ACTIVE ASSESSMENT IN ENGINEERING DESIGN

USING A SYSTEMS APPROACH

By

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of KELLEY ANN RACICOT find it satisfactory and recommend that it be accepted.

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Abstract

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A major challenge for faculty is how to develop a "culture of evidence" in the classroom that supports student-centered formative learning and aligns with program and accreditation goals. Another challenge is the development of assessment tools that lighten, rather than add to, faculty workload. In this study, a systems approach is used for gathering evidence centered on the development of group artifacts. Specifically, online project management (PM) and knowledge management (KM) resources are purposefully developed by students at the intersection of working, learning, and assessment. The KM and PM archives are assessed using a multi-method approach, with three criteria in mind: 1) ease of implementation, 2) real-time documentation of improvements, and 3) alignment of course assessments with program and institutional goals.

A wiki is used for documenting social knowledge in the context of an industrially-based capstone design course and for assessing group learning. Students create a course wiki for the explicit purposes of sharing lessons learned with wider audiences and engaging in *active group assessment*, where students actively develop the product to be assessed. Because students are encouraged to verbalize in their own words concepts learned in class, the KM wiki reinforces learning and serves as a formative assessment

tool, or perception check, for students and professors. Similarly, Basecamp, a web-based PM tool, is used by students to manage the day-to-day tasks and communication required to produce a deliverable on time that meets customer needs. This quantitative and qualitative study involved collecting feedback from key stakeholders, including professional skills evaluations, focus group interviews, student ownership surveys, temperament surveys and mid-term feedback. A difference approach was used to analyze industry partner perceptions of actual and expected performance. An average improvement score, based on a rubric, was obtained that maximizes reliability for small, variable groups like advisory boards.

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Dedication

This thesis is dedicated to my *boys*

CHAPTER ONE

INTRODUCTION

Across education disciplines, and particularly in engineering education research, a substantial body of literature points to the need for the development and dissemination of authentic project- and team-based learning environments as well as innovative methods of assessing team- and group-skills that do not easily lend themselves to traditional methods of evaluation, such as testing and grading. In the following series of published papers, an ongoing study is described that aims to answer specific research questions regarding the development and implementation of social software tools in a senior capstone design engineering course with this broad directive in mind. The focus, processes, results, and next steps for implementing social software platforms and a systems approach for demonstrating success in a hands-on, team-based design curriculum is presented.

In the Fall of 2005, the Industrial Design Clinic in the School of Mechanical and Materials Engineering at Washington State University was in the market for new technology. The loss of social learning in project- and team-based engineering courses from semester to semester was dramatic. Professors and instructors were typically the mechanism by which social and group knowledge was transferred from one group of students to the next. Online media, such as html-programmed web pages, proved to be difficult to maintain and were chronically out-of-date. This problem, similarly described by information theorists[1], was exacerbated by a rapid decrease in the half-life of knowledge, which has been shown to manifest itself in an increasingly information-rich and dynamic engineering workplace, which is what the Design Clinic is modeled on. This is not surprising, even in this limited context. Some estimate that in high-tech fields, such as science and engineering, society is approaching a time when half of

what undergraduate students learn will be obsolete before they graduate, perhaps even from year to year[2].

There was a need to seek solutions to this problem. In the case of the Industrial Design Clinic, the clinic turned to social software. Social software is now readily available that makes it easier for people to share and manage short-term and long-term knowledge. Wikipedia[3], for example, was launched in 2001, and is an online encyclopedia where anyone, anywhere in the world, can add to and modify the content. In 2005 at the start of this study, there were approximately 700,000 wiki articles in English. In July 2007, there are 1,862,700 articles, with nearly five million registered users[4]. The WSU Center for Teaching, Learning, and Technology launched a wiki during the Fall of 2005, which provided a unique opportunity for the Design Clinic to leverage social technology for long-term knowledge management (KM). Similarly, easy-to-use web-based project management (PM) software, a product called Basecamp launched in 2003 by company 37 Signals[5], appeared to be a simple and affordable solution for short-term, day-to-day project management for the Industrial Design Clinic.

One of the primary goals of the Design Clinic is to model contemporary practice. Engineering in a global context is increasingly multidisciplinary and paperless, with a focus on Product Lifecycle Management (PLM)[6], or the process of managing the entire lifecycle of a product from specification writing, through design and manufacture, to use and disposal. In the Design Clinic, students work on real-world industrial projects, with real budgets, and are expected to deliver the specified product on time. KM and PM tools appeared to hold promise for moving the Design Clinic to a paperless process, accelerate product time-to-market, and leverage social knowledge for the benefit of the larger group in a PLM framework. The KM and PM electronic archives also held the potential—in addition to functioning as technical

repositories— to serve as formative and summative evidence of students' social learning and professional skills, as communication, teamwork, and lessons learned are tracked over time.

The majority of KM and PM platforms are developed for societal and industrial applications. Performance is supported and documented, not based on a collection of work by an individual, but on the contribution of many individuals toward a common outcome. In education, where the traditional emphasis remains on grading individual performance, based on a collection of individual assignments, these tools challenge us to think differently about group assessment of group artifacts. Similarly in education research, where rigorousness for many decades has been defined by variable isolation, uniform treatments, control groups, and the accuracy, reliability, validity, and repeatability of measures, these tools challenge us to think differently about the assessment of social networks, dynamic and connected knowledge, and group learning in education environments. That is, there is a need in education research to understand components of systems in education in relationship to, and not isolated from, other components of the system. From information technology to neural networks, a systems approaches based on modeling, simulation, pattern recognition and ecosystem evolution— in addition to the scientific method— have helped researchers to bridge the local and global contexts of their work[7].

At the core of the systems approach presented in this thesis, is the development of a direct, more rigorous, measure of social skills using a professional skills rubric and expert evaluation of group artifacts. Additionally, related assessments are used to triangulate this data in order to surface patterns and new ideas that don't necessarily emerge from the core assessment alone, but inform the results. These assessments are designed to reduce, rather than add to, faculty and student workload. The assessment tools are subject to a benefit/cost analysis in the

process, and are not used primarily for judging and evaluation, but are designed to meet student, faculty, program, and industry needs at the intersection of working, learning, and assessment. Finally, the implications for professional skills assessment in the global engineering context are discussed, as the Design Clinic is in the process of expanding global partnerships.

1.1 A Mixed Method Systems Approach

The conceptual framework of this study is a systems, or "ecosystem" perspective, where the components of complex learning environments are considered as a whole, comprised of interconnected parts (see Chapter Three for a detailed review of systems epistemology). A mixed method research plan was employed in this framework to both look directly and with depth at one aspect of learning in a team- and project-based engineering design course—namely professional (social) skills development using a direct, quantitative evaluation method—as well as to assess the quality of related social, material, and technical aspects of this course-level assessment process using qualitative methods.

Using mixed methods in education research has advantages and liabilities. Attention must be given to a host of trade-offs[8] in order that validity is maximized, not only for each method in isolation, but for stated relationships, results, and conclusions across methods as well. The methods used in this research study are designed and implemented in order that subordinate methods have a direct connection to a core methodology and that the results and conclusions are strengthened by increasing the breadth of the evidence base. The core method developed and employed in this study is the use of a Professional Skills rubric by Industry Partners to evaluate student-authored group artifacts in the context of a senior engineering design course. In complement to this quantitative approach, qualitative data was gathered using focus group interviews, surveys and questionnaires aimed to answer specific questions related to both the

tools and processes associated with the development of the group artifacts being evaluated and the dimensions of the professional skills rubric used to assess the quality of student work.

1.2 The Role of the Researcher

The greatest challenge in defining the researcher's role using mixed methods was to determine what degree of participation with Design Clinic stakeholders would yield the most meaningful data. According to Corrine Glesne[9], there are two primary roles a researcher should consider: researcher's role as researcher and researcher's role as learner. That is, a researcher is to varying degrees both an analyst and a reflective practitioner. In the context of the Design Clinic, it was important that I attend to both aspects of my role as a researcher, as understanding and operationalizing the start-up and implementation of novel assessment tools and processes was as important as the professional skills assessment results themselves to improving the Design Clinic. In order to fulfill these roles, I volunteered to become a member of the Design Clinic community, rather than collect data as an outside observer. Several factors contributed to my decision to participate as a community member to the greatest extent possible on the participant-observer continuum.

First, the cultural underpinnings of the Design Clinic, based on trust, respect, and learner-centered philosophies, lend themselves to multiple stakeholder participation. Students already engage with a variety of people during the course of completing their projects both inside and outside of the university, and my participation, according to Design Clinic managers, would be viewed as another resource, rather than as a liability. Second, I hold a bachelor's degree in mechanical engineering, which made it easier for me to function as a member of the community, as I was equipped to understand and interact with participants regarding the technical aspects of engineering design, as well as the social aspects, which were the focus of this study. Finally, the

theoretical framework of my study, and choice of multiple methods, led me to consider a participant role. First-hand experience with the relationships and interactions of participants, and participants and the technology and assessment tools they used, not only adds to the evidence base connecting the results from multiple methods, but lends itself to the development of contextually-relevant conclusions and recommendations for future work. That is, it was important in this study, as researcher-learner, that the Design Clinic benefit directly from the research project, and, as researcher-researcher, that the results contribute in a small way to answering big questions in education research.

My adopted role in this study was the equivalent of a graduate teaching assistant, even though participation was unpaid and voluntary. The role included:

- Teaching/facilitating in the Design Clinic
- Collaborating with faculty to develop the professional skills rubric based on course, program, institutional and industry outcomes
- Collecting qualitative and quantitative feedback from students and Industry Sponsors
- Sharing assessment results with students, faculty, Industry Partners, and the engineering education community.

I facilitated the Design Clinic class for one hour of a three-hour block, twice per week in two sections for four semesters. During this time, students worked on developing KM and PM resources, as well as project-related activities. Additionally, I participated in all of the data-collecting sessions in this study, except for student ownership surveys and mid-term feedback, which, although introduced by the researcher, were anonymous and collected by a student volunteer. Student feedback was gathered during regular class time.

Industrial Partner feedback was gathered by appointment and during regularly scheduled campus visits, in a nearby conference room, office, or computer lab. I was the primary interviewer, sometimes accompanied by a back-up note taker from Washington State University's Center for Teaching, Learning, and Technology. The protocol included an introduction to the Professional Skills Rubric and group artifacts. Participants, once oriented, were provided individual, private space to review and score student work. I was available to answer questions at all times. I also facilitated and recorded the follow-up focus group discussion.

1.3 Guiding Research Questions

Chapter Two covers what was learned during the first two pilot semesters of this study. The guiding question during the pilot phase was: How is team or group learning in project-based engineering courses assessed using social software and expert feedback from Industrial Partners? Lessons learned from start-up and the results of Industry Partner assessments are discussed. Chapter Three builds on the work of the previous chapter by describing in more detail the research epistemology and industrial trends that comprise the backdrop of this study, as well as assessment results using additional data collection methods, a larger number of participants, and a longitudinal perspective. The guiding question for Chapter Three is: Building on what was learned during the first two pilot semesters, how are professional skills assessments using group artifacts and a systems approach explained, improved, and operationalized for use at the course, program, and university-industry partnership levels? Chapter Four, in conclusion, explores what aspects of the guiding questions are informed by this study, and areas of further research, particularly professional skills assessment in the context of global engineering projects.

1.4 Attribution

Kelley Racicot is the first author of Chapters Two and Three, based on peer-reviewed work previously published in the 2006 and 2007 conference proceedings of the American Society of Engineering Education. A version of Chapter Three is currently under review by the ASEE Journal, *Advances in Engineering Education*.

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CHAPTER TWO

ASSESSING GROUP LEARNING USING WIKIS: AN APPLICATION TO CAPSTONE DESIGN

In this chapter, the use of a wiki for documenting social knowledge in the context of an industrially-based capstone design course and for assessing group learning is presented. Students create a knowledge management (KM) tool for the explicit purposes of sharing lessons learned with wider audiences and engaging in *active group assessment*, where students actively develop the product to be assessed. Because students are encouraged to verbalize in their own words concepts learned in class, the wiki reinforces learning and serves as a formative assessment tool, or perception check, for students and professors. This case analysis involved collecting feedback from key stakeholders, including Advisory Board and Industrial Sponsor interviews, student focus group discussions and assessment surveys. In addition, the wiki itself serves as a summative assessment tool. A difference approach was used to analyze rater perceptions of actual and expected performance. An average improvement score, based on a rubric, was obtained that maximizes reliability for small, variable groups like advisory boards.

2.1 Introduction

New, creative uses of web-based group platforms, such as wikis and weblogs in industry and education, have been adopted for project management, to support "folio thinking"[1], to encourage reflective practice and to build communities of practice. This qualitative and quantitative study looks at the pilot semester of using social software in a well-established senior capstone design course to support collaborative knowledge management and group assessment. The guiding question for this project was: How is team or group learning in project-based engineering courses assessed? From this research question, three project goals were developed:

1. Leverage the group-editing capabilities of WSU Wiki to facilitate a new course dimension: collaborative knowledge management.
2. Pilot the use of social software as a tool for assessing group learning and performance.
3. Collect feedback from students, College Advisory Board members and Industrial Project Sponsors in order to assess student performance and meta-level project efficacy.

2.1.1 Background: The Capstone Industrial Design Clinic

Team-oriented student design[3] has been part of this ABET-certified mechanical engineering program for many years. In its current form in the School of Mechanical and Materials Engineering at Washington State University, for the past 10 years, student groups work on revenue-sponsored engineering projects ($60-$80,000 annually) for industry partners. The projects are completed in one semester. Students are responsible for every aspect of project management, from scoping to production, including budget, travel, and business communication.

Clinic sustainability is achieved through a philosophy that the clinic director calls "the circle of treats," whereby every stakeholder invested in the program gets something of value from it. It is within this decision-making framework that the wiki project was launched. Students potentially benefit from learning important knowledge management skills and engaging in untapped peer-learning opportunities. Industry stakeholders and faculty potentially benefit from a new assessment approach and improved team performance.

In order to fulfill the project goals, the social software WSU Wiki [14] was adopted for use in the class. WSU Wiki is a site for WSU students, faculty, staff and alumni to collaboratively develop hyper-linked documents for the purpose of growing communities of practice across courses, programs, and disciplines. WSU Wiki appeared to be a practicable and exciting tool to launch our project.

WSU Wiki was put into production fall 2005 at Washington State University by WSU's Center for Teaching, Learning and Technology. It uses the same open-source software, MediaWiki, that powers online encyclopedia Wikipedia[12]. The wiki is organized into individual "article" pages, each of which is put into one or more category. Category pages automatically index articles within that category. Every article page has a discussion page "behind" it for discussion and feedback. Article pages also have history pages with an archived list of contributors and versions. Users can search their contributions across articles and versions can be compared using the *dif* function.

WSU Wiki uses an editor that functions much like a word processor, but requires "wiki markup" language for formatting. For example, "*" creates a bulleted item or "==" creates a new section. Users can also create User Pages, which are publicly viewable but can only be edited by the user. This function was not employed in the pilot project, but holds great promise for assessing individual performance and group performance in the same environment.

In addition to WSU Wiki, which was used solely for Knowledge Management (KM) in the class, the commercial Project Management (PM) software application, Basecamp, was also utilized. Basecamp is a commercially available web-based project management system that provides basic PM functions such as calendaring, messaging, and grouping and is relatively inexpensive. Basecamp is used to manage the day-to-day project activities, such as creating to-do lists, scheduling activities, and monitoring project milestones. All students, corporate sponsors, staff and faculty upload their contact information and photos. The entire project history is archived at the end of each semester.

The Industrial Design Clinic serves other purposes besides giving students an opportunity to master engineering design. Engineering graduates are increasingly expected to have the social

and “soft skills” necessary to be successful on the job. While the clinic provided real opportunities for students to learn social skills during their practicum, they had few opportunities to share their experiences with each other, future participants, or the public. A course website was difficult to maintain, chronically out-of-date and ultimately abandoned.

The wiki is intended to give the Industrial Design Clinic an archival memory of social information that is independent of the instructor. Such a contribution is extremely valuable in the Capstone Design context, as students that take the class one semester typically graduate at the end and the sum of their personal experiences is lost. Student participants craft narratives in their own words about academic topics and personal experiences. Short activity prompts are used as scaffolding, after which the students assume control of the structure and nature of their wiki contributions.

During the Fall 2005 semester, 25 students in two sections spent one hour per week, for eight weeks, on the wiki project. Interview and survey data was collected from three College of Mechanical and Materials Engineering Advisory Board members and three Industrial Project Sponsors during campus visits. Focus group data was collected from design students. Student artifacts and usages are available online[14].

2.2 Literature Review

One of the project goals was to develop tools for assessing group learning. This has historically been a difficult task. The term “group assessment” is defined loosely in the literature. Our study looks to both organizational studies as well as education research for the definition. The “ecosystem” perspective in business is at the forefront of organizational studies[10]. Managers place a high value on social and “soft skills,” as well as content-specific knowledge.

They are interested in group learning and the social construction of knowledge[2,5,10]. If a business goes belly-up, for example, it is generally regarded as a failure of the group, not an individual.

Educators, because of the individual nature of the grading system and implicit reward structure in academic culture, focus on individual performance to the extreme. This has led to a dearth of research on group learning that is based on group performance criteria. Many studies have focused on the positive effects of group work on individual performance and the sum of individuals' artifacts to support program evaluation[8]. The lack of assessment tools for group learning has hampered the adoption of progressive group-based pedagogies.

One of the strengths of using social software to support group assessment is that its architecture is extremely flexible and diffuse. Wikis provide an easy way for non-technical users to publish writing, links, images, etc., to the World Wide Web using a web browser. Looking at Wikipedia, for example, authors collectively contribute and maintain articles that are multi-disciplinary and freely hyperlinked. Wikis have been used successfully in engineering classrooms as a design tools[13] and to support reflective learning activities[1].

Portfolios for teaching, learning, assessment, and evaluation are being widely researched and put into practice. Reflective artifacts based on individual learning outcomes and performance criteria underpin the "folio thinking" concept[1]. Relatively unpracticed is a strategy rooted in *Quality Management* (QM)[9], whereby formative and summative group assessments, supported by group artifacts, are reviewed by multiple stakeholders— students, faculty, administrators and practitioners from business and industry.

In the group assessment framework, group criteria are explicit and individual criteria are implicit. Potential benefits include: (1) students focus on the "good of the group," rather than grading, pleasing the instructor, or superficial aspects of individual assessment criteria (2)

program faculty have evidence to support their answer to the question: How do you show that your program is doing a better job?

2.3 Methods

The democratic architecture of wikis holds great potential for collaborative learning, but presents challenges during start-up. There is a learning curve associated with wiki mark-up, editing and linking pages, and organizing articles into categories. Students introduced to the wiki by creating a course page that included short start-up activities, help information and announcements. This page evolved into an index of student articles that are both course-related and searchable in the greater wiki landscape. For example, the Conference Calls article page is linked to the Design Clinic main page. It is also indexed in the Social Skills category, which is not course-specific.

The wiki uniquely supports both face-to-face and distance (online) collaboration for any size group. Students and the instructor spent 15-20 minutes each one-hour class period discussing weekly progress and new topics. A consensus process was used to decide what new topics would be posted the following week and to delegate tasks. Students spent the remaining time on task. Most of the students worked in small groups of 2-3 per computer and occasionally by themselves.

Students were encouraged to post articles of interest. Instructors also prompted discussions on topics relevant to the course, such as writing case studies, providing Strength, Improvement, Insight[11] (SII) feedback to peers, and interviewing for a job. The job interview discussion, for example, happened during a week of on-campus interviews and two groups contributed to an article on the topic that week.

2.3.1 Instruments

Three instruments were used to collect data: (1) Industry/Advisory Board survey, questionnaire and interview; (2) student focus group discussion; and (3) an online wiki archive. These instruments were selected based on best-practice methodologies in education assessment[8] and best fit for the scope of the study.

Three College Advisory Board members and three Industrial Partners were invited to review the wiki project and provide feedback. A six-point Likert-type scale was used to separately rate student performance and expected performance of first-year engineers in seven performance areas (Appendix A). The raters were then asked to provide SII feedback for the wiki project. The seven dimensions are based on existing course outcomes, plus new project and knowledge management dimensions. Space was provided for additional comments related to each dimension and 15 minutes were allotted for discussion following the rating session.

A second data set was obtained by interviewing 18 design students in two focus groups. The focus group discussions were conducted in the design lab classroom by the first author during regular class time. Focus Group questions are listed in Appendix B. The question pool was based on the need to understand what was learned, what worked, what didn't and how to improve the program.

Wiki artifacts include 23 article pages written by 25 design students. Appendix C shows a table summarizing major category and article pages.

2.4 Results

2.4.1 Student Ownership

Instructor versus student contributions were tracked on the main page in order to assess how effective our scaffolding was in moving students to "own" the project (Figure 1.1). Ten

individuals and one instructor edited the Index Page. By mid-semester students assumed responsibility for the online management of the wiki.

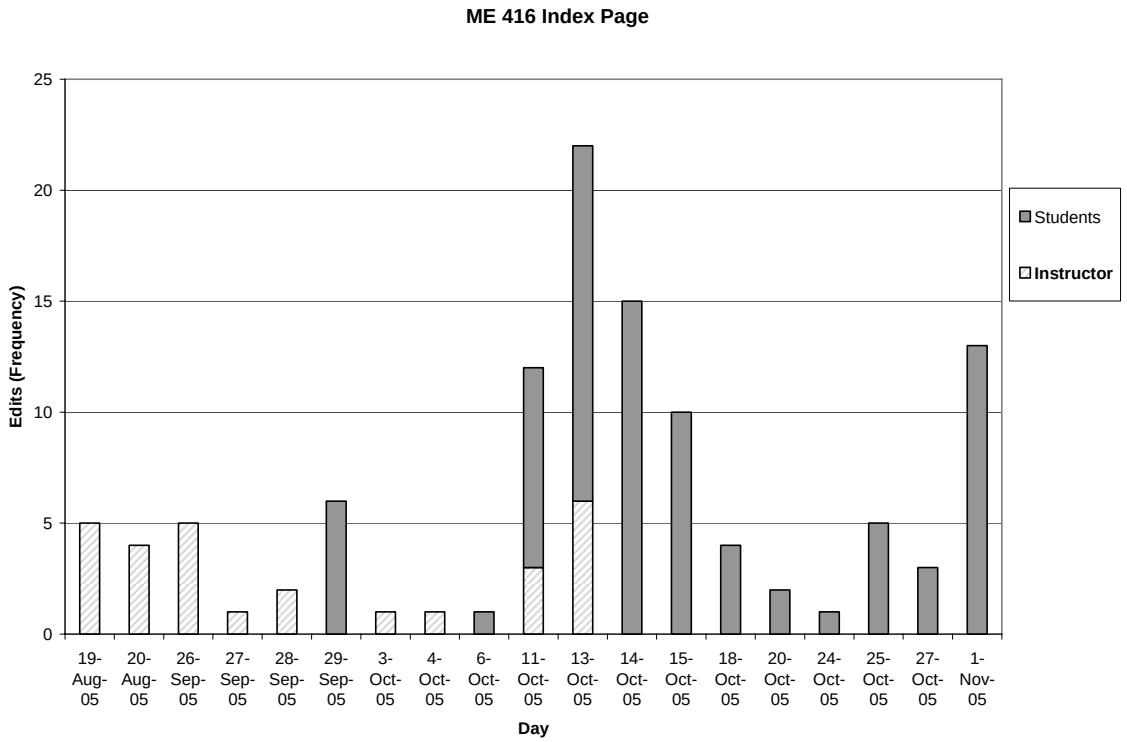

Figure 2.1: Instructor and student edits to the capstone Index page in chronological order.

Similarly, in order to get a sense of how well Basecamp actually worked in the first semester that it was used in the class, Table 1.1 gives a glimpse.

Messages Posted	**3.1 +/- 1.12**
To-Do Lists Posted	**0.73 +/- 0.29**
Milestones Posted and Completed	**1.0 +/- 0.30**

Table 2.1: Average weekly values

Though the number of groups participating in this first-time experiment was relatively small, including results from six individual groups, project sponsor participation in using the messaging functions did not appear to be critical to the students' use of the function. Of the six

groups that used Basecamp, two had little or no communication with their project sponsors through Basecamp. One used the tool extensively—the other used it only when requested.

2.4.2 Results

Time constraints made the use the test-re-test method for determining reliability among the raters infeasible and our sample size, N=6, was small. It was also important for this study to capture raters' first impressions and the values they brought from industry to university settings. In order to get normative feedback in the absence of test-re-test protocol, difference between rater perceptions of actual and expected performance was measured. The scores were averaged to determine the category of average actual performance and average expected performance for each question. Because each rater brings different assumptions about what these categories mean in the "real" and "academic" world, the difference between actual and expected ratings for each question and the average delta, or "room for improvement" score was calculated.

Table 1.2 shows a summary of the average performance category for students, average expected performance category for first-year engineers, and the average difference between the average performance rating and expected performance rating for each question.

Rating key: (1-2) emerging (3-4) developing (5-6) mastering			
Dimension	Ave. Performance	Ave. Expected	Ave. dif
a) group interaction	developing	developing	**-0.5**
b) written engineering communication	developing	developing	**-0.5**
c) safety, ethical, and societal constraints	emerging	emerging	**-0.4**
d) integrating ideas	developing	developing	**-1.1**
e) corporate etiquette and "customer" ethic	developing	developing	**-0.3**
f) project management	emerging	emerging	**+0.4**
g) knowledge management	emerging	developing	**-0.1**
	Total Average		**-0.4**

Table 2.2: Summary of the average difference between actual and expected performance ratings

2.4.3 Findings

Six of the seven average performance ratings fell into the same performance-level category as the average expected ratings. Knowledge management was the exception, as first-year engineers were rated *developing* and students were rated at the *emerging* level. This is supported by a negative average difference, which indicates a consensus among raters that they would want to see improvement in this dimension.

Six of the seven average differences are negative, indicating that raters would like to see improvements in these areas. Integrating ideas is in the *developing* category for both actual and expected performance. This dimension has the largest negative average difference, which suggests that raters see the greatest need for improvement in this dimension.

Project management is in the *emerging* category for both actual and expected performance, yet it has a +0.4 average difference. Two possible reasons for this were surfaced in this study. First, in practice, employers don't see many engineering graduates with project management skills. Expectations for performance in emerging fields tend to be low relative to the high need. Second, the wiki project provides a meta-level view of project management using BaseCamp, thus the expectations for the wiki project to meet specific project management outcomes are low. Interview and focus group questions suggest that students and raters believe wiki knowledge management and BaseCamp project management are complementary but serve different purposes. Those findings are summarized in rater and student perceptions.

2.4.4 Industry Partner Perceptions

Raters responded positively to the Wiki project overall, indicating that graduates with KM experience would be highly valued in industry. Rater responses are summarized in Appendix D. Raters identified strengths in three general categories: (1) archived knowledge; (2)

peer communication; and (3) flexible systems. Raters agreed that the wiki is a great way to pass on "tribal knowledge" from one class to the next that would otherwise be lost. Raters also indicated that peer sharing is an important KM attribute, i.e. that much of the advice is in "student-speak." The flexible nature of the wiki was identified as an important aspect of this project. Students have access to the material "24/7" and it makes sharing information easy and quick.

Raters identified how to improve in three general categories: (1) scaffolding; (2) motivation; and (3) dissemination. Raters indicated that it was important for students to understand the need for KM in industry and that a more explicit approach to providing background information, such as examples and articles, might be helpful. Raters wanted to know what motivates students to contribute to the wiki and how to help students get started when later groups will benefit more from the information in the wiki than the pilot group. Improving dissemination was identified as an important aspect of the wiki project. Inviting student clubs and other classes to participate was one suggestion. Another was to archive engineering events, such as speeches at the annual Order of the Engineer dinner.

Rater insights included support for including the KM and wiki concepts in the curriculum across courses, introducing conflict resolution skills explicitly, and the need for an incentive structure for graduating seniors to "leave behind" their knowledge.

2.4.5 Student Author Perceptions

Focus group discussions were conducted at the end of the semester (Appendix E). Students were asked to compare and contrast KM and PM using wiki and Basecamp. Most agreed that "they are totally different" and complementary, suggesting that "BaseCamp is better for day to day management, wiki for long-term management." Students liked the concept of

helping people “down the road.” Students liked the flexibility of the wiki platform to independently organize and manage pages and unlimited access, even after graduation. Student dislikes generally related to learning new software, user-unfriendliness, lack of pre-defined structure and lack of privacy.

Most students felt that the wiki project was academically and professionally relevant. Students said the wiki was important because it provides a record “beyond design factors” and a place to share information that BaseCamp didn’t automatically archive. Students felt that the wiki project reinforced learning. Discussions, such as SII, “were helpful because they were something everyone can benefit from.” Some students weren’t sure that they would use the wiki, as they looked to experts, rather than peers, for information.

Based on SII feedback, most students found the activity prompts and supplemental materials helpful, such as editing help and case study writing tips. Students suggested that basic wiki markup be introduced earlier in the semester, when there is more time to learn the software and explore other successful wikis, such as Wikipedia. Most students agreed that continuing the wiki project would help others and that inviting student clubs to participate is a good idea. Many students were unsure about the expectations employers have for first-year engineers to have KM and PM skills and how the WSU wiki project would help them in their first year on the job.

2.5 Discussion

An important overarching concept was surfaced in this study: there is a substantive difference between active assessment and passive assessment. Passive assessment is the process of mining for finite artifacts, such as examining final papers after the semester has ended. Such final papers are written for the benefit of the student receiving the grade, and not with the improvement of the course or learning structure in mind. Students are passive—they are given

assignments, they complete them, and they are not enfranchised in a direct way in the knowledge continuity or evolution of the class.

The development of a wiki for the purpose of assessment is fundamentally different. Students actively develop the product—the wiki—with the intent that it will be used for group assessment, improvement of the course, and the benefit of future students. Students and other stakeholders care very much about active assessment: learning, helping others, and partnership in design. Akin to the money-and-deliverable "circle of treats," active group assessment relies on the emotional, intellectual, and practical investment of students, faculty, programs and corporate interests. This social network is supported by an implicit incentive system that benefits everyone. Our study characterizes the incentive-benefit network of a small-scale group assessment project.

Another important concept is the development of an assessment technique for averaged group assessment when the concepts to be measured do not lend themselves easily to classical methods of testing and grading. Taking a client out to lunch may, in many ways, influence the success or failure of a professional's career more than remembering how to solve a complex integration problem—yet educational programs shy away from teaching the latter, in part because such skill sets are considered intangible and difficult to measure. Facilitating measurement of such tasks may influence the academy to add more such material in their curricula once accepted methods of charting progress are developed.

Difference analysis offers a way to quantize overall class learning by observing external advisor rubric/questionnaire deltas for actual and expected performance ratings. Processes such as ABET, as well as departmental internal audits, often use members of external advisory boards to determine if a program is "on track." but such surveys are highly variable. The wiki gives a

fixed artifact of body of knowledge learned in the class and across courses. By utilizing the presented system of rubric/questionnaire deltas, an average improvement score, based on a rubric, can be obtained and compared cross-semester that minimizes unreliability for small groups like advisory boards. Advisory board memberships can be highly variable, and their memberships are usually filled with upper-level managers that have little time for standardizing their viewpoints with others on the board, or engaging in extensive evaluation training. Because of this, it is important to have a tool that normalizes rater perceptions without rater training.

Aside from use of the wiki as an assessment tool, one of the adjunct benefits is that it forces to students to verbalize concepts presented in class in their language. In our experience, students that cannot discuss a topic, regardless of nature (technical or non-technical), do not understand that topic. In a larger culture that is known for its generation gaps, social software offers a mini- Rosetta Stone—a translational document between professors and students, who, while both might be speaking English, may not be speaking the same language. Since instructors do not contribute to wiki construction, other than providing material for the dominant schema and stubs, the resultant knowledge is expressed in ways that the students understand. Even the student-fashioned structure can give benefit to the students in giving them a schema for charting and retaining material in a class.

2.5.1 Next Steps

Students provided feedback for this study primarily from the wiki-author perspective. In Spring 2006, students will also provide feedback from the wiki-user perspective, as they will benefit from the previous semester's work. Additionally, a pre and post survey is being developed to gauge student perceptions of the importance of the seven rater dimensions in their academic and professional lives. Students will be asked to rate how important these skills are in

their academic life, what skills an employer expects them to have in their first year, and how solid they perceive their skills to be in their senior year.

The wiki project in its current form is cumulative, such that new topics are added and large topics are broken into smaller pieces for further development, or "stubbed out." The authors anticipate that the wiki project could grow to such an extent that starting over with a new "home base," or main page, might be necessary after several semesters. This could be accomplished without deleting existing content pages by prompting students to begin work in a clean Course Page, using existing article pages as a resource like any other. Either way, author contributions are searchable by user and by date.

2.6 Conclusions

A classroom wiki for documenting social knowledge was developed by the students and used for assessment of group performance in a team-based capstone design class. Assessment feedback was collected from both corporate and academic venues. Though preliminary, the work offers novel solutions for some of the problems facing professors wishing to pursue team-based curricula, but lacking assessment tools to execute it. Results include methods of norming external-rater evaluations, promoting an active, engaged assessment environment with the students being assessed, and the development of a student-professor Rosetta Stone. Active group assessment is defined and results point to further work in demonstrating the benefits of team-based curricula in novel classroom and external environments.

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APPENDIX CHAPTER TWO

Appendix A: Professional Skills Rubric

Emerging		Developing		Mastering	
1	2	3	4	5	6
1. Students will learn successful group interaction for a project.					
2. Students will learn and demonstrate written engineering communication skills.					
3. Students will consider safety, ethical, and other societal constraints in execution of their design.					
4. Students will have the opportunity to integrate a majority of their skills acquired in the last four years regarding engineering science, design, and communication.					
5. Students will learn appropriate corporate etiquette and a strong "customer" ethic.					
6. Students will learn successful project management skills.					
7. Students will learn successful knowledge management skills.					

Appendix B: Student focus group questions

Focus Group date: Facilitated by: # participants: Location:
1. How did working with WSU Wiki compare with working with BaseCamp this semester? a. How was it similar? b. How was it different? c. How well did they work together? 2. What didn't you like about using the WSU Wiki in ME 416? Why? 3. What did you like about using the WSU Wiki in ME 416? Why? 4. How could the use of WSU Wiki in ME 416 be improved? How? 5. What did you learn from using WSU Wiki in ME 416? 6. Did you feel that the use of WSU Wiki in ME 416 was relevant? If so, why? If not, why not? 7. Thinking about the social, knowledge and management skills a first-year engineer needs to be successful on the job, do you feel that the Wiki project was helpful in learning those skills? 8. Do you think continuing this project—building community knowledge-- will help others? 9. I would like to invite the ME student clubs to use the wiki as a place to share their projects, history, etc. with the ME community. What do you think of this idea? 10. Are there any other groups or classes that you think might benefit from using the wiki? 11. Is there anything that you would like to add that we haven't covered?

Appendix C: Summary of student-generated category and article pages from WSU Wiki

Social Skills • Group Member Roles • Conference Calls • Interpersonal communication • Lunch Etiquette • Communication • Base Camp **Specification Writing** • Specifications **Negotiations** • Buying a Car • General Negotiation Skills **Purchases** • Travel Expenditures and Reimbursements • Purchase Request Forms • General Reimbursements **Case Studies** • Case Studies from your peers	**Personal Skills** • Interviews • Resumes • Self Assessment • Public Speaking • Negotiating **Travel** • Travel **Quality Function Deployment (QFD)** • Overview • Customer Defined • Building the House of Quality **Project Information** • Understanding your Topic • Engineering Notebook • Vendor Resources **Contact Information**

Appendix D: Summary of rater responses by shared category

Raters identified strengths in three categories:	
Archived knowledge	• Captures "tribal knowledge" that would be lost. • This is a great way to pass on knowledge from one class to the next. • Ideal for lessons learned type of indexing. • If used by students. . .it will not only allow students to benefit from previous year work, but more importantly they can see the value of setting up something like this out in the "real" world.
Peer communication	• One strength is that much of the advice is in "student-speak" so it is easily assimilated. • Students will listen to what other students say.
Flexible system	• Readily available 24/7 when students want to use resource. • Putting information down at all is impressive. . . another strength would be if it is maintained (current).
Raters identified how to improve in three basic categories:	
Scaffolding	• Grasping the concept. Provide students a clear understanding of the need for knowledge management, some good examples, and a few descriptive survey articles to read. • A "graded approach to quality" seems particularly difficult for many.
Motivation	• What motivates students to add information to the wiki project? • The challenge is to get enough information entered so it becomes a valuable resource.
Dissemination	• Maybe student clubs can participate. Get input from club members, e.g. ASME, Solar Splash, etc. • It might be interesting to input some of the advice given by speeches at the "Order of the Engineer" dinner. • Links to other resources.
Rater insights included:	• support for including the knowledge management and social software concepts in the curriculum, benefit of learning conflict resolution skills, and the need for an incentive structure for graduating seniors to "leave behind" their knowledge.

Appendix E: Summary of student focus group responses by shared category

Compare and contrast knowledge management and project management	• Most agree that "they are totally different." And that they work together: "BaseCamp is better for day to day management, Wiki for long-term management." • Similar in that there is "a record of progress over time for all steps," and "updates will remain until you make changes." • A few students indicated a preference of one software platform over the other.
Likes and Dislikes	• Dislikes generally related to having to learn a new software, user-friendliness, lack of pre-defined structure and lack of privacy. • Likes generally related to helping people "down the road," freedom to independently organize and manage, and software flexibility, and unlimited access, even after graduation. "Hopefully after we graduate we can come back and use it."
Learning: academic and professional relevance.	• Students generally find that it is "useful to look at what other people [students] wrote." • Discussions, such as SII, "were helpful because they were something everyone can benefit from." • Some students felt the project was unnecessary: "I don't think I'll read it. I look for information from people above me rather than my peers. I'd look to Dr. Chuck to tell me what to do. . ." • Provides a record "beyond design factors." And a place to put "the other stuff that BaseCamp didn't have." • Reinforces learning: "I would have forgotten a lot of stuff if I hadn't written it down." "I would put something up there because I'd need to reference it, but then I wouldn't need to reference it because I learned it well enough in the process."
Strengths of the WSU Wiki Project, and why.	• Most students found it was useful for "passing on information." • Prompting with activities was generally viewed as a good and necessary part of the project. Supplemental materials, such as software help-sheets, were helpful.
Suggested Improvements, and how.	• Introduce Wiki-markup earlier in the semester when there isn't as much going on with projects. More time to practice and look at other wikis, such as Wikipedia. • Other courses could benefit: "depending on the

	teacher, Wiki might be better than the class—[laughter]."
General insights about the WSU Wiki project	• Most students thought that continuing this project will help others. • Many students were unsure about the expectations employers have for first-year engineers to have knowledge management and project management skills and how the WSU wiki project would help them in their first job. • Most students enthusiastically agreed that inviting student clubs to use WSU Wiki is a good idea. • Some students associated the Wiki project with portfolio building. "The idea of a portfolio is for us to work on things that interest us in our field."

CHAPTER THREE

ACTIVE ASSESSMENT IN ENGINEERING DESIGN USING A SYSTEMS APROACH

A major challenge for faculty is how to develop a "culture of evidence" in the classroom that supports student-centered formative learning and aligns with program and accreditation goals. Another challenge is the development of assessment tools that lighten, rather than add to, faculty workload. In this chapter, a systems approach for gathering evidence centered on the development of group artifacts, building on previous work outlined in Chapter One, is presented. Specifically, online project management (PM) and knowledge management (KM) resources are purposefully developed by students at the intersection of working, learning, and assessment. The KM and PM archives are assessed using a multi-method approach, with three goals in mind: 1) ease of implementation, 2) real-time documentation of improvements, and 3) alignment of course assessments with program and institutional goals.

3.1 Introduction

Faculty are being asked by legislators, accrediting agencies, institutions, employers and the public to provide more and better evidence of students' academic achievement. At the same time, they are asked to provide evidence of higher-order thinking and professional skills, which are complex and difficult to measure. This poses a paradox for faculty who want to implement innovative team- and project-based pedagogies. The lack of assessment tools, incentives, and support structures in higher education can discourage faculty from adopting active, student-centered learning approaches, such as collaborative, problem-based, team-based, project-based, inquiry-based, inductive and experiential learning[1,2,3,4]. Faced with more difficult-to-measure learning outcomes, a major challenge for faculty is how to reconcile what stakeholders want with

what faculty can reasonably do. At the same time, faculty are evaluated on the rigorousness of their methods and their contributions to theory and practice beyond the local context.

To solve this problem by measuring every variable using every available technique isn't practical or useful. In order to avoid what Gloria Rogers, Associate Executive Director of Professional Services for ABET, Inc.— the nationally-recognized accreditor for college and university programs in applied science, computing, engineering, and technology (ABET)— calls "death by assessment," alternative assessments are needed that: 1) target specific educational questions, 2) improve organization, learning and assessment, together as an interconnected whole, and 3) reduce faculty workload[5]. Complex learning environments do not lend themselves to traditional positivist methodologies, where a single variable is isolated and controlled for, and the results repeated and generalized. For example, it is impossible (and counterproductive) to isolate and control for interpersonal communication from the ability to function on multi-disciplinary teams without affecting the variable you want to measure in the first place.

In response, the engineering education community is calling for more rigorous methods in education that use a systems approach. ABET, for example, suggests that it is important to use a "multi-method/multi source approach to maximize the validity and reduce the bias of any one approach"[6]. While systems thinking is not new to program evaluation or engineering design, it is seldom employed in course-level research, where the focus tends to be on evaluating the local impact of specific teaching methods on individual student achievement[7]. Unlike traditional courses, project-based courses, such as capstone design, are not bounded by the walls of the classroom, the term of the course, or the enrollment list. Project sponsors, faculty, and students (future project sponsors), may contribute to the program for many semesters. In many respects,

project-based courses resemble programs or learning organizations, more than they do content pit-stops in students' academic trajectory.

The assessment focus in this study is on professional skills in a team- and project-based capstone design course using a systems approach (see Appendix A for Professional Skills outcomes matrix). Now in the fourth semester, the growth and efficacy of a course assessment system was examined for the purpose of answering the following research question:

- Building on what was learned during the first two pilot semesters, how are professional skills assessments using group artifacts and a systems approach explained, improved, and operationalized for use at the course, program, and university-industry partnership levels?

From this guiding question, the following project goals were developed:

- Leverage the group-editing capabilities of
    - new wiki technology for collaborative knowledge management (KM).
    - web-based commercial software, Basecamp, for project management (PM).
- Implement KM and PM tools for assessing group learning and performance.
- Collect feedback from students, College Advisory Board members and Industrial Project Sponsors in order to assess student performance, attitudes, and meta-level project efficacy.

The project goals were developed with the following criteria in mind:

- Ease of implementation.
- New tools integrate and consolidate work, rather than add to student and faculty workload.
- Social, material, and technical support for working, learning and assessment are considered as a whole.
- Real-time documentation of improvements.
- Alignment of course assessments with program, institutional, and industry educational objectives.

In order to consolidate the work associated with using a multiple-source/multiple-method approach, the focus of this study is on the development of group artifacts. The first group artifact is a collaborative website called WSU Wiki[8]. Students actively develop the wiki with the intent that it will be used as a community resource, for self and group assessment, improvement of the course, and the benefit of future students. The second group artifact is a PM archive developed using Basecamp[9]. These group artifacts serve as electronic portfolios, which are assessed by the students, faculty, and external partners. New student and external-rater assessments are presented here.

Recent literature identifies the sparsity of rigorous, systematic, reliable and direct methods of assessing professional skills in engineering education as problematic[10]. In this study,a direct measure of professional skills development is developed that actively involves program stakeholders in the assessment process, as opposed to passive methods, such as locally-developed or standardized exams[11]. External assessment partnerships improve the expert validity of direct assessments, as well as provide the affective benefit of growing community relationships. In this study, external-raters directly assessed students' professional skills, for both the wiki project and the final projects, using a rubric. Raters also participated in focus group discussions and interviews. After four semesters, findings suggest that students and external-raters care very much about active assessment, which involves active learning, helping others, and partnership in design.

3.2 Background

3.2.1 Systems Epistemology

Much has been written recently about the new discipline of engineering education and defining what constitutes rigorous research. One element of this discussion is the importance of

linking education research to relevant strands of epistemology and learning theory. According to two recent guest editorials in the Journal of Engineering Education, engineering education research can and should contribute to learning theory, not only be informed by it[7,12]. Reflecting on epistemology helps researchers to situate research questions in the big picture. For example, in this study, it is important to explore why and how traditional academic structures persist in light of new learning theories that reflect increasingly dynamic and active views of knowledge and learning, and how the study of methods of group assessment will contribute to solving this epistemological problem.

Contemporary theories of learning reflect a shift from a teaching-centered approach, focused on knowledge transfer from teacher to student, to a learning-centered approach, focused on knowledge construction. In the literature, this movement is generally characterized as the shift from behaviorism to cognitivism to constructivism, recognizing that there are many branches of thought and overlapping concepts within and between these categories. Major learning theories build on previous theories, rejecting only some key tenets and building on others. For example, famous cognitivists, such as Noam Chomsky, did not reject behaviorism outright, but challenged the notion that language could be explained in purely behavioral terms. Similarly, famous constructivists, such as Jean Piaget (cognitive constructivim), and Lev Vygotsky (social constructivism) paved the way for research that examines how knowledge is constructed by, rather than given to, learners[13, 14, 15].

In education, the *how* and *why* of knowledge appear to be more flexible than the *who*, *what*, and *where* of knowledge. That is, the complexity and evolution of theories about how people come to know, and for what purpose, mask foundational beliefs of what knowledge is, where knowledge resides, and whose knowledge it is. The key tenets of behaviorism,

cognitivism, and constructivism, for example, represent very different models of knowledge acquisition and communication: stimulus response, knowledge transfer, and social construction. However, all three maintain that knowledge is a state that is achieved by an individual. This creates a tension between dynamic, technology-mediated, and social views of learning and static, individualistic views of knowing (see Appendix B for a learning theory map). In education, this tension is seen in the challenge of trying to assess innovative, learning-centered pedagogies using traditional assessment methods, such as testing and grading.

Educational theorists George Siemens and Stephen Downes propose network-based learning theories that draw on systems theory, chaos, complexity, organizational learning, technology, and communication. Siemens coined the term *connectivism*[16] to describe this learning theory; Downes calls it *connective knowledge*[17]. In essence, what they agree on is that new, individualized learning technologies blur traditional boundaries between learning, working, and living. The ubiquity of technology in contemporary life enables people to leverage multiple learning strategies and technologies in and out of the classroom and across disciplines. People rely less on traditional modes of learning in every aspect of their lives. The new science of learning, they suggest, will include pattern recognition, modeling, simulation and interpretation, rather than traditional cause-and-effect methods.

The purpose of knowledge in a dynamic, global society is increasingly for making decisions and for seeing connections between fields, ideas and concepts, rather than learning specialized content. Connective learning theory highlights the need for faculty to leverage the flexible technology, visual and social skills students bring to the classroom. The same tools used to perform day-to-day activities are the same tools used to learn and assess performance. Understanding, facilitating, and improving effective learning networks is also paramount. There

is a limit to how many students can be packed into a lecture hall, and with high enrollments, most universities push the limit. On the other hand, 3.2 million online students were enrolled during the fall term of 2005, approximately 17 percent of all higher education students in the United States. This represents an increase of approximately 850,000 students, and a growth rate of 35 percent. This is the largest total increase in the number of online students and the largest-ever percentage increase[18]. Network structures, like those used in distance education and online networks, if adapted for face-to-face and blended learning environments, hold promise for solving assessment, workload, and scalability problems in higher education.

3.2.2 The Capstone Industrial Design Clinic

Project-based engineering design has been part of this ABET-certified mechanical engineering program for more than a decade. In its current form in the School of Mechanical and Materials Engineering at Washington State University, student groups work on industry-sponsored engineering projects ($80-$120,000 annually) for one semester. Students are responsible for every aspect of project management, from specification writing to delivery, including budget, travel, and business communication.

The Design Clinic learning structure is illustrated in Figure 3.1. The social, material, and technical support for working, learning and assessment are considered as a whole.

Figure 3.1: Design Clinic learning structure

The PM and KM tools used in this study (already outlined in detail in Chapters one and two and summarized in this section) were selected to fit this requirement—they needed to support students' work, learning and active assessment. WSU Wiki is a website for WSU students, faculty, staff and alumni to collaboratively develop hyper-linked documents for the purpose of growing communities of practice across courses, programs, and disciplines. Basecamp is a web-based project management tool for managing day-to-day project activities, such as scheduling, managing tasks, logging time, and communication.

WSU Wiki was put into production fall 2005 at Washington State University (WSU) by the Center for Teaching, Learning and Technology. It uses the same open-source software, MediaWiki, that powers online encyclopedia Wikipedia[19]. The wiki is organized into individual "article" pages, each of which is put into one or more category. Category pages automatically index articles within that category. Every article page has a discussion page tab for discussion and feedback. Article pages also have history tabs with an archived list of contributors and versions. Users can search their contributions across articles and versions can be compared using the *dif* function.

The wiki is intended to give the Design Clinic an archival memory of social information that is independent of the instructor. Such a contribution is extremely valuable in the capstone design context, as students that take the class one semester typically graduate at the end and the sum of their personal experiences is lost. Students craft narratives in their own words about academic topics and personal experiences. Short activity prompts are used in the beginning, after which the students assume control of the structure and nature of their wiki contributions.

Basecamp is a commercially available web-based project management system that provides basic PM functions such as calendaring, messaging, and grouping and is relatively inexpensive. Basecamp is used to manage the day-to-day project activities, such as creating to-do lists, scheduling activities, monitoring project milestones and sharing documents. All students, corporate sponsors, staff and faculty upload their contact information and photos. The entire project history is archived at the end of each semester and significant work products are saved as electronic portfolios for project sponsors.

3.2.3 Assessment overview

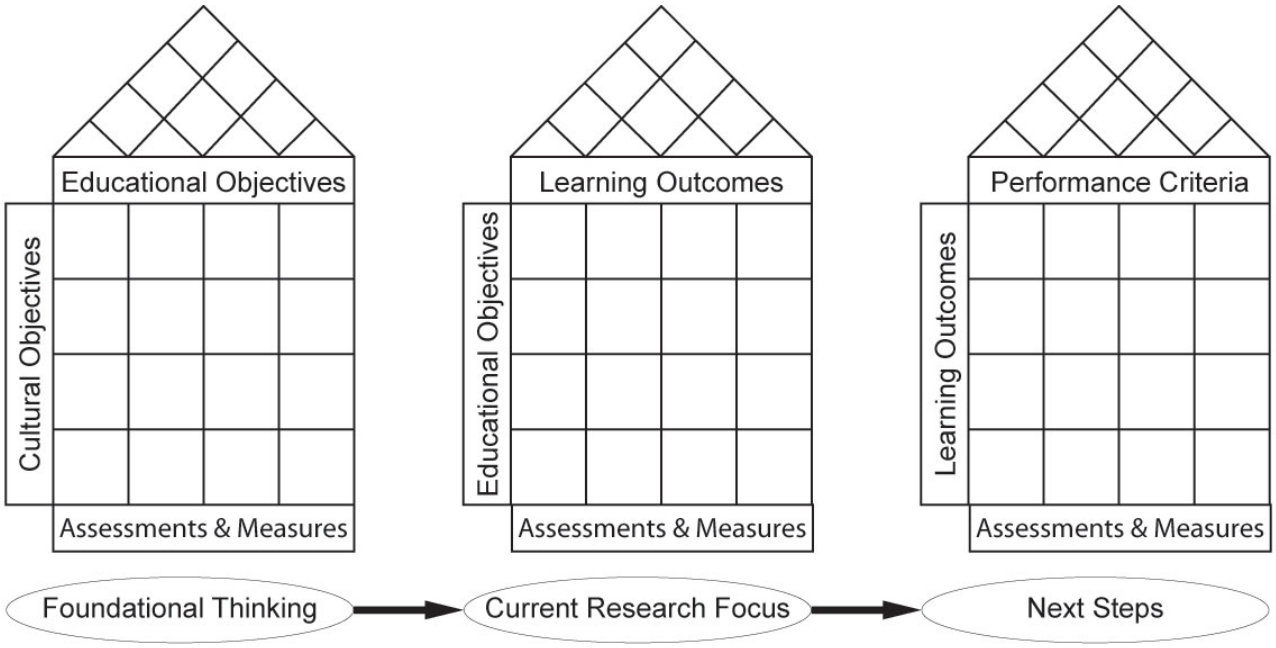
Tracking the many goals, objectives, outcomes and criteria that apply to a course can be difficult, particularly when there are redundancies, overlaps, or trade-offs. The Design Clinic used the same design principles that the students are expected to learn and use for mapping complex outcome relationships and assessment results. A House of Quality (HOQ) format[20] was used to keep track of industry, ABET, institution, program and course goals (Figure 2). The House of Quality is a design tool used by industry to create a conceptual map of customer and engineering requirements and is used for planning and communication. In the Design Clinic, the HOQ matrix was used to map the relationship between and across learning outcomes, track assessments, identify areas for improvement, and create action plans.

As a general rule, the definitions become more specific as you move from left to right. For example, cultural objectives are the important— and often undisclosed— social, cultural, philosophical and epistemological underpinnings that impact student learning, work and relationships. Educational objectives are educational targets, such as "ensuring that our graduates have the technical knowledge, hands-on experience, and communication skills that will allow them to function successfully as members of technical teams." Learning outcomes are more specific and define what is to be achieved by the learner. The associated performance criteria define *how* the learning outcome is to be achieved. The learning outcomes used to assess student work in this study (see Appendix A outcomes matrix) are derived from ABET standards[21], Boeing Attributes of an Engineer[22] and course objectives for project management and knowledge management skills. These outcomes are also mapped to WSU's Six Learning Goals in order to track design clinic progress towards measuring more directly, and meeting institutional learning goals. Finally, performance criteria are the specific, observable, and measurable attributes used to assess student work and performance.

The Design Clinic has four primary cultural objectives: 1) to establish and maintain a foundation of trust and respect, 2) to foster student independence, 3) to ensure that every stakeholder invested in the program gets something of value from it (known by clinic participants as the "circle of treats" philosophy, which is imperative for clinic sustainability), and 4) to promote cognitive, social, cultural, creative, and technical diversity. The relationship between the cultural objectives and educational objectives are analyzed qualitatively, informally, and longitudinally by the Design Clinic faculty (Figure 3.2a). The cultural objectives of the course generally support the educational objectives. The only exception is that the traditional

emphasis on grading in academia, which can negatively impact the cultural objectives of the course. In the Design Clinic, products and performances are assessed, but not graded.

The results of Design Clinic assessments for professional skills learning outcomes are mapped in a spreadsheet resembling Figure 3.2b. The results of assessing learning outcomes using KM and PM tools will inform development and subsequent refinement of the performance criteria used in Design Clinic rubrics (Figure 3.2c). For the first four semesters, raters use the learning outcomes without pre-defined performance criteria to rate students' work. In written comments and follow-up focus group discussions, external-raters provided insights regarding the criteria they used to score students' work. Performance criteria are then updated for use in subsequent semesters. The results of external-rater evaluations are presented in the following sections.



(a) (b) (c)

Figure 3.2: House of Quality format for mapping objectives, outcomes and criteria.

The benefits of using a graphic approach for tracking assessment data can be described in the example of adding ABET outcome (*i), a recognition of the need for, and an ability to engage in life-long learning*, for use during the fall semester of 2006 (see Appendix A for a complete list of ABET 2007/2008 criteria)[21]. According to recent research, students' readiness for self-directed learning (SDL) is a positive indicator of students' ability to engage in life long learning[23]. In order to establish validity of the new direct measure of LLL using the external-rater scoring rubric, LLL measures were triangulated with related SDL measures. This was accomplished by identifying SDL objectives and outcomes in the matrix. The SDL results, such as external-rater scores for student-directed project management skills provided a cross-check for direct measures of LLL. If external-raters assigned student work higher-than-expected scores for LLL, but lower-than-expected scores for student-directed project management, for example, the LLL outcome measure would be re-examined.

3.3 Methodology

For four semesters, 155 students from two course sections participated in this study. The following data has been collected (see Appendix C for details): Industry Partner evaluations (N=22), Industry Partner focus groups (N=15), student focus groups (N=49), pre-post student survey (N=68 pre, N=50 post), wiki archive, Basecamp archive, and instructor observations.

3.3.1 Professional skills rubric

The professional skills evaluation rubric used by external-raters to assess student performance is trait-analytic. Trait-analytic rubrics have been shown in the literature to improve validity and reliability, and the quality of the feedback to the participants[24]. The rubric development process is user-centered. General attributes are fleshed out first, and more specific criteria are refined based on stakeholder feedback.

The rubric has a six-point scale with three categories: 1-2 emerging, 3-4 developing, and 5-6 mastering. This format was adopted from the WSU Critical Thinking Rubric[25]. The Professional Skills Rubric history is posted on the Design Clinic director's wiki user page[26].

In the case of a missing or illegible score, mean substitution was used in order to avoid losing the rater's entire data set. The advantage is that it produces an internally consistent result. The disadvantages are that mean substitution artificially decreases the variation of scores. In this case, however, the average differences are not significantly effected by this statistical method. If the rater indicated a particular reason for not scoring a particular outcome dimension, it was recorded in the qualitative record.

3.3.2 Focus groups

Group size was determined by the number of questions asked, the format, the allotted time and participant availability, with six to ten as the target number27. Focus groups were conducted after each rating session with external-raters, when possible, and at the end of each semester with students from each of two sections. External-rater focus groups were smaller, two to four participants, due to scheduling issues. Discussions were conducted in the design lab, office, or department conference room by a Design Clinic facilitator.

Student focus group discussions were conducted in the design lab classroom by a Design Clinic facilitator during regular class time, with 6-10 participants in each group. A participatory research method was selected instead of a third-party, or neutral interviewer method, for two reasons. First, the interviewer is a voluntary facilitator in the class with no grading authority. Second, in exploratory questioning, familiarity with the students, context and technology can help the interviewer determine when it is, and is not, important to follow-up with detailed probing questions for unanticipated topics of discussion that are surfaced. The question pool is

designed to analyze what students learn, what works, what doesn't and how to improve the program.

3.3.3 Mid-term feedback

The student focus group interviews were introduced as a way to understand the user perspective during the pilot phase of this project. Generally, focus groups are continued until the themes and ideas that emerge tend to be repeated. After two semesters, it was determined that focus groups would be conducted through the fourth semester before being phased out. Therefore, a new, easy, in-class method of student feedback was needed for the long term. A classroom assessment technique (CAT) was introduced in the third semester. Students were asked to identify strengths, improvements, and insights (see Appendix D) for the KM wiki and PM. Feedback was collected anonymously on index cards and the summarized results were discussed by the entire class.

3.3.4 Pre-post student survey

Many students at the end of the first semester said they were unsure about the KM and PM skills employers expect, and how the wiki project might help them in their first year on the job. A pre-post student survey was developed and implemented during the second and third semesters that asked students to rate the level of importance of seven learning outcomes in their engineering education and employer expectations in the first year. They were also asked to rate how solid their understanding was of KM and PM and employer expectations for these dimensions. A five point Likert-type scale was used from strongly agree to strongly disagree. The function of this survey was two-fold. First, this survey was designed to surface student perceptions of the relative importance of learning professional skills in their education and what they perceive employer expectations to be. Second, students were asked to assign a level of

confidence to their understanding of KM and PM. They were also asked to assign a level of confidence to their understanding of what KM and PM skills an employer might expect in their first year on the job.

3.4 Results

3.4.1 Industrial Partner Evaluations

Feedback was gathered from external-raters that measures the difference between rater scores of actual and expected performance. That is, raters scored actual student performance based on a rubric and, in a separate section, the performance they expect from a first-year engineer on the job. The scores were averaged to determine the average actual performance and average expected performance for each question. Because each rater brings different assumptions about what these categories mean in the "real" and "academic" world, the difference between actual and expected ratings for each question, and the average delta, or "room for improvement" score, was calculated.

The average ratings of student performance for actual performance was 3.2 (developing). The average rating of expected performance was 3.5 (developing). Overall, student performance was -0.3 points below the expected performance, indicating that there is room for improvement (Figure 3.3 and Table 3.1).

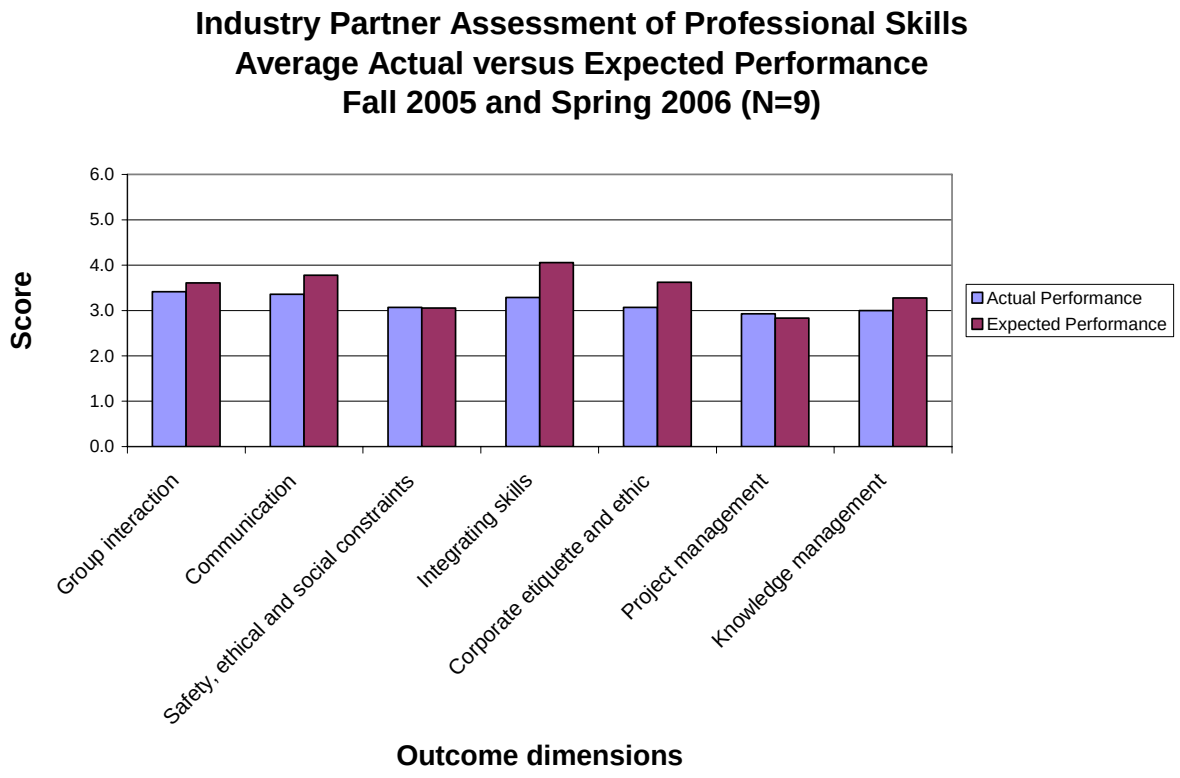


Figure 3.3: Industry partner assessment of professional skills, average versus expected performance Fall 2005 and Spring 2006

The Design Clinic learning outcomes were updated for use during the Fall of 2006. ABET criteria (i), *recognition of the need for, and ability to engage in lifelong learning* and (j), *the knowledge and appreciation of contemporary issues*, were added[21]. Figure 3.2 illustrates average actual and expected performance for the Fall 2006 and Spring 2007 semesters using the updated professional skills rubric. The average rating of actual performance was 4.4 (developing/mastering). The average rating of expected performance was 4.1 (developing). Overall, student performance was +0.3 above the expected performance (Figure 3.4).

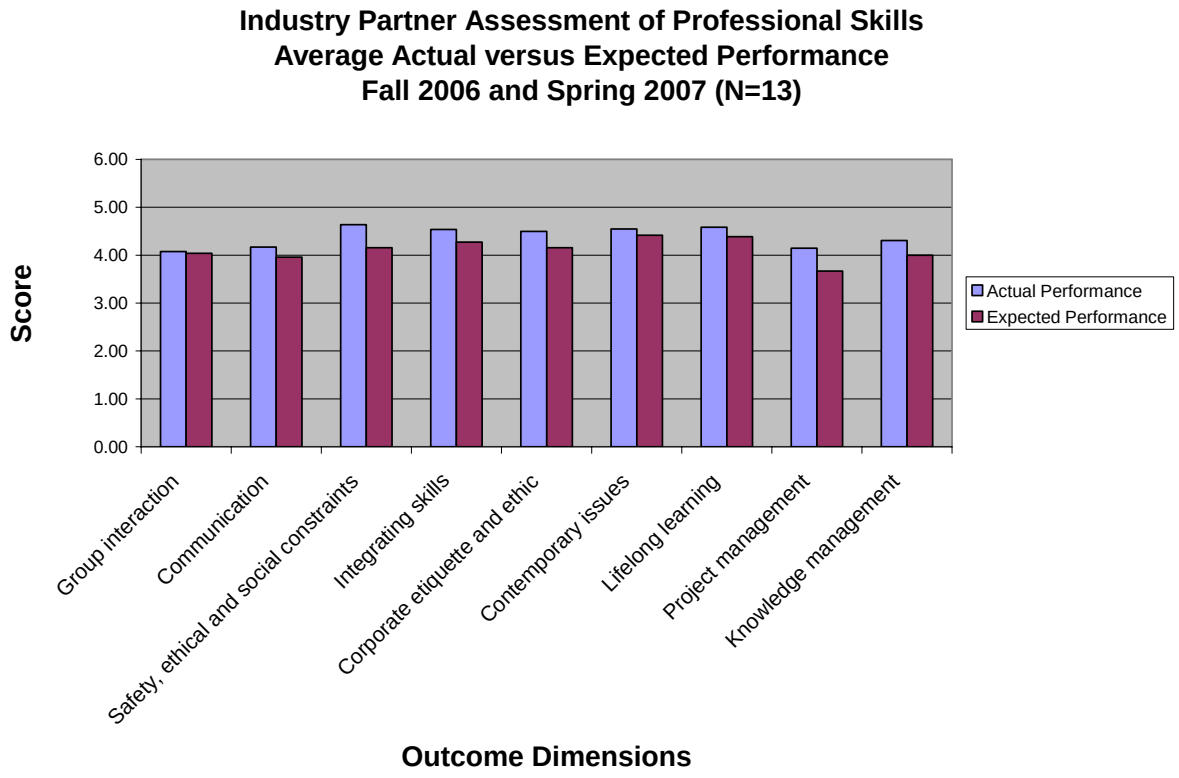


Figure 3.4: Industry Partner assessment of professional skills, average versus expected performance, Fall 2006 and Spring 2007

Table 3.1 shows a summary of the average performance category for students, average expected performance category for first-year engineers, and the difference between the average performance rating and expected performance rating for each professional skills dimension. The average performance ratings increased from the first to second academic year. Room for improvement scores indicate that students met or exceeded industry expectations for graduating seniors in the second year.

	Rating key: (1-2) emerging (3-4) developing (5-6) mastering					
	Fall 2005 and Spring 2006 (N=9)			**Fall 2006 and Spring 2007 (N=13)**		
Professional Skills Rubric Outcome Dimensions	**Average Actual**	**Average Expected**	**Dif**	**Average Actual**	**Average Expected**	**Dif**
Group interaction	3.4	3.6	-0.2	4.1	4.0	+0.0
Communication	3.4	3.8	-0.4	4.2	4.0	+0.2
Safety, ethical and social constraints	3.1	3.1	0.0	4.6	4.2	+0.5
Integrating skills	3.3	4.1	-0.8	4.5	4.3	+0.3
Corporate etiquette and ethic	3.1	3.6	-0.6	4.5	4.2	+0.3
Contemporary issues	*	*	*	4.5	4.4	+0.1
Lifelong learning	*	*	*	4.6	4.4	+0.2
Project management	2.9	2.8	0.1	4.1	3.7	+0.5
Knowledge management	3.0	3.3	-0.3	4.3	4.0	+0.3
Total Room for Improvement	3.2	3.5	**-0.3**	4.4	4.1	**+0.3**

* indicates that the outcome dimension was not included in the assessment at that time.

Table 3.1: Summary of the average room for improvement scores for 2005-2007.

3.4.2 Pre-post student survey results

The student survey was implemented for two semesters (N=68 pre, N=50 post). The survey has two parts. The first part consists of two sets of seven questions. Questions 1-7 asked students to rate how important the Professional Skills Rubric dimensions are to their engineering education. Questions 8-14 asked students to rate the skill level an employer in the first year expects for the same skills. Questions 15-18 ask students to rate how solid their understanding of KM and PM is and how solid their understanding of what KM and PM skills an employer will expect during their first year on the job.

Most students agreed- to strongly agreed (score 4-5) that the seven professional skills learning outcomes are an important part of their engineering education, both pre and post (see Table 3.2 for Survey Results). Similarly, students generally agreed-to-strongly agreed that employers expect strong skills in all seven dimensions during their first year on the job. Pre- to-post changes were examined for statistical significance and questions 1-14 did not demonstrate a significant change.

The second part of the survey asks students to rate how solid their understanding is of KM, PM and employer expectations. The number of students who reported that they agree- to-strongly agree increased

- from 37 to 66 percent for understanding of KM
- From 22 to 42 percent for understanding KM skills employers expect
- From 71 to 84 percent for understanding PM
- From 44 to 66 percent for understanding PM skills employers expect

Survey Questions Consider what you learn during your four-year engineering education and what you will learn on the job during your first year in industry. **5= strongly agree 4= agree 3= neutral 2= disagree 1= strongly disagree**	% that Agree to Strongly Agree		Change
	Pre	Post	+/n/-
1. Learning successful **group interaction** for a project is an important part of my engineering education.	0.91	0.98	+
2. Learning **written engineering communication skills** is an important part of my engineering education.	0.93	0.96	+
3. Considering **safety, ethical, and other social constraints** in my work is an important part of my engineering education.	0.76	0.88	+
4. Having the opportunity to **integrate skills acquired in the last four years** is an important part of my engineering education.	0.87	0.88	+
5. Learning appropriate **corporate etiquette and a strong "customer" ethic** is an important part of my engineering education.	0.85	0.86	+
6. Learning successful **project management skills** is an important part of my engineering education.	0.88	0.94	+
7. Learning successful **knowledge management skills** is an important part of my engineering education.	0.82	0.84	+
An employer in my first year in industry expects me to have strong skills in:			
8. **group interaction** for a project.	0.94	0.92	-
9. engineering **communication** skills.	0.94	0.94	n
10. consideration of **safety, ethical and other social constraints** in the execution of design.	0.84	0.86	+
11. **integrating ideas acquired in the last four years** regarding engineering science, design and communication.	0.72	0.84	+
12. **corporate etiquette** and a strong **"customer" ethic**.	0.75	0.74	-
13. successful **project management** skills.	0.69	0.64	-
14. successful **knowledge management** skills.	0.76	0.74	-

15. I have a solid understanding of what **knowledge management** is.	0.37	0.66	+
16. I have a solid understanding of what **knowledge management** skills an employer will expect me to bring to the job in my first year.	0.22	0.42	+
17. I have a solid understanding of what **project management** is.	0.71	0.84	+
18. I have a solid understanding of what **project management** skills an employer will expect me to bring to the job in my first year.	0.44	0.66	+

Table 3.2: Pre-Post Student Survey Results

3.4.3 Student and Industry Partner perceptions

Student and Industry Partner perceptions from semesters 2 and 3 generally support the findings from the pilot semester. Raters identified strengths of using the wiki for KM and assessment in three general categories:

1. archived knowledge— "a legacy of learning," "value-added knowledge," or "tribal knowledge."
2. peer communication and "consensus editing."
3. flexible, multi-purpose systems that can be accessed anytime, anywhere.

Raters identified how to improve in three general categories:

1. engaging students more deeply in topics such as safety, conflict resolution, or "questioning colleagues about advice on solutions to specific problems," and documenting lessons learned at the project end.
2. motivation— understanding and analyzing the incentive/benefit structure for contributing knowledge for the good of the group.
3. dissemination of this technology to first- and- second year students and engineering clubs to strengthen the engineering community and improve retention.

Students and external-raters both indicated during the pilot semester that the wiki tool was very early in development and the usefulness they saw was potential, rather than actual. In subsequent semesters, it was discovered that students and raters increasingly viewed the wiki as a resource used by students to get work done. For example, students found that the wiki "gives a lot of information that is useful for 'firsts' that happen on the project," and "is a good resource for questions you may be ashamed to ask." Several students and raters indicated that companies would benefit from graduating engineers with wiki experience for helping to find knowledge-sharing and collaboration solutions in the "real world." For example, one student said

> I saw at the company I interned last summer that they are desperately trying to put together a program to make sure all the senior engineers pass on their knowledge to new hires so it is not lost when they retire. Something like the wiki might be something they should look into.

The most common area of concern for students is time management. Setting aside lab time early in the semester, when the projects are just getting started isn't a problem for most. However, students find it challenging to set aside the time to work on the wiki later in the semester when their projects are in full swing. The issue has been raised each semester and discussed as a group. Alternative solutions were suggested, such as independently tracking hours of wiki work outside of class, or moving the wiki time to the one-hour lecture period, rather than one of the three-hour lab periods as it is currently run. However, the consensus continued to be that working on the wiki for a short, focused period at the beginning of class, once per week for the middle weeks of the semester, is the best, if not perfect solution.

It was observed that students generally agree that Basecamp and the wiki are complementary platforms. Students also said that the wiki was useful for sharing information

that Basecamp didn't automatically archive. Basecamp, on the other hand, was useful for tracking day-to-day project activities, creating action plans and communicating with team members and project sponsors. Students were generally more satisfied with Basecamp if their project sponsors used it regularly, than if the project sponsors did not. Approximately 80% of project sponsors are highly engaged using Basecamp, 10% moderately engaged, and 10% rely primarily on email and conference calls for communication.

3.5 Findings

3.5.1 Industry Partner assessment findings

The researcher purposefully asked Industry Partners to provide an expected performance score for each individual dimension on the rubric, and not a uniform, or standard expected performance level for all dimensions, since it is unknown if industry expectations in hiring, for example, are uniform or relatively different. The expected performance score is the competency level that external-raters expect graduates to achieve as they enter industry. The average expected performance score results are variable in two ways: between professional skills dimensions for the same year, and, on average, longitudinally from year one to year two.

The first type of variability indicates that the Industry Partners in this study did not expect a uniform level of performance across the professional skills dimensions. Of the 22 participating Industry Partners, only one participant scored all dimensions at the same level for expected performance. Instead, the majority of participants indicated that they had higher or lower expectations for individual professional skills dimensions relative to each other. For example, for the professional skills dimensions rated in both year one and year two, raters on average indicated that they had the highest expectations for students to integrate engineering skills learned in the last four years (4.1 and 4.3 on the six-point scale) and lowest expectations

for project management skills (2.8 and 3.7 on the six-point scale). This suggests that while Industry Partners might agree that all of the professional skills dimensions are important to engineering education, there may be some professional skills that take longer or shorter than others to develop, given the four- to five-year education window, to achieve the same level of competency for their particular environment. In the future, research that focuses on ranking areas of emphasis in professional skills development, as well as the associated criteria for measuring success, might be useful to programs working to improve professional skills development in the curriculum.

The second type of variability in this study is the change in overall average expected performance from 3.5 to 4.1 from year one to year two. Data was not collected in this study that can be used to identify the cause of this unexpected result, but it raises some important questions. Does the scope of the artifact being assessed influence rater expectations? That is, do expectations shift upwards for artifacts of larger scope and downward for artifacts of smaller or limited scope? Is the shift in expectations related to the quality of the criteria used to describe levels of performance? Grant Wiggins[24] suggests that developing analytic-trait rubrics may necessarily use general language in the beginning, but that the criteria used to describe different levels of performance should be unique, empirical descriptors or qualities. On the other hand, is the influence of criteria quality subordinate to the influence of artifact scope? What implications does this have for establishing expert validity and reliability, and aligning course assessments with programs that assume a uniform standard year to year and across dimensions? This finding suggests that further analysis using a difference approach is warranted, but that additional data should be tracked regarding project scope and criteria development.

3.5.2 Pre-post student survey findings

The pre-post student survey was used to better understand what knowledge and understanding students bring to the Design Clinic and what effect the new PM and KM components of the course might have on their learning. Most students agreed-to-strongly agreed that all seven outcomes were important parts of their engineering education and that employers expect strong skills in these areas. This is important for establishing buy-in to the assessment process. If the students are being evaluated using these criteria, it is important that they value these outcomes, and that they are important to their professional success. A shortcoming of this survey is that it does not ask students to identify outcomes that are missing and should be included. Students during focus group interviews suggested that a third set of questions should be added that ask if and where professional skills are emphasized in the curriculum. Several students commented that, in spite of believing that professional skills are an important part of their engineering education, they had not had the opportunity to learn or use these skills in the curriculum outside of the capstone design experience.

The second part of the student survey was designed to indirectly assess if students' understanding KM, PM, and employer expectations improved over the course of the semester. The percentage of students that agreed- to- strongly agreed that they have a solid understanding of KM, PM, and employer expectations increased pre- to- post. When pre- to- post changes were examined for statistical significance, three of the four questions demonstrated a significant change at the 0.05 level. However, there is room for improvement. Only sixty-six percent of students indicated that they had a solid understanding of KM at the end of their senior year. Fewer than half indicated they had a solid understanding of the KM skills employers might expect their first year on the job. Eighty-four percent of students had a solid understanding of

PM, while only sixty-six percent had a solid understanding of the PM skills employers might expect in their first year on the job. This suggests that a gap exists between student perceptions of learning in the design curriculum and industry expectations. This finding supports external-rater perceptions of the need for explicitly addressing industry expectations in the curriculum. For example, one external-rater suggested that the Design Clinic, "provide students a clear understanding of the need for knowledge management, some good examples, and a few descriptive survey articles to read."

3.6 Operationalization

The results of four semesters of assessment data might appear at first to be a great deal of work for faculty to take on. In this section, an operation schema is presented for systematically starting up and maintaining a course assessment system using group artifacts, which illustrates how an assessment system using KM and PM tools can reduce, rather than add to faculty workload. The workload for a course professor, supervising two sections and approximately eight industrial design projects, and one teaching assistant are discussed.

3.6.1 Getting started: A user-centered approach

As with any new project, there are start-up costs. There are three main components to getting started: finding and implementing the right technology, identifying assessment goals based on stakeholder needs, and developing assessment instruments, such as rubrics, surveys, and interview questions.

Finding and implementing new technology takes time, and sometimes, money. However, widely-available web-based platforms make it possible to locate and implement new technologies in a short period of time, without prior experience, and for relatively small costs. For example, it took the Design Clinic director approximately one hour to locate and subscribe to

Basecamp. WSU Wiki, an institutional technology, satisfied the Design Clinic need for long-term knowledge sharing. A Design Clinic volunteer spent approximately two hours adopting open-source help tools from Wikipedia for WSU Wiki and handouts for helping students to get started. Another three hours were spent preparing activity prompts and setting up starter pages in the wiki. There are many open-source and hosted wiki platforms available for free or nominal fees[30].

Identifying assessment goals based on stakeholder needs takes a variable amount of time depending on how much groundwork has already been done. The Design Clinic had a set of outcomes based on ABET criteria from previous semesters. The director wanted to update the criteria to reflect the latest standards, industry expectations, and new KM and PM professional skills. In addition, new institutional and program-level educational objectives had been approved. Collecting the new information took approximately one hour online. A House of Quality matrix was used to map the objectives and outcomes, using a student-created Excel template[31]. Designing a template from scratch using Excel can take several hours.

Tips:

- Prioritize technologies, based on educational objectives and basic functionality, leaving "bells-and-whistles" for later.
- Don't worry if one technology does not satisfy all of your high-priority requirements. Students have flexible technology skills that support using multiple complementary technologies.

3.6.2 Management

Getting a large group of people to share what they know for the good of the group is a perennial challenge for organizations. For managers, striking the right balance between

dedicated and independent work time can be difficult. The strategy used in the Design Clinic for managing the wiki project is to set aside short, focused work sessions. The class sessions last approximately 50 minutes for ten of fifteen weeks. This provides for a flexible schedule. A Design Clinic facilitator prepared short activity prompts early in the semester to help students identify new topics and areas for improvement in the wiki. Students used peer feedback to help refine contributions.

Basecamp is used for the entire semester by all Design Clinic participants, including students, faculty, project sponsors and department staff. Student photos are uploaded into contact information. It takes the Design Clinic director approximately two hours to put students into the system at the beginning of each semester. Basecamp has a "dashboard" which allows the director/administrator to monitor all of the projects at once. Student groups and project sponsors have access to individual project space.

Tips:

- As the wiki develops, students must attend to developing navigation and structure, as well as content. Facilitators can help by encouraging them to identify emerging structures early on, and develop navigation bars, indices, etc.
- Project management platforms that support direct communication between students and project sponsors can increase productivity and reduce faculty workload.

3.6.3 Gathering data

Student data was gathered during regular class time. The pre-post survey takes students approximately ten minutes to complete. The focus groups discussions take approximately one hour near the end of the semester. The mid-term evaluation takes students approximately ten minutes to complete.

External-raters were invited to participate in rating sessions during regular campus visits. Advisory board members visit campus each semester for regular meetings. Project sponsors visit campus the week prior to the end of the semester for final project presentations. External-raters are invited to participate in one-hour sessions, including rating and discussion. External-rater packets are currently being developed, using the latest version of the professional-skills rubric, which will allow a greater number of external-raters to participate remotely, on their own time.

Tips:

- Coordinate assessments with existing face-to-face opportunities, if possible, to increase participation and response rates.
- Be flexible. Phase out, or modify, qualitative assessments that have served their purpose. If similar themes and ideas emerge over the course of several interviews, refer to your research question pool for fresh ideas.
- Start small, think longitudinally—a small N in the beginning is a reality of working with industrial and faculty partners. However, cumulative results add up to significant patterns and trends.

3.6.4 Improvements

The purpose of a course assessment system is to "close the loop." That is, assessment data should provide feedback that leads to positive change. The major areas for improvement identified from student and external-rater feedback include:

- Refine professional skills rubric learning outcomes and criteria based on external-rater and student feedback.
- Prepare external-rater packets in order to increase participation during the next phase of this study.

- Collect student and external-faculty ratings of group artifacts using the professional skills rubric.
- Phase out pre-post survey and update focus group questions to answer new research questions.
- Disseminate the results. Invite student clubs and early-program engineering students to participate in the wiki. Most participants agree that heterogeneous knowledge sharing will benefit the program.
- Optimize/address high-priority concepts identified by external-raters in the curriculum: graded approach to quality, specifications process, safety issues, for example.

3.7 Conclusions

An Australian Army captain, David Kilicullen, with a doctorate in political anthropology, studies fundamentalist insurgencies, including those in West Java and East Timor. According to a recent *New Yorker* expose[32], Kilcullen is being tapped by some in United States government to help with the global counterinsurgency effort—a new term for the War on Terror. His conclusion from years of field research was that the problem of insurgency was not rooted in ideology, Christian or Islamic, but human social networks and the way they operate. After 9/11, tactical counterinsurgency was developed in the United States to address an "Islamic problem." Kilicullen had a different perspective. Cited in the article, he says "This is human behavior in an Islamic setting. This is not 'Islamic behavior.'" What makes counterinsurgency even more difficult, Kilicullen says, is the "globalized information environment," which supports sophisticated propaganda campaigns and loosely knit organizational structures.

This example illustrates, in a global context, some of the challenges faced by educators in the discipline of engineering education. A great deal of effort, time, and money has been given

to address an “engineering problem.” That is, funding agencies have focused on re-defining the engineer of the future for the purpose of recruiting more, better and diverse students. This is evidenced by a host of exit survey and focus group projects asking students to identify: why and why not engineering? But if Kilicullen is correct, and people get pulled into movements and organizations (facing much greater challenges and deterrents than engineering) by their social networks and not by ideology, there is work to be done in studying social networks that happen to be in engineering.

This study represents a systematic effort to implement social technology in engineering design courses for the purpose of facilitating and assessing student-centered engineering networks. In particular, the focus is on assessing professional skills by triangulating direct and indirect assessments of collaborative group artifacts. Industry Partners are actively involved in the assessment process in order to improve direct measures of professional, social, and team skills. Finally, students and external-raters also provide qualitative feedback regarding the learning outcomes and overall project efficacy.

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APPENDIX CHAPTER TWO

Appendix A: Mapping of course outcomes to ABET, institution, and industry goals and outcomes.

● **Primary/strong relationship**
○ **Secondary/weak relationship**
↔ **Across dimensions**

	Professional Skills Rubric Dimensions								
ABET Criterion 3: Program Outcomes and Assessment	Students exhibit successful group interaction for a project.	Students successfully demonstrate effective engineering communication skills.	Students appropriately consider safety, ethical, and other societal constraints in design.	integrate a majority of their skills acquired in the last four years regarding engineering science,	Students successfully demonstrate appropriate corporate etiquette and a strong "customer" ethic.	Students are appropriately knowledgeable of contemporary issues.	Students successfully recognize the need for, and an ability to engage in life-long learning.	Students demonstrate successful project management skills.	Students demonstrate successful knowledge management skills.
(a) an ability to apply knowledge of mathematics, science, and engineering				○				○	
(b) an ability to design and conduct experiments, as well as to analyze and interpret data				○				○	
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability			●		○				○
(d) an ability to function on multi-disciplinary teams	●	○						○	
(e) an ability to identify, formulate, and solve engineering problems				○				○	
(f) an understanding of professional and ethical responsibility			○		●	○			
(g) an ability to communicate effectively		●						○	○
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context			●			○			○
(i) a recognition of the need for, and an ability to engage in life-long learning							●	○	○
(j) a knowledge of contemporary issues			○		○	●			
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.				●				○	○

		group interaction	engineering communication skills	safety, ethical, and other societal constraints	Integrate engineering skills	corporate etiquette and a strong "customer" ethic	knowledge of contemporary issues	life-long learning	project management skills	knowledge management skills
(1) Critical and Creative Thinking: Graduates will use knowledge of evidence and context to reason and reach conclusions as well as to innovate in imaginative ways.	**WSU Six Learning Goals**	↔								↔
(2) Quantitative & Symbolic Reasoning: Graduates will analyze and communicate appropriately with mathematical and symbolic concepts.		↔								↔
(3) Information Literacy: Graduates will use a disciplined and systematic approach to accessing, evaluating and using information.									○	○
(4) Communication: Graduates will write, speak, and listen to achieve intended and meaningful understanding.			●						○	○
(5) Self in Society: Graduates will employ self-understanding and interact effectively with others of similar and diverse cultures, values, perspectives, and realities.		●		○		○	○	○		
(6) Specialty: Graduates will hone a specialty for the benefit of themselves, their communities, their employers, and for society at large.		↔								↔
(1) A good understanding of engineering science fundamentals.	**BOEING Attributes of an Engineer**								○	○
(2) A good understanding of design and manufacturing processes.									○	○
(3) A multi-disciplinary, *systems* perspective.				○	○	○	○			○
(4) A basic understanding of the *context* in which engineering is practiced.				●						
(5) Good communication skills.			●							
(6) High ethical standards.						●				
(7) An ability to think both critically and creatively - independently and cooperatively.		↔								↔
(8) Flexibility. The ability and self-confidence to adapt to rapid or major change.		↔								↔
(9) Curiosity and a desire to learn for life.								●		○
(10) A profound understanding of the importance of teamwork.		●							○	○

Appendix B: Learning Theory Map

Epistemology	Objectivism		Pragmatism		Evolutionary Epistemology	Emergent/Connectivist Epistemology
Philosophy	Essentialism		Structuralism		Post-structuralism	Technology
Science	Modernism/Positivism		Post-Positivism		Postmodernism	Systems and Networks
Education	Conditioned Learning	Natural Learning	Information Processing	Sociocultural Learning	Engaged Learning	Knowledge Building
Learning Theory	Behaviorism	Cognitivism	Social Cognitivism	Cognitive Constructivism	Social Constructivism	Connectivism
Static/Passive view of knowledge ←						→ **Dynamic/Active view of knowledge**
What is knowledge?	• exists in an objective reality separate from personal experience • is reached through reason		• is transferred from teacher to student • corresponds to reality, but is hard to know	• is internal, socially and culturally constructed • does not necessarily correspond to a transcendent reality		• is distributed • is interconnected • is personal • is context dependent
Whose knowledge?	• individuals (stimulus response, behavior)		• individuals (teacher to student transfer)	• individuals in context (student-centered)		• individuals (connectionism/neural networks) • networks and organizations • human and non-human
Where is knowledge?	• in the facts based on empirical evidence		• triangulated facts based on empirical evidence	• constructed both empirically and socially		• distributed across networks • In patterns of organization
What is the purpose of knowledge?	• a quest for certainty • a view of progress that is always forward moving toward a unified system of knowledge. • a clear distinction between subject and object		• a quest for certainty to the extent possible. • progress that is forward moving toward a unified system of knowledge. • objectivity to the extent possible.	• interpreting empirical and social evidence. • creating new meaning through interaction with others.		• Make decisions • See connections between fields, ideas and concepts.

Appendix C: Assessments

Data sources	#Participants	Semester	Assessment focus	Instruments
Industry Partner evaluations	N=9 N=13	1,2,3,4	Professional Skills (Wiki and Final)	Six-point Likert-scale rubric, written comments
Industry Partner focus groups	N=15	1, 2, 3, 4	SII Professional Skills	Focus group discussion with note taker.
Student focus groups	N=49	1, 2, 3	Wiki and Basecamp	Focus group discussion with note taker
Pre-post student survey	N=68 (pre), N=50 (post)	2, 3	Learning outcomes—level of importance, confidence	Anonymous paper survey, five-point Likert-scale.
Wiki archive	N=120	1,2,3	Wiki	Wiki artifacts/history
Basecamp archive	N=120	1,2,3	Final Projects	Faculty evaluation based on student-industry sponsor specifications
Instructor Observations	2	1,2,3, 4	All aspects	Notes

Appendix D: Summary of Mid-term evaluation results

Strengths	Improvements	Insights
• Useful information • Easy to navigate and organize • Like helping future students • Answers questions about projects and Design Clinic processes	• Ongoing improvement of organization and navigation. • Horizontal scope—a process of growing and pruning ideas. • Depth—improve depth of information by providing detailed examples, references, testimonies and procedural information. • Setting aside time is difficult—no easy/perfect solution.	• Improve links to outside sources of information • The wiki project is a cycle of using and giving back—the wiki as a valuable resource in the beginning. We contribute the most towards the end, after gaining project experience.

CHAPTER FOUR

CONCLUSION

In this study, the development of a course assessment system using social software and expert evaluation was developed which fosters active participation by all stakeholders—students, faculty, and Industrial Partners. The assessment purpose was to capture the quality of student professional skills development in a senior engineering design course in order to make improvements in the course, program, and university-industry partnerships. During the first two semesters of this study, two new social software platforms were introduced: a course wiki for long-term knowledge management and a commercially available, web-based project management tool. A direct measure of students' professional skill development was desired, and the group artifacts produced by students using social software during the regular course of completing industry-sponsored projects lent themselves to this purpose. During the pilot semesters, the research focus was how to get started using social software in engineering courses, and the development of a professional skills rubric for use by industry partners to give feedback on the group-developed artifacts. Qualitative feedback was collected from Students and Industry Partners in order to determine what was working well and what needed to be improved in this process.

A normative approach was used to collect quantitative feedback from Industry Sponsors using the professional skills rubric in order to calculate a room-for-improvement score for each rubric dimension. This was accomplished by asking participants to score student work for each professional skills dimension and, additionally, the level of expected performance of a graduating engineering student entering industry. The assessment results from semesters one and two indicated that on a six-point scale, the average room for improvement score was -0.3

points, indicating a slight room for improvement was required in a majority of the professional skills dimensions in order to meet industry expectations. Qualitative data collected from students and Industry Partners was used to improve the project for the subsequent two semesters. Improvements to wiki development, the professional skills rubric, and qualitative data collection were implemented.

Building on what was learned during the first two pilot semesters, professional skills assessments using group artifacts and a systems approach was explored in greater depth. New qualitative methods were introduced in order to better understand the level of student engagement and ownership in the wiki and project management development and assessment processes, as well as identify new areas for improvement. In the second year, Industry Partner participation increased, and the average room for improvement score of +0.3 indicated that student professional skills development based on group artifact evaluation had improved from year one to year two.

4.1 Active Assessment and the Global Engineer

4.1.1 Lessons Learned

Lessons learned about developing a systems approach to active assessment in engineering design have been integrated into the Design Clinic in its current form. However, in order for this work to be of long-term value to the Design Clinic, it is important to look toward the future and to employ a benefit/liability analysis of this approach in emerging contexts. The business of engineering is moving toward truly borderless operation, with notable examples such as the Boeing Company or Daimler executing a 24/7 design and production cycle, with partners sharing data around the world. It is becoming more important than ever to give students exposure in a meaningful way to working with colleagues trans-nationally[1]. The Design Clinic is in the

process of expanding globally, actively working to cultivate partnership projects for students at WSU to work with engineering student colleagues around the world.

The key ideas from chapters, examined through the lens of a Global Engineering Design Clinic case study, include:

- Actively including multiple stakeholders in the assessment process
- Assessing group-developed artifacts
- Using a variety of flexible social software to provide students the opportunity to verbalize concepts presented in class in their language
- Developing a technique for averaged group assessment using a difference approach
- Triangulating core measures with other select direct and indirect measures. In this study, a systems approach was developed using:
    - Student ownership survey, which measures the level of importance students place on learning professional skills in their engineering education versus on the job training.
    - Focus group interviews, which provide students and other stakeholders the opportunity to explain in more detail what works, what doesn't, and why they feel that way. It also is a forum for gathering detailed data about the criteria experts in the profession use to measure professional skills, which is then used to improve the professional skills rubric.
    - Mid-term feedback, which is an easy way for faculty gather information about what is working well, and what isn't early in the semester, so that improvements can be implemented along the way.

- Lightening professor workload by implementing tools that leverage students' flexible technology skills, improve workflow and long-term knowledge sharing, and foster student independence, which frees up time for program development.

The Global Engineering component of the Design Clinic was started by a grant to the Design Clinic director from the Boeing Company for implementation during the Spring semester 2007. With approximately half the budget dedicated to equipment, and the other half to personnel support for set-up by graduate research assistants, a pilot project was completed in partnership with students at the Technical University of Vienna (TUV) and professor Wolfgang Wimmer. The project consisted of the collaborative design and manufacture of a coating wear-testing machine for Boeing by WSU and TUV student teams.

4.1.2 Stakeholders

One of the first steps in actively involving interested persons in the assessment process is to identify all of the stakeholders, at every level, with an interest, or potential interest, in the Design Clinic. In the case of global partnerships, the number of stakeholders immediately doubles, and a host of complex interests are surfaced. For example, in the case of the WSU-TUV pilot project, a new group of students, professors, European industrial partners and accreditors have a stake in the outcome of such enterprises. The Design Clinic assessment process captured only the U.S.-half of project performance, as the timeline was too short for all of the new stakeholders to be fully integrated into the suite of tools and rapid time-to-market processes available to Design Clinic students. Similarly, Design Clinic students were not assessed on how much they learned about the strengths of the TUV design approach, which is European eco-design[2]. Additionally, the professional skills rubric did not include outcomes dimensions specifically related to global teamwork, so the WSU team did not receive industry

feedback on this aspect of their work. What is required in the future is a preliminary needs review of which assessments will be jointly developed, and which will be developed individually by partner programs. The development of an online survey tool for new partners, completed by program directors, to share assessment plans, goals, outcomes and criteria prior to the beginning of the semester would help identify mutual and exclusive stakeholders, and appropriate levels of collaboration.

4.1.3 Social software and group artifacts

Group artifacts, as the results of the previous chapters illustrate, are a key component of Design Clinic success. The social software tools used to develop these resources are integrated into the Design Clinic from the beginning, and may or may not be familiar to or integral to partner programs. In the case of the WSU-TUV project, the TUV design team was invited to use Basecamp as the primary communication and collaboration tool with WSU and Seattle-based Boeing sponsors. There were two unanticipated outcomes from this arrangement. First, it was assumed that because the TUV students were fluent in English that Basecamp would be an easy-to-use and effective tool for students to get to know each other and share ideas early in the collaboration. This assumption was proved incorrect in the TUV case, as the artifacts students eventually produced were independent design reports, rather than a synthesis of the design strengths each team brought to the project. Similarly, the wiki resource was available to TUV students to use, but not to contribute to, as WSU Wiki requires a WSU network ID and login. TUV students used the wiki in a limited way as a way to familiarize themselves with the Design Clinic, but did not benefit from the resource as much as Design Clinic students. As it turned out, based on information gathered in a personal visit and project debrief in Vienna in May 2007, the TUV students were less comfortable writing in English than they were speaking in English. In

the end, text-based Basecamp and the Design Clinic wiki were not the most effective tools for facilitating inter-team cohesion in the short nine-week timeframe that the university schedules allowed for.

From this case, a visual/oral communication plan for the first weeks of new projects was devised. Students entering the university are visually-oriented [3] and have flexible technology skills [4]. As visual communication increasingly replaces textual information for sharing information across distances and cultures, students will need access and the freedom in academic environments to create (and receive credit for) visual as well as textual representations of their work in terms of technical quality, critical and creative thinking, and communication. In this pilot project, both student groups produced high quality 3-D models. The major insights gained between both parties happened during exchange of the visual models. In fact, a major, positive design revision that would have occurred had there been more time came directly from solid model-generated insights. However, getting to that point took longer than expected with the assumption that text-based social technology was better than visual technology for sharing personal information, not just technical information.

4.1.4 Professional Skills

The second lesson learned is that the professional skills students need to effectively ramp up collaboration with partners in different cultures can be different than the skill set required for domestic projects, even when teamwork and social skills are emphasized in the curriculum. In the TUV example, WSU students successfully managed travel, scheduling, and group roles in conjunction with Boeing sponsors. However, the same team had a difficult time assuming ownership for managing for differences in university schedules between WSU and TUV, student-professor relationships, communication protocols and language barriers. The WSU

student team relied much more on the professor to navigate these challenges. This suggests that improving the curriculum for cultural flexibility and assessments for professional skills in global contexts is the next step for rubric development and gathering feedback.

4.1.5 Triangulating Evidence

In addition to developing a core set of professional skill outcomes, other methods of gathering evidence might be transferred to the global context with varying degrees of success. There are a variety of strategies faculty can use to collect additional feedback, foster student independence and ownership that easily transfer to the global context. Design Clinic students appreciated the opportunity to give honest focus group feedback about what worked and what didn't, particularly for the newer aspects of the course. Similarly, the Student Ownership Survey provided a baseline perception check of the level of importance students place on professional skills in their education. Similarly, TUV students appreciated the opportunity to summatively discuss their project face-to-face with the Design Clinic director and the author in Vienna, and to attend a conference call with the Boeing project sponsor to wrap things up. However, the TUV students in the pilot project had fewer opportunities to give and receive formative feedback.

In conclusion, much of the Active Assessment and Systems framework discussed in this thesis is transferable to global engineering. However, a more in-depth understanding of all stakeholders' interests must be researched. In the case of the domestic version of the Industrial Design Clinic, interests have been clearly established for all external stakeholders. Corporations want completed projects and new hires. But when projects go international, because of the increased pedagogical nature of the projects, and difference in learning outcomes, more negotiation is needed between the academic parties, as often the desired results can be different.

Overriding all of this is the increase of cost in international collaborations. The Industrial Design Clinic has prided itself on being a 'pay-as-you-go' operation, with the bottom-line being in sync with the learning outcomes. Projects are sized according to corporate payback, and this fortunately coincides with the cost necessary to run the operation, as well as the desired learning outcomes. More research, and diligence must be exercised in picking the appropriate external university partners so that an effective set of incentives can be developed.

This is important for students, professors, industry, and the individuals engaged in active assessment. The clinic is self-sustaining because everyone sees the cost of participating in activities that may or may not be in their direct interest as minimal to the benefit realized from overall project participation. Careful thought must be applied to the fundamental structure of the clinic, as well as the assessment protocol, to preserve this careful balance. The self-sustaining nature of this innovative program is one of its hallmarks. And it must be one of the key elements that is preserved in any expansion or continuance of an assessment protocol for the clinic.

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