale from 1-not at all true of me to 7-very true of me. Table 1 details the results of this comparison study.

TABLE I. MSLQ Results

	PBL (n=73)	Comparison (n=80)	t-test (p<0.05)
Self-Efficacy	5.63	4.93	4.53
Intrinsic Value	6.05	5.75	2.34
Cognitive Strategy Use	4.97	4.81	1.26
Self-Regulation	4.79	4.69	0.84

The self-efficacy score relates to both the students' perceptions that they can master a task and their confidence in doing so [14]. The higher the score, the higher the self-efficacy. Intrinsic value relates to the level to which the student is participating in the learning for personal mastery, challenge, and curiosity. Cognitive strategy use scores the levels students use rehearsal, elaboration, and organization. Self-regulation refers to the levels to which students continually monitor and refine their learning strategies [14].

The results would indicate that the PBL experience significantly increases the self-efficacy of engineering students, as well as the intrinsic goal orientation of their learning. While cognitive strategy use and self-regulation are less impacted. Further qualititative study will be designed to determine which aspects of the student experiences led to the marked differences in self-efficacy and intrinsic value and to further investigate impacts on cognitive strategy and self-regulation.

Given these results, it would be expected to see a higher reported professional importance and performance of professional skills for the students who experienced the PBL experience versus the control group. However, there are no areas in the 31 items of the two instruments where the PBL students combined from all subgroups self-reported higher than the control group. An evaluation of each sub group itself compared to the control group shows similar results with no items of higher reporting for the 2012 and 2014 groups.

An evaluation of the 2013 subgroup shows six items of higher self-reporting than the control group. Five items of higher importance for the individual professional development are:

1. Speak professionally, free of vulgarities and with appropriate grammar
2. Meet the needs of your team by completing work on time and of high-quality
3. Give proactive feedback to others
4. Continually seek to improve yourself
5. Act safely while completing all tasks

One item of higher performance for the team professional development:

Developing shared vision & plans; empowering to achieve individual & mutual goals

Further qualitative study will be designed to determine why the 2013 group only has the items of higher self-reported results.

VI. Acknowlegments

This work was supported by NSF DUE 106023.

References

[1] T. Litzinger, L. Lattuca, R. Hadgraft, and W. Newstetter. Engineering Education and the Development of Expertise, Journal of Engineering Education, Vol. 100, No. 1, 2011.

[2] G. Heitmann. Project-oriented study and project-organized curricula: A brief review of intentions and solutions. European Journal of Engineering Education 21, 2, 121-131, 1996.

[3] Felder, R. M., and Brent, R. Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. Journal of Engineering Education., 92(1):7-25, 2003.

[4] D. G. Beanland and R. Hadgraft, UNESCO Report: Engineering education. Melbourne: RMIT University Press, 2013.

[5] S. Sheppard, K. Macatangay, A. Colby, and W. Sullivan. Educating Engineers. San Francisco, CA: Jossey-Bass, 2009.

[6] National Academy of Engineering, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, Washington, DC: The National Academies Press, 2005.

[7] National Science Board, Moving Forward to Improve Engineering Education (NSB-07-122), Arlington, VA: National Science Foundation, 2007.

[8] National Research Council, The Engineer of 2020: Visions of Engineering in the New Century, Washington, DC: The National Academies Press, 2004.

[9] R. R. Ulseth, J. E. Froyd, T. A. Litzinger, D. Ewert, and B. M. Johnson. A new model of education in engineering: project based learning. In ASEE Annual Conference & Exposition, Vancouver, BC, Canada, 2011.

[10] A. Kolmos, and F. K. Fink The Aalborg PBL model: progress, diversity and challenges. Aalborg: Aalborg University Press, 2004.

[11] R. Ulseth, and B. Johnson. Self-Directed Learning Development in PBL. In International Research Symposium for PBL, San Sebastian, Spain, July 2015.

[12] B. Johnson, and R. Ulseth. Professional Competency Development in PBL. In International Research Symposium for PBL, San Sebastian, Spain, July 2015.

[13] H. Kirschenbaum and V. Land Henderson. The Carl Rogers Reader. New York: Houghton Mifflin, 1989

[14] P. R. Pintrich, D. A. F. Smith, T. Garcia, and W. J. McKeachie, "Reliability and predictive validity of the Motivated Strategies for Learning Questions (MSLQ)." Educational and Psychological Measurement, 53, pp. 801–813, 1993.

[15] J. Rotgans, and H. Schmidt. The Motivated Strategies for Learning Questionnaire: A Measure for Students' General Motivational Beliefs and Learning Strategies. *The Asia-Pacific Education Researcher*, 19(2). 2010.

[16] L. J. Shuman, M. Besterfield-Sacre, & J. McGourty. The ABET "Professional Skills" – Can They Be Taught? Can They Be Assessed?. (2005). *Journal of Engineering Education, 94(1),*41-55

[17] M. C. Loui. Ethics and the Development of Professional Identities of Engineering Students. *Journal of Engineering Education*, 94: 383–390. (2005).

[18] H. Ibarra & R. Barbulsescu. Identity as narrative: Prevalence, effectiveness, and consequences of narrative identify work in macro work role transitions. *Academy for Management Review, 35(1),* 135-154. 2010.

[19] M. Eliot and J. Turns. Constructing Professional Portfolios: Sense-Making and Professional Identity Development for Engineering Undergraduates. Journal of Engineering Education, 100(4): 630-654. 2011.

[20] R. Thornton & P. M. Nardi. The dynamics of role acquisition. American Journal of Sociology, 870-885. 1975

[21] R. Ulseth and B. Johnson. 100% PBL Curriculum: Startup Phase Complete. Frontiers in Education Conference, Madrid, Spain, October 22-25, 2014.

[22] H. J. Passow. Which ABET Comptencies Do Engineering Graduates Find Most Important in their Work? Journal of Engineering Education, 101(1):95-118. 2012.

[23] S. Beyerlein, D. Davis, and Mike Trevisan. "Workshop—Using IDEALS to demonstrate development of professional skills in project courses." Frontiers in Education Conference (FIE), IEEE, 2011.