

AC 2007-464: ACTIVE ASSESSMENT IN CAPSTONE DESIGN USING A SYSTEM APPROACH

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Abstract

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 paper, we analyze a systems approach 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 goals in mind: 1) ease of implementation, 2) real-time documentation of improvements, and 3) alignment of course assessments with program and institutional goals.

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 (ABET outcome *g*) from the ability to function on multi-disciplinary teams (ABET outcome *d*) 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, p. 2]. 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 even 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.

In this study, we focus on the assessment of professional skills in a team- and project-based capstone design course using a systems approach. Now in the third semester, we examine the growth and efficacy of a course assessment system for the purpose of answering the following research questions:

- How do we assess team learning and professional skills?
- How do we assess organizational learning in team- and project-based courses?
- How do we demonstrate and document continuous improvement?

From these research questions, we developed the following project goals:

- Leverage the group-editing capabilities of
 1. new wiki technology for collaborative knowledge management (KM).
 2. web-based commercial software, Basecamp, for project management (PM).
- Pilot the use of 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, we focus 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, we focus on developing direct measures that actively involve 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 three semesters, we continue to find that students and external-raters care very much about active assessment, which involves active learning, helping others, and partnership in design.

2. Background

2.1 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, we want to know why and how traditional academic structures persist in light of new learning theories that reflect increasingly dynamic and active views of knowledge and learning. It is our hope that studying 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 constructivism), 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 we 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 A 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 we use to perform day-to-day activities are the same tools we can use to learn and assess performance. Understanding, facilitating, and improving effective learning networks is also paramount. There is a limit to how many students we can pack 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 about 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.

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 2. The social, material, and technical support for working, learning and assessment are considered as a whole.

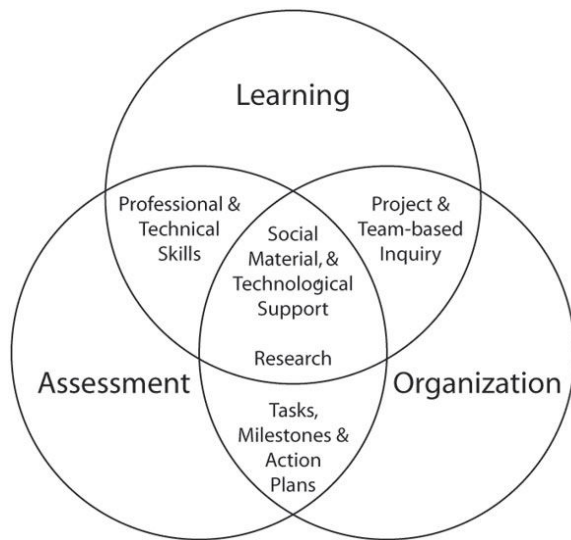


Figure 2: Design Clinic learning structure

The PM and KM tools used in this study 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.

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 uses the same design principles that the students are expected to learn and use for mapping these relationships and assessment results. A House of Quality (HOQ) format [20] is 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 is used to illustrate 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 are derived from ABET standards [21], Boeing Attributes of an Engineer [22] and course outcomes for project management and knowledge management skills. Finally, performance criteria are the specific, observable, and measurable attributes used to assess student work and performance.

Four cultural objectives are integral to the Design Clinic: 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 3a). The cultural objectives of the course generally support the educational objectives. The only exception is that the traditional emphasis on grading students in academia 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 3b. The results of assessing learning outcomes using KM and PM tools will inform development and subsequent refinement of the performance criteria we use in our rubrics (Figure 3c). For the first three 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 into the criteria they used to score

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].

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 number [27]. 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 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 a summary of the results) for the KM wiki and PM. Feedback was collected anonymously on index cards and the summarized results were discussed by the entire class.

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.

3.5 Keirseey Temperament Sorter

The Keirseey Temperament Sorter-II (KTS) [28] is a self-assessed personality questionnaire designed to help people better understand themselves and others. Developed by David Keirseey and based on the Myers-Briggs Temperament Indicator, the KTS is a useful tool for helping people to appreciate the differences between individuals' perceptions, emotions, and cognitive styles. Rather than seeing differences as a problem, this framework helps students to develop strategies for working together, making decisions and communicating effectively in teams. The KTS activity was implemented during regular class time.

4. Results

4.1 External-rater evaluation results

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. We averaged the scores 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, we calculated the difference between actual and expected ratings for each question and determined the average delta, or "room for improvement" score.

The average ratings of student performance for the wiki project 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 4.1).

**External Rater Assessment of Wiki Project
Average Actual versus Expected Performance Fall 2005 and Spring 2006**

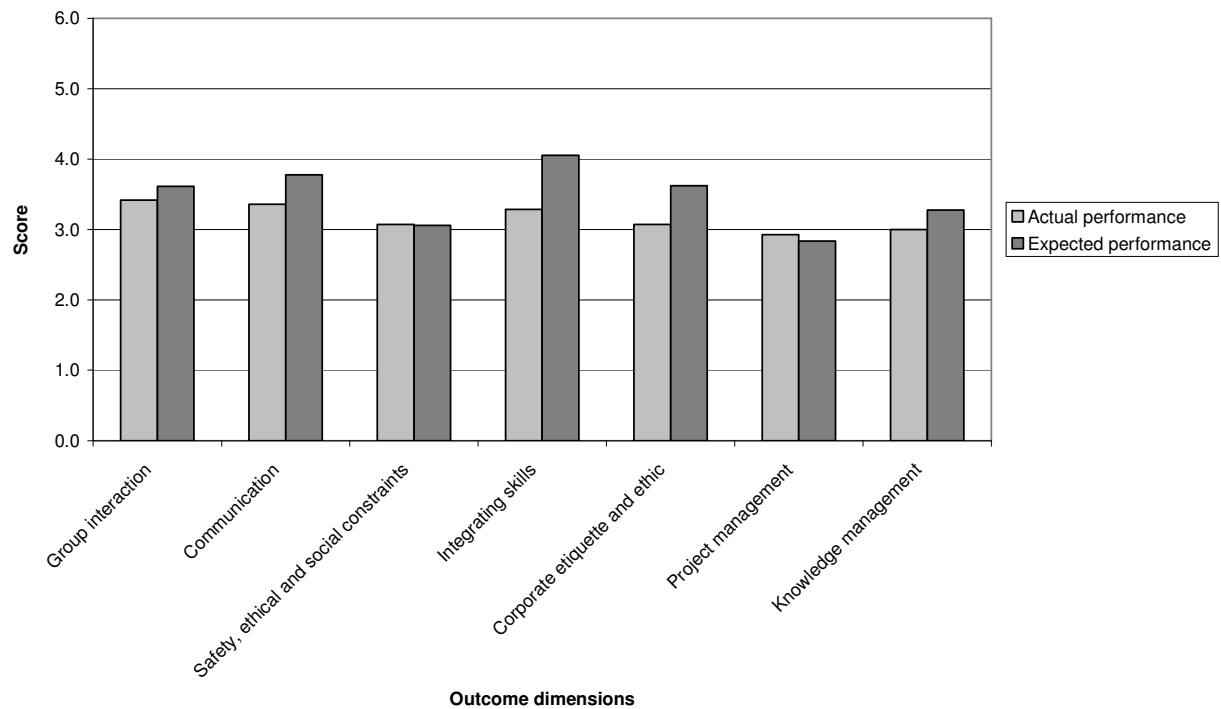


Figure 4.1: External-rater assessment of professional skills for the Design Clinic Wiki.

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 4.2 illustrates average actual and expected performance for final projects using the updated professional skills rubric. The average rating of actual performance for final projects was 4.7 (developing/mastering). The average rating of expected performance was 4.1 (developing). Overall, student performance was +0.6 above the expected performance (Figure 4.2).

**External Rater Assessment of Final Projects
Average Actual versus Expected Performance Fall 2006**

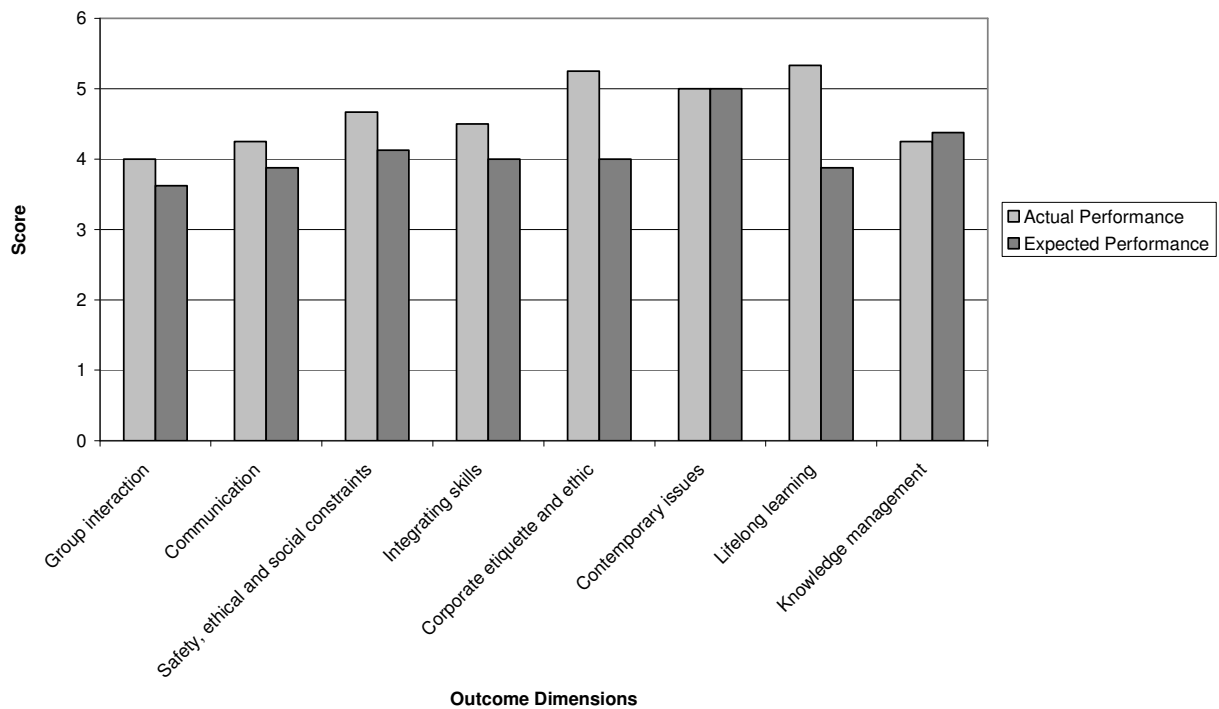


Figure 4.2: External-rater assessments of professional skills for Design Clinic final projects.

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 4.1 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

Pre- to- post changes were examined for statistical significance and questions 15, 16 and 18 demonstrated a significant change at the .05 level.

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	% Agree to Strongly Agree (4-5)		Change +/n/-
	Pre	Post	
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	+(*)

* indicates significant change at the 0.5 level

Table 4.1: Pre-Post Student Survey Results

4.3 Temperament sorter results

Seventy-seven students participated in the temperament sorter activity during two semesters. The class distribution is mapped against the Keirsey temperament distribution [29].

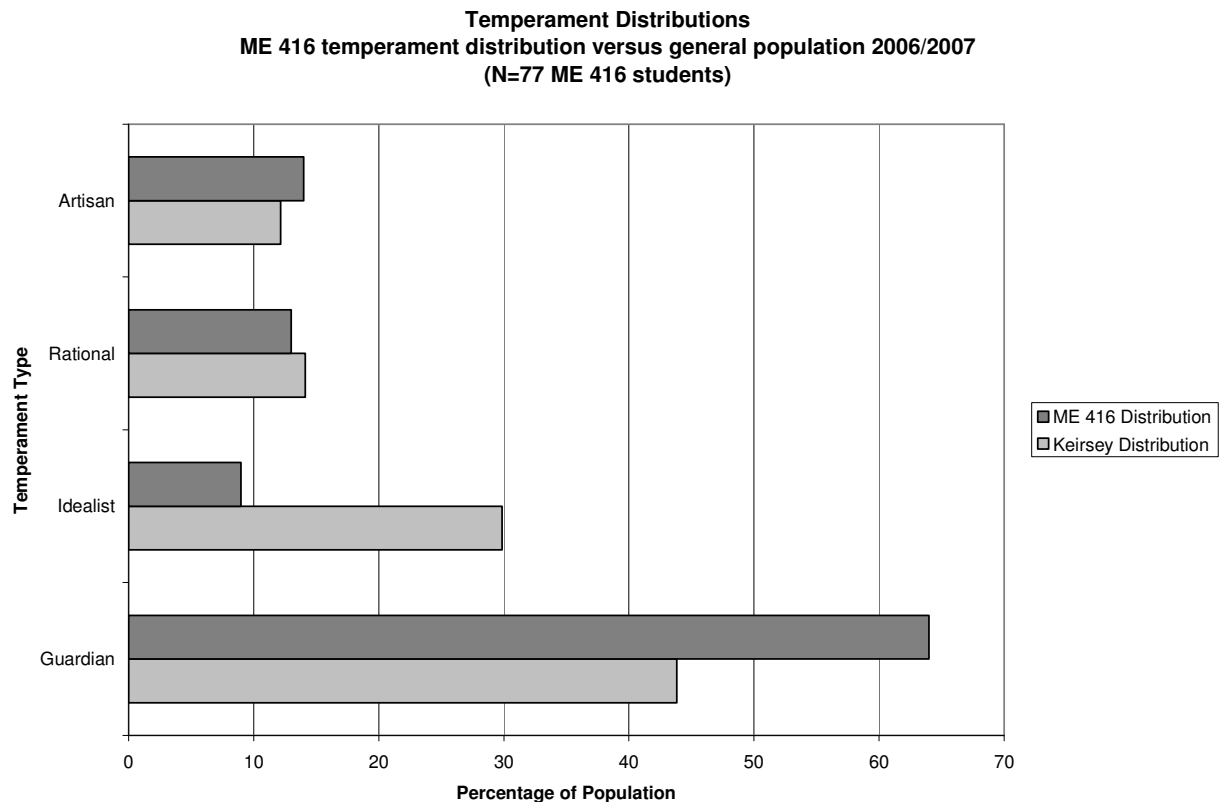


Figure 4.3: Temperament distribution of Design Clinic students versus general population for Keirsey’s four major temperament types.

4.4 Student and external-rater perceptions

Student and external-rater 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, we found 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.

We found 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.

5. Findings

5.1 External-rater assessment findings

The expected performance score is the competency level that external-raters expect graduates to achieve. The average expected performance score from wiki project ratings is 0.5 points below the the average expected performance score from the final project rating. There is not enough data in this set to determine the reason for this, but it raises some questions. Does the scope of

the artifact being assessed influence rater expectations? Do raters adjust their expectations when rating a single assignment, project (wiki), or semester portfolio (final project)? Is the level of specificity of the rubric criteria a factor? Grant Wiggins 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 [24]. On the other hand, is the influence descriptors have on rater expectations subordinate to the influence of artifact scope? What implications does this have for establishing expert validity and reliability, and aligning course assessments with programs? This finding suggests that further analysis using a difference approach is warranted. We will track external-rater expectations versus actual performance scores over time as the rubric evolves.

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."

5.3 Temperament findings

Temperament sorter data was not collected initially, but was a needs-based course addition in the third semester. The results provide helpful information for the Design Clinic and engineering program regarding retention and curriculum design. We want to know if the temperament distribution of students who persist in engineering is significantly different than the general population. The initial results show that the population of Guardians (SJs) in capstone design are significantly higher than the general population. The population of Artisans (SPs) is moderately higher than the general population. The population of Rationals (NTs) is roughly the same, and Idealists (NFs) are significantly underrepresented. A table of temperament descriptors for the four main types and percentages are presented in Appendix E.

6. Operationalization

The results of three semesters of assessment data might appear at first to be a great deal of work for faculty to take on. In this section, we present an operation schema for systematically starting up and maintaining a course assessment system using group artifacts. We illustrate 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.

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.

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.

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.

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 that we have 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.

7. Conclusions

A recent article in the New Yorker magazine is about an Australian Army captain, David Kilicullen, with a doctorate in political anthropology [32]. He studies fundamentalist insurgencies, including those in West Java and East Timor. He is now 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 work 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 we face 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, we focus on the assessment of professional skills by triangulating direct and indirect assessments of collaborative group artifacts. We actively involve external-raters in the assessment process in order to improve direct measures of professional, social, and team skills. Students and external-raters also provide qualitative feedback regarding the learning outcomes and overall project efficacy. Finally, temperament data is analyzed for the purpose of providing initial feedback regarding big-picture questions of how academic structures and curriculum influence the composition of student networks that persist in engineering.

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Appendix A: 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			Social Cognitivism	Cognitive Constructivism	Social Constructivism	Connectivism		
Static/Passive view of knowledge ←————→ Dynamic/Active view of knowledge								
What is knowledge?	<ul style="list-style-type: none"> exists in an objective reality separate from personal experience is reached through reason 		<ul style="list-style-type: none"> is transferred from teacher to student corresponds to reality, but is hard to know 		<ul style="list-style-type: none"> is internal, socially and culturally constructed does not necessarily correspond to a transcendent reality 		<ul style="list-style-type: none"> is distributed is interconnected is personal is context dependent 	
Whose knowledge?	<ul style="list-style-type: none"> individuals (stimulus response, behavior) 		<ul style="list-style-type: none"> individuals (teacher to student transfer) 		<ul style="list-style-type: none"> individuals in context (student-centered) 		<ul style="list-style-type: none"> individuals (connectionism/neural networks) networks and organizations human and non-human 	
Where is knowledge?	<ul style="list-style-type: none"> in the facts based on empirical evidence 		<ul style="list-style-type: none"> triangulated facts based on empirical evidence 		<ul style="list-style-type: none"> constructed both empirically and socially 		<ul style="list-style-type: none"> distributed across networks In patterns of organization 	
What is the purpose of knowledge?	<ul style="list-style-type: none"> 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 		<ul style="list-style-type: none"> a quest for certainty to the extent possible. progress that is forward moving toward a unified system of knowledge. objectivity to the extent possible. 		<ul style="list-style-type: none"> interpreting empirical and social evidence. creating new meaning through interaction with others. 		<ul style="list-style-type: none"> Make decisions See connections between fields, ideas and concepts. 	

Appendix B: Assessments

Data sources	#Participants	Semester	Assessment focus	Instruments
External-rater evaluations	N=6 N=3	1 2	Wiki Wiki	Six-point Likert-scale rubric, written

	N=4	3	Final projects	comments
External-rater focus groups	N=6 N=3	1 2	Wiki Wiki	Focus group discussion with note taker.
Student focus groups (2 sections)	N=8, N=10 N=9, N=8 N=7, N=7	1 2 3	Wiki and Basecamp Wiki and Basecamp Wiki and Basecamp	Focus group discussion with note taker
Pre-post student survey	N=33, N=35 N=22, N=28	2 3	Learning outcomes— level of importance, confidence	Anonymous paper survey, five-point Likert-scale.
Temperament Sorter	N=77	3,4	Student temperament profiles	Keirsey temperament sorter-II
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		1,2,3	All aspects	Notes

Appendix C: External-rater evaluations

(a) External-rater evaluation results for the wiki project, Fall 2005 and Spring 2006

Rating key: (1-2) emerging (3-4) developing (5-6) mastering			
Dimension	Ave. Performance	Ave. Expected	Ave. dif
1. group interaction	3.4	3.6	-0.2
2. written engineering communication	3.4	3.8	-0.4
3. safety, ethical, and societal constraints	3.1	3.1	0.0
4. integrating ideas	3.3	4.1	-0.8
5. corporate etiquette and "customer" ethic	3.1	3.6	-0.5
6. project management	2.9	2.8	0.1
7. knowledge management	3.0	3.3	-0.3
Total Average	3.2	3.5	-0.3

(b) External-rater evaluation results for final project presentations, Fall 2006

Rating key: (1-2) emerging (3-4) developing (5-6) mastering			
Dimension	Ave. Performance	Ave. Expected	Ave. dif
1. Group interaction	4.0	3.6	0.4
2. Communication	4.3	3.9	0.4
3. Safety, ethical and social constraints	4.7	4.1	0.6

4. Integrating skills	4.5	4.0	0.5
5. Corporate etiquette and ethic	5.3	4.0	1.3
6. Contemporary issues	5.0	5.0	0.0
7. Lifelong learning	5.3	3.9	1.4
8. Knowledge management	4.3	4.4	-0.1
Total Average	4.7	4.1	+0.6

Appendix D: Summary of Mid-term evaluation results

Strengths	Improvements	Insights
<ul style="list-style-type: none"> • Useful information • Easy to navigate and organize • Like helping future students • Answers questions about projects and Design Clinic processes 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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.

Appendix E: Design Clinic temperament percentages with descriptors

Guardians (SJs) 64%	Artisans (SPs) 14%	Rationals (NTs) 13%	Idealists (NFs) 9%
Conservative, stable, consistent, routinized, sensible, factual, unimpulsive, patient, dependable, hard-working, detailed, painstaking, persevering and thorough.	Adaptable, artistic, athletic, aware of reality and never fighting it, open-minded, on the lookout for workable compromises, see the need of the moment, storing up useful facts, having no use for stories, easygoing, tolerant, unprejudiced and persuasive.	Analytical, systematic, abstract, theoretical, intellectual, complex, competent, inventive, efficient, exacting, independent, logical, technical, curious, scientific and research-oriented.	Humane, sympathetic, enthusiastic, creative, intuitive, insightful, empathetic, diplomatic enthusiastic, authentic, a catalyst.