AC 2011-1931: ACADEMIC LITERACY AND ENGINEERING EDUCATION: DEVELOPMENT THROUGH CORNERSTONE DESIGN

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Abstract

Traditional views of literacy argued that student acquisition of the "technologies" of reading and writing were causally responsible for cognitive and developmental benefits that could subsequently be transferred to other educational tasks. [1,2,3,4] This "autonomous" model has gradually given way to a more "social" model of literacy that takes into account the context in which a literacy practice takes place, and the effects that setting may have on how literacy is conceived and enacted.[5,6,7,8,9] One of these new literacies, Academic Literacy, indicates a fluency not only in reading and writing, but also in particular ways of thinking, doing and being that are peculiar to academic contexts such as undergraduate engineering education. This paper reviews the changes in the concept of literacy over time and highlights the ways in which a sophomore level design course at a technological university in the Middle East has incorporated an explicit focus on Academic Literacy in order to enhance the progress of undergraduate engineers towards the competencies and attributes needed by professional engineers.

Introduction

Today's global economy is fueled by rapid innovation and technological breakthroughs. To function in such an economy, engineers require a full set of professional skills in addition to technological know-how. The effective engineer in industry is one who has excellent interpersonal skills, is able to work on multi-disciplinary teams, possesses a broad knowledge base, is aware of global issues, possesses information and leadership skills, is creative, and has the skills and knowledge to bring about innovation.[10,11] Traditional engineering programs and courses frequently struggle to address outcomes related to these skills, often working with the assumption that students either enter their programs with the abilities, or will acquire the skills with little explicit instruction or assessment. Others, such as that described in this paper, have recognized a need to include process oriented, project-based engineering courses in their programs as a means to address the calls of accreditation boards and industry for engineers with both technical and professional skills. For example, in design courses students work together in teams to solve open ended problems through the design process while simultaneously developing both types of skills. While such courses can be quite successful in meeting identified outcomes, they do not come without frustrations. As undergraduate engineers, the skill set of the students is still limited and projects which are clearly marked as engineering-related often result in discouraged students, particularly when the product is emphasized over the process. Frustration does not only result from a lack of technical background. It may also arise from students having limited experiences in the way engineers talk, write, think, and approach problems. These aspects, while often looked at as separate skills, are in fact all part of a concept termed Academic Literacy. Academic Literacy refers to the particular ways of thinking, doing and being in a specific academic context. Development of this type of literacy, it is argued, is a vitally important aspect of preparing students to become successful and competent professional engineers.

In this paper I will provide an overview of how the concept of literacy has changed over the decades, focusing in particular on the autonomous and ideological models. I will then describe the various components of Academic Literacy and illustrate their importance in providing

undergraduate engineers with the knowledge, skills, and dispositions that will enable them to become successful professional engineer. Within each component, specific examples will be drawn from a sophomore level introductory design course for Petroleum Engineers and Geoscientists. The paper will address how an infusion of the concept of Academic Literacy, in the form of Engineering Literacy, can serve to help transform the undergraduate engineering teaching/learning environment in ways that improve student engagement and the overall quality of future engineers.

Transforming engineering education

As both industry and engineering practice continue to evolve, engineering education should, it can be argued, also be transforming. However, the rate of change in educational practices has mostly lagged behind those of industry, with the basic model of engineering education, particularly in North America, continuing to reflect the recommendations made in the 1955 Grinter Report.[12] Based on this five decade old report, engineering schools chose to focus on a scientifically oriented curriculum that emphasizes the basic sciences, mathematics, chemistry and physics through a core set of six engineering sciences, ignoring concurrent calls to include professional and social responsibilities in the curriculum. As May and Strong[10] point out, "Five decades after this report was published, how many engineering schools can truly claim that their programs have evolved in terms of core content and methods of instruction in order to maintain pace with modern professional engineering practice?"

The Accreditation Board for Engineering and Technology (ABET) is one institute that has recognized the need for change, and now focuses the accreditation process of engineering programs not on credit hours and detailed specifications, but on educational outcomes and objectives. The ABET EC2000[13] criteria for accrediting engineering programs include a stronger emphasis on design capability and professional skills, as highlighted in the Criterion 3 a-k outcomes. In fact, six of the eleven suggested program outcomes (d, f, g, h, i, and j) are focused on non-technical skills and abilities. These criteria have been developed in order to guide engineering programs toward graduating engineers who can respond quickly and effectively to both technological and organizational change, who understand how to access and utilize information, and who can contribute collaboratively across multiple perspectives. As such, the focus on undergraduate engineering education should include not only technical skills and knowledge, but also development of problem solving skills and the abilities to communicate ideas and think critically and creatively, all aspect of Academic Literacy.

From a teaching standpoint such changes require moving away from teacher-centered lectures to learning environments that actively engage students with discussion of, and critical thinking about, economic, ecological and social issues. Cohen[14] has shown that for young adults, such skills are best learned through experiential approaches. Key practices that encourage desired student behaviors include problem-based discussion, cooperative learning, hands-on projects, critical reading, and student writing and presentations. No longer can learning only the material presented by the course instructor be considered sufficient, there is simply too much to cover. Rather, students need to learn how to learn – and how to think and act like engineers. To achieve these goals requires changes in how engineers are educated. It also requires, I argue, an understanding and infusion of the concept of Academic Literacy into undergraduate engineering curricula.

Concepts of literacy

Federico Mayor, former director General of UNESCO, wrote that "literacy is at the heart of world development and human rights."[15, p. xiii] Western society, in general, is very attached to the view that literacy is "casually associated with earning a living, achieving expanded horizons of personal enlightenment and enjoyment, maintaining a stable and democratic society, and, historically, with the rise of civilization itself."[16, p. 303] Literacy is associated with self-empowerment, economic development, and cognitive benefits. In fact, literacy is often linked to the most positive aspects of human civilization.[17] Illiteracy, on the other hand, "threatens people's ability to defend themselves, feed themselves, hold a job, and even communicate."[18] How are these concepts related to engineering? What would it mean to be a "literate" engineer? It is certainly more than simply being able to read and write, as will be discussed below, beginning with an examination of two dominant models of literacy, the autonomous model and the ideological model.

The autonomous model

The belief that literacy alone can be causally responsible for the positive benefits outlined above has been promoted by a number of authors. Such a perspective is known as the "autonomous" or "individual" model of literacy. While most academics in the field of literacy theory have moved beyond the initial conjectures of the proponents of this model, it can be argued that the early views presented still strongly influence popular thinking, the policy of international agencies, and the focus of most educational institutions, including those focused on educating undergraduate engineers. It is therefore important to look at the claims of those who have argued for an autonomous model of literacy. Generally speaking, an autonomous model of literacy is one which considers literacy (reading and writing) to be a neutral technology, a technology that can easily be detached from social context. Followers of this model argue that literacy can be isolated as an independent variable, thereby allowing the predicted cognitive effects of literacy to be examined. The autonomous model attempts to distinguish literacy from schooling and sets up a dichotomy between written and oral modes of communication. Finally, it assumes that there will be certain intellectual and developmental consequences of students acquiring the "technologies" of reading and writing.[7] Some of the most widely read authors holding this view of literacy are Goody[1,2,19,20], Goody and Watt[21], Olson[4,22], Ong[23,24], and Havelock[3,25,26].

One of the earliest writings from an autonomous perspective was that of Havelock[25], who compared Homeric poems and Platonic dialogue and concluded that oral and written communication could lead to differences in thinking. Drawing on evidence from a wide range of sources, Goody and Watt[21] further developed Havelock's thought, attempting to demonstrate the existence of hypothesized links among literacy, logic and various classification schemes. They argued that literacy has played a major role in the development of Western industrialized society. Literacy, in their view, affects the way the members of a society think, thus leading to great differences between oral and literate societies. Writing, they argue, serves as an aid to memory, allowing people to reflect, which, they claim, increases one's cognitive abilities. In other words, they are arguing that having the ability to read and write will causally lead to improved thinking. Goody and Watt did not provide concrete empirical data to support their claims, instead basing their arguments on historical analysis and thought experiments. They made great leaps from observed historical social and cultural changes to individual cognitive benefits. Their

conclusions stem from the belief that rational thought is the most valued of thought, which may not be the position held by all cultures, or by engineering firms looking for creative and innovative solutions. Goody continues to look at the differences between oral and written societies, arguing that literacy fosters higher cognitive skills. He postulates that writing allows one to be more abstract and less personalized and that it has led to the formalization of logic.[1,2] Street[7] has argued that Goody overstates generalities, creates a false dichotomy between oral and literate, and presents hypotheses which cannot be tested.

An early criticism of the autonomous model was its failure to separate the effects of literacy from those of schooling. This issue was addressed in the work of Scribner and Cole.[27] Scribner and Cole's study focused on the Vai people of Liberia who had developed a writing system of their own that was used in commercial and personal affairs. The script was taught at home, not in schools, therefore providing an ideal natural experiment that allowed for the separation of cognitive consequences of schooling from those of literacy. The principal focus of this study was to test the hypotheses about literacy's impact on cognition. After exhaustive research which implemented psychological testing methods adjusted by ethnographic and demographic information, the authors reached the conclusion that literacy did not appear to be the cause of any generalized changes in cognitive abilities. However, literacy did lead to localized changes in cognitive skills. The skills gained through literacy include being able to present information in an expository form, being better at organizing and presenting information, and being able to give clear and appropriate instructions. The study further demonstrated that it is schooling, not literacy, which provides the essential context for the development of the cognitive skills of analysis and reasoning, key attributes desired in professional engineers. These skills are also important for the decontextualization of language, that is, the skills the supporters of the autonomous model had attributed to literacy.

To summarize, those who adhere to the autonomous model argue that literacy itself is responsible for enabling individuals and cultures to expand their range of activities, that having learned to read and write would, alone, enable engineering students to think and read critically and communicate effectively. The experimental findings, however, indicate a need to include development of cognitive skills as part of any educational program if the overall desired outcomes are to be obtained, that simply having the technical, autonomous abilities to read and write are not enough. In other words, literacy development is specific to context, and should continue to be developed in new contexts such as undergraduate engineering education.

The ideological model

The view that literacy is a technical skill that is key to both individual and societal development has in the past two decades given way to a new model of literacy put forth in the early 1980s, the "ideological", or "social", model. This model takes into account the social context in which a literacy practice takes place, and the effects that setting may have on how literacy is conceived and enacted. It is thus much more than the mere technologies of reading and writing. When viewed from a social perspective it is often seen that literacy practices involve struggles for power and control over the literacy agenda.[8,28]

The ideological model concentrates on the *social practices* of reading and writing. It recognizes that these practices are culturally embedded, that literacy is a socially constructed practice and thus has different meanings for different groups in different contexts.[7,8] Research which looks at

literacy from an ideological, or social, perspective, argues that peoples' cognitive skills, their abilities to reason, are domain specific and cannot be generalized across task domains that differ in surface form (Erickson 1984/1988). In other words, the ways of thinking, being and doing developed in one's English class is not directly transferrable to engineering courses; rather, there is a need to explicitly talk about how they differ, and to provide opportunities to learn to read, write, and think "like an engineer." Much of this philosophy is supported by studies which have looked cross-culturally at the contexts in which literacy is practiced. These include Akinnaso[30], Besnier[31, 32], Hornberger[33], McLaughlin[34, 35], and Reder and Green[36].

Perhaps the most important aspect of a social perspective on literacy is that it requires one to look not only at the set of skills associated with literacy, but more importantly the enactment of the literary event, that is, the larger social and cultural events and relationships that result from it. In terms of engineering education, this means, for example, being cognizant of who is writing a journal paper, who has funded the research, and what the purpose of the research is. Such aspects are especially vital when looking at the impact of engineering solutions in a global, economic, environmental and societal context.

The criticism of the ideological model of literacy is that in creating a pluralization of literacies, theorists may simply be creating a new reification in which each literacy is viewed as a fixed and essential thing.[28] Street has responded by writing that the plurality argument is important if for no other reason than to counteract the assumption that there is a single autonomous literacy that is the same everywhere.[9]

Academic literacy

One of these new literacies, Academic Literacy, has many apparent connections to the new directions being promoted in undergraduate engineering education. Academic Literacy indicates a fluency not only in reading and writing, but also in particular ways of thinking, doing and being that are peculiar to academic contexts such as undergraduate engineering education.[5] Beyond these, it also includes the use of technology, the ability to think both critically and creatively, and "habits of mind" - attitudes and predispositions - as part of its definition. The similarities between these components of Academic Literacy and the professional skills outcomes of ABET are striking. Foundational abilities in each of the areas of Academic Literacy are what is expected from matriculating students. ABET 3a-k are indicators of what students should attain by completion of an engineering program. As such, they encourage continuous development of the critical reading, writing and thinking abilities of entering engineering students over the course of their studies. Thus, I argue that ABET 3a-k, particularly those related to professional skills, are, in fact, a indicators of a specific type of Academic Literacy unique to engineering students who are preparing for an engineering profession, what could be called Engineering Literacy. They are also, it can be argued, a foundation of the nine attributes of a professional engineer described in *The Engineer of 2020*.[37] These attributes are: strong analytical skills, practical ingenuity, creativity, communication, mastery of business and management principles, leadership, professionalism, high ethical standards, and life-long learners.

Engineering faculty often work from the assumption that incoming students already possess sufficient skills to engage in the learning of engineering. Unfortunately, it is often the case that student aptitudes and attitudes regarding communication, thinking, use of technology and habits

of mind is less than desired. A 2002 study by the Intersegmental Committee of Academic Senates[38] found that most first year students lack strategies in effective critical reading, and that 83% of faculty felt that a lack of analytical reading skills contributes to students' lack of success in a course. Additionally, it was found that only 1/3 of entering college students are sufficiently prepared for writing assignments that require analyzing information and synthesizing information from several sources. In fact, faculty respondents indicated that more than 50% of their students fail to produce papers relatively free of language errors. While these statistics are based on the responses of faculty at universities in the state of California, they mirror those obtained anecdotally at the university were I work in the Middle East, and that I have heard from faculty at conferences around the world. In other words, there appears to be a need across the board to infuse development of Academic Literacy knowledge, skills and positive dispositions into engineer programs to ensure that students are best prepared to achieve desired outcomes, such as ABET 3a-k. By doing so, we will be able better prepare students to think and act like professional engineers as we connect the basics of Academic Literacy with the outcomes of ABET and the attributes outlined in documents such as *The Engineer of 2020.*

Academic literacy and Engineering Education: *The Context*

This research seeks to explore how the desired competencies/outcomes/attributes might be achieved by asking how students acquire the skills, experiences, or competencies that they are missing at matriculation[38], and how programs can ensure that they continue to develop in these areas over the course of their studies, eventually acquiring Engineering Literacy. The study took place in a sophomore level design course at a technological university located in the Middle East. The university itself focuses on providing quality undergraduate education for future energy sector engineers, with an annual enrollment of just over 1000 students (70/30 split between male /female engineering students). Its academic structure consist of six engineering programs within a College of Engineering plus six departments within a College of Arts and Sciences, with degrees only being offered through the engineering programs. The College of Arts and Sciences provides a common first and second year for all students. The student population consists of approximately 75% students from the host country and 25% students from other areas of the Middle East. As an English medium university located in the Middle East, nearly 100% of students have English as a second language. In addition, a large percentage of students are among the first generation in their family to attend a university.[39] A majority of the students come from a public school system that for the most part has tended to focus on rote memorization of teacher presented material. As a result of this background, a substantial percent of students enter engineering studies with limited exposure to the Academic Literacy components of Communication, Thinking Skills, Use of Technology, and Habits of Mind that are needed to develop Engineering Literacy. Thus, if we hope instill the attributes of a professional engineer, we must begin with an explicit focus on the various components of Academic Literacy.

A total of 20 two-hour classroom observations were conducted over the course of a semester. Detailed fieldnotes from each session were reviewed and coded based on the core components of Academic Literacy outlined above. During the analysis process, one additional theme emerged which is relevant to the discussion in this paper: Explicit discussion/instruction related to Engineering Literacy. This theme included references to either ABET a-k outcomes or the expectations of the professional engineering work environment. Findings from the classroom observations where triangulated through review of course materials and focus group interviews

with course instructors and students. The ethnographic component was further extended through corpus analysis of textual materials used in the course in order to determine Academic English particular to the design course under study. This aspect aids in the identification of features of subject specific and Academic English important to the process of becoming an engineer. It will be tangentially referred to within this paper, as analysis is still in its early stages.

As mentioned in the background section, the types of activities that could potentially best support an infusion of Academic Literacy are those which move away from the traditional lecture followed by *product* focused exams, to teaching and learning that is *process* oriented, one that helps transition young people towards becoming professional engineers. In many ways, a well taught introductory design course can do just that. In such courses students are exposed to engineering design projects at an early stage in their engineering education. Such courses provide an opportunity for students to experience the creative nature of the engineering design process while simultaneously developing professional skills such as project management, team-work, life-long learning, communication, and problem solving, providing ideal opportunities for explicitly talking about Academic Literacy. Thus, one of the introductory design courses at the university were the author teaches, STEPS 251 PGEG, was chosen for the purposes of this research. Before describing the specific course, a brief philosophical perspective on the design approach is provided.

Quality design courses should do more than just teach the functional and technical aspects of design; they need to teach the design process and the professional skills needed to manage a design project.[10] This is best done by ensuring that the course includes the following core components:

a. The project or problem is given as client statement or need for a potential new design
b. Students have to make decisions to arrive at their proposed unique solution
c. Students evaluate their design based on known engineering science
d. Students receive constructive feedback on their design *process* performance.

Importantly, it is vital that assessment of the students consider the professional skills developed and the design process used, not just the product. In fact, the final product assessment component should be minimal. For the STEPS 251 course the final product accounts for only 10% of the overall grade. Other deliverables focus on technical skills and knowledge, and include assessment components that look at students' development across the four aspects of Academic Literacy: a) communication (reading, writing, speaking, listening, academic language), b) critical and creative thinking, c) the use of technology, and d) life-long learning (habits of mind). Each deliverable is process focused and based on clear performance indicators that are shared with students in early stages of the course and referred to throughout the course. In each sub-section below, the indicators observed being discussed in class are highlighted. In this way, STEPS 251, and quality design courses in general, provide a means for modeling how engineers think, what they do, and what they are. As mentioned earlier, this is a key aspect of looking at Academic Literacy from an ideological, or social, perspective.

Developing engineering literacy through the design experience

The Strategies for Team-based Engineering Problem Solving (STEPS) program was first instituted in 2002 with an understanding of the design process and development of team-based, project management, and communications skills set as primary outcomes. Human values, social aspects of engineering design, and engineering ethics are also discussed within the context of the course projects. STEPS is a student's first exposure to engineering design, occurring in the Sophomore year for most. The specific course of this study, STEPS 251 PGEG, is a project-based design course for sophomore level students studying Petroleum Engineering and Petroleum Geosciences. Its purpose is to provide students with an experiential overview of the petroleum industry through the planning of exploration and development of a local concession area. The course is team taught, with 1 Geosciences, 1 Petroleum Engineering, and 1 Communication faculty all serving as facilitators and providing input at various points throughout the semester. In the course, student teams begin with a real-life set of seismic data provided by a local company. The students interpret the seismic data using *GeoGraphix* software, identifying key geological structures, estimating the potential reservoir volume, and determining the potential Original Oil in Place (OOIP). They present their results to the client both through an oral presentation and a written Seismic Report. Based on these findings, the client requests that the team propose exploration plans which could be used to confirm the presence of hydrocarbons as well as the actual extent of the reservoir. Working on an assumption that hydrocarbons will be found, the groups also design three conceptual development plans, taking into consideration different configurations of well types, drilling rigs and production facilities as well as constraints regarding lease period, recovery factors, structure permeability data, and Enhanced Oil Recovery (EOR) methods. A full economic analysis is carried out for each conceptual design in order to determine the potentially most profitable plan that satisfies all constraints and best achieves the identified objectives. Throughout the process, students are also asked to consider environmental and social impacts of the planned activities, and to develop a clear statement as to how any potential impacts could be mitigated, taking into consideration their effect on overall profits. A final report is written and presented orally to the client. In addition, posters are developed and presented to other students and faculty during an end of semester poster session.

We now discuss they ways in which each of the components of Academic Literacy were seen to be addressed and developed in this course. The core components of Academic Literacy include Communication (Reading, Writing, Listening, Speaking, Academic Language), Thinking Skills (critical and creative), Use of Technology, and Life-long learning/Habits of Mind. Below, each of these are discussed along with their relevant ABET outcome(s) and connections to attributes of a professional engineer. Specific example activities/assignments observed in the STEPS 251 course are presented, including learning objectives that have been identified as helpful in developing Academic Literacy specific to the engineering context.

Communication

Communication is the aspect of Academic Literacy most closely associated with traditional concepts of literacy. However, in the ideological model, reading and writing are much more than mere technical abilities. They include an ability to interact with written materials in a critical manner, and to write in a way that illustrates critical and creative thinking. Beyond reading and writing, communication also includes the ability to speak and listen in ways appropriate to

academic environments. These concepts are embodied in ABET outcomes 3g "an ability to communicate effectively" and 3d "an ability to function on multidisciplinary teams," which involves sharing ideas and listening attentively. The NEA points to the importance of communication as engineers increasingly work on interdisciplinary teams, must be able to explain their thinking to diverse audiences and partners, as well as think with others in order to arrive at solutions to problems.[37, p. 55]

In the STEPS 251 course the entire design process is initiated through a client statement sent to each team. The first team task is to define the project and respond to the client through a letter of understanding. The letter of understanding includes a clear outline of the identified objectives and constraints, along with a set of clarification questions for the client. Assessment of this document includes a focus on content, task completion, organization and language. The first two components are graded by the technical instructors and the latter two by the communications instructor. In terms of language, there is a focus on style and formality of language to be used in the letter, as well as in the written seismic and final reports. There is also discussion and assessment of the use of academic vocabulary and grammar, as well as vocabulary specific to the course. Each team member also makes three presentations throughout the semester. As with the writing, assessment is divided between content (team based) and individual presentation skills. For both the writing and the speaking, particular emphasis is put on the development of Academic English skills, particularly in terms of development of the vocabulary and grammatical structures appropriate to academic writing, otherwise known as Academic English.

Academic English The register of English that students encounter and are expected to use in their engineering courses is labeled as "Academic English." Academic English is the language that is characteristic of the texts of academia, including the multiple competencies needed to understand and produce it, and it is what is expected in student reports and formal presentations. It tends to be more precise and specific in reference. It is much more dependent on "text" than on "context" for interpretation. The vocabulary of Academic English tends to include many more items that are Latin or Greek in origin.[40] Additionally, it is much more complex syntactically, making use of distinctive grammatical constructions such as the passive voice, adjunct temporal phrases, and an abundance of prepositional phrases. Overall, it is the register that most native speakers of English learn through literacy, either in the home or at school. While it usually takes second language learners only 1-2 years to learn social language, research has shown that learning Academic English may require as much as 4-10 years.[41,42] This process can be sped up if we draw students' attention to specific features of Academic English, and provide them with guided practice on how to interpret and use it. In STEPS 251, features of Academic English are focused on during the writing process, with specific attention paid to using more formalized language. There are fours specific areas that were seen to be addressed:

Vocabulary –Both content vocabulary and Academic English. Vocabulary refers to such issues as the multiple meanings of words (e.g. *wildcat* in drilling vs its meaning in everyday speech), the presuppositional levels of meaning and use; the choice of words reflecting or implicating subtle gradations of meaning for effect (smart, clever, intelligent); and the choice of words for precision in reference. Examples of academic words are: *analyze, assign, consist, distribute, chapter, selected, obtain, random, corresponding, indicated, procedure, approximately, occur, assume, specified, consists, preceding, substitute, variation.* These words are not in the most common 2000 English words, and are more likely to only be encountered and used in academic

contexts.[43] It is thus important to draw students attention to how they are used, and to encourage the use of academic vocabulary in student writing.

Grammatical Structures – Discussion of grammatical structures focuses on the ways in which information is fore-grounded, back-grounded, organized and structured in academic writing. Common syntactic structures found in academic writing include passive voice (*FPSO are generally recommended by most companies* as opposed to *Most companies recommend an FPSO*), adjunct temporal phrases (*After completing the seismic interpretation, the company…,*) and prepositional phrases.

Rhetorical and Cohesive Devices – These are the means for holding text together. They include phrases such as *began in …and ended in, during the period, so, because, the effect of…was, as a result of….* In other words, these are the grammatical means for linking words and ideas together. Particular focus was seen to be put on the cohesiveness within and between paragraphs, as well as between different sections in the written reports.

Phraseological Patterning – This is the most elusive aspect of really knowing a language. It includes the natural, idiomatic, or preferred ways of expressing ideas in the language (e.g. *to catch up with, down the river*). Without these phrases the language might be grammatical, but nonetheless, not natural. Many of these are particular to a given discipline.

Additional objectives shared with students support the process of understanding particular aspects of reading, writing and speaking like an engineer are listed below.

By the end of the course, the student will have…

- read skeptically;

- sustained and supported arguments with evidence;

- embraced the value of research to explore new ideas through reading and writing;

- identified and used rhetoric of argumentation and interrogation in different disciplines, for different purposes, and for diverse audiences;

- engaged in intellectual discussions.

These objectives expect much more than simply reading, writing and speaking. They push the classroom focus toward much more critical approaches to the communication skills such that they strongly overlap the Academic Literacy component of Thinking Skills.

Thinking skills

The thinking skills movement of the 1980s and 1990s has produced a substantial body of research through which three main principles have emerged: 1) The more explicit the teaching of thinking, the greater its impact on students, 2) the more classroom instruction incorporates an atmosphere of thoughtfulness, the more open students will be to valuing good thinking, and 3) the more the teaching of thinking is integrated into content instruction, the more students will think about what they are learning. These principles provide the basic rationale for infusing thinking skills into content instruction. These skills are not just part of Academic Literacy, but

are also expressed in ABET outcomes 3a, b, e, and k. However, the assumption that engineering *is* problem solving and thinking often leads faculty to assume that students will acquire the ability to think "like an engineer" simply by studying engineering. This is not always the case.

The instructors in the STEPS 251 work with, and share with students, the following definition of thinking skills:

> "Thinking skills are those skills which enable a person to decode information and make connections in order to reach a plausible conclusion or create new scenarios."

This locally developed definition contains many components similar to those found in the literature. For example, most definitions of thinking skills refer to a need to "comprehend." Locally, this has been defined as "decoding information." Other definitions refer to "make decisions" and "synthesize many elements". Similar components are also found in the locally developed definition. Throughout the semester instructors talk about and encourage students to reflect on what behaviors are indicators of critical or creative thinking. Table 1 provides a list of those highlighted, or that were mentioned by students and faculty during interviews.

Table 1. Indicators of thinking skills discussed or mentioned in STEPS 251 during the semester under study.

asking questions	justifying solutions	inferring and predicting	transferring ideas
seeing exceptions	providing counter examples	comparing	making connections
demonstrating curiosity	identifying patterns	gathering information	organizing information
deducing	focusing on task	using strategies	generalizing
critiquing	synthesizing	visualizing	evaluating

These indicators are similar to the habits of mind referred to in the section on life-long learning, reiterating the strong connections among the components of Academic/Engineering Literacy. The thinking skills learning outcomes that were observed to be explicitly modeled and assessed during the course include:

> *By the end of the course, the student will have…*

- built an argument to justify your solution;

- made a connection between the result and a real life scenario in order to make a decision;

- used physical images to confirm the accuracy of the claim;

- made a prediction using data generated;

- reasoned beyond available information to fill in gaps;

- asked probing questions.

These criteria serve as part of the grading criteria for the written reports of the course. Instructors were observed regularly talking about the need to do these things when working in the petroleum industry, and students were encouraged to practice each during the process of completing the project tasks.

Use of technology

Technology has greatly transformed the learning community, having shifted the concept of learning from an ability to amass (or remember) facts to the ability to adapt to constantly changing ways of finding information, evaluating its validity, and using it in ethical and creative ways. In fact, as pointed out by ICAS "Students' success in college has as much to do with their ability to find information as to recall it."[39, p. 6] Another consequence of technology is that available resources have increase exponentially. Academic Literacy focuses on students having the ability to find, evaluate, use and communicate information in all its various formats. All of these are required of an undergraduate engineer. In addition, professional engineers are also expected to have familiarity with discipline specific technical software, be it *MathLab, SolidWorks,* or *Geographix.* Use of technical tools in engineering means having the ability to apply them to specific situations and to analyze results. The use of technology for engineering problem solving is embedded in EC2000 3k "an ability to use…modern engineering tools necessary for engineering practice." It is also part of 3b, c, g, and j, which focus on communicating effectively and having a knowledge of contemporary issues. In STEPS 251 teams were seen develop web pages that served as a Data Retrieval System for their work. The link to this webpage was shared with the client, so that they could have 24/7 access to documents and information regarding the progress of the project. The objectives observed being shared with students during the semester included:

> *By the end of the course, the student will have…*

- used search engines effectively;

- evaluated material found on the Web, including the authenticity of the Website and the author, and the validity of the material;

- presented material in Web format or media;

- used interactive lab-based software (*SeisVision and Geographix*) to interpret and present seismic data.

In addition to those related to Communication aspects, it can be seen that students were exposed to, and expected to appropriately and accurately use software specific to the field. Students' individual technical skills were observed to be assessed through practical quizzes, while the accurate and appropriate use of it for presenting technological data was assessed in a written seismic report and through the oral seismic presentation. During the economic analysis stage of

the project, students are expected to develop robust Excel worksheets for determining a series of key economic indicators relevant to the overall objectives of the project. These worksheets were not directly assesses, but the information generated was assessed as part of the final report and presentation.

The NAE highlights the "interdependence between technology and the social and economic foundations of modern society."[37, p. 55] While strong efforts were made to teach technology and how to use it in the STEPS course, no direct discussions or comments were observed that referred to this important attribute of a professional engineer. There were, however, comments about the ever changing sophistication of engineering software tools. These, inevitably, led instructors to mention the need for life-long learning, the final component of Academic/Engineering Literacy infused into this introductory design course.

Life-long learning/Habits of mind

Siewiorchk et al[44] draw attention to the fact that it is not possible for students to learn all the theory and skills that they will need upon graduation during their university years; thus, an ability to continue to learn is vital. In essence, this is why ABET 3i – "life-long learning" is so important. It is generally accepted that life-long learning skills, while originating during a students' undergraduate career, are not fully realized or utilized until after graduation. In many ways, what educators are tasked with is providing students with models of the skills and competencies that will be required to continue self-education beyond the end of formal schooling. As educators, we need to provide the "spark". However, as Mourtos[in 44] has pointed out, the main component of the ABET criteria 3i "…recognition of the need for… lifelong learning" is not an aspect of the traditional cognitive domain usually focused on in higher education. Rather, it belongs to the affective domain, not a skill that can easily be "taught" and directly assessed, but still vitally important. The second component of 3i "…an ability to engage in lifelong learning" better fits within the cognitive domain, and can thus be more easily "taught" or at least modeled. Van Treuren[45] supports this perspective in his discussion of the views of Mechanical Engineering faculty regarding life-long learning. He points out that faculty often think of themselves as models of life-long learning. While this belief seems to make the teaching of life-long learning skills straightforward, the traditional lecture model so prevalent in engineering education does very little to prepare the student for life-long learning,[46] instead leading to passive students who rely on a more knowing other to tell them what to do, not exactly a desirable attribute of a professional engineer. Instead, it is active learning approaches in which much of the responsibility for learning is transferred to the student that best "model" and prepare students for life-long learning. Life-long learning is also connected with ABET 3f "an understanding of professional and ethical responsibility, 3h "the broad education necessary to understand the impact of engineering solutions ins a global, economic, environmental, and societal context, and 3j " a knowledge of contemporary issues." Each of these can be touched on in engineering courses, but eventually it will be up to the future engineer to continue to stay informed and up-to-date. Any attempt to promote the development of recognition of the need for, and ability to engage in, life-long learning inevitably requires student-centered activities. To be most effective, such activities should support the achievement of specific learning objectives. Within the STEPS 251 course, the instructors start by stating what they mean by life-long learning:

"Life-long learning means having the desire and skills to continue to access knowledge outside of the formal education setting."

As with thinking skills, a number of indicators of students who possess life-long learning skills and a recognition of the need to engage in life-long learning were observed being shared over the semester. These are shown in Table 2.

Table 2. Indicators of life-long learning discussed or mentioned in STEPS 251 during the semester under study.

finds new materials on his/her own	is aware of current events	keeps up-to-date with events in the world	accesses information from a variety of sources
reads critically	categorizes and classifies information	synthesizes new concepts	able to make estimations and approximations based on prior knowledge
reflective	motivated to learn	goes the extra mile	able to frame questions and seek solutions

From these indicators, STEPS 251 instructors have established several life-long learning learning objectives.

By the end of the course, the student will have…

- synthesized new concepts from a variety of sources;

- framed research questions and sought solutions;

- identified, accessed and critically read relevant materials from a variety of sources;

- justified design decisions through reference to information found outside of formal instruction;

- discussed current events and their relevance to the discipline;

- asked probing questions;

- demonstrated initiative and developed ownership of their education;

- exercised the stamina and persistence to pursue difficult subjects and tasks;

Through the initial process of Defining the Problem in the STEPS 251 course, each team identifies areas in which they require more in depth background in order to successfully

complete the project. This leads to formulation of research questions and individual literature reviews. It is this activity, the literature review, which is used to explicitly talk about life-long learning and develop the skills needed to engage in it. The activity itself has three main learning objectives that are drawn from those listed above: a) Framed research questions and sought solutions; b) Identified, accessed and critically read relevant materials from a variety of sources; and c) Synthesized new concepts from a variety of sources. For STEPS 251 students, this is their first experience of identifying and refining a research question related to the petroleum industry, their first experience accessing peer-reviewed articles in the field, and their first experience needing to synthesize the information into a coherent review that will inform a specific project. Thus, the process is broken down into parts and scaffolded, with students receiving guiding questions from the instructor at various stages. This is not a process of the instructor telling students what to do. Rather, the instructor is acting as a facilitator. The guidance was often observed to follow a think-aloud process in which the instructor posed probing questions or verbally stated the types of questions they would be asking themselves as they went through the iterative process of framing the research question, finding sources, and synthesizing information. The task description and assessment rubric used clearly provide additional scaffolding for students as they actively engage in learning.

Summary

As can be seen, the life-long learning activity described as the fourth component of Academic Literacy is intimately related to the previous three. Students use technology to access resources, organize their references, and type their papers. They must critically read the articles they have identified and synthesize the ideas across from the articles. They are expected to reference the literature as a means of justifying the recommendations they make for their final development plans. Finally, in writing their literature review, they are asked to focus on the accurate and appropriate use of formal vocabulary and grammar in a coherent, well organized document. All of this is done within the context of developing an ability to apply the design process, technical skills and knowledge, thus developing both technical and professional skills simultaneously.

Conclusion

The purpose of this paper was to highlight developments in the understanding of the concept of literacy and to describe the aspects of Academic Literacy addressed and developed in a sophomore level design course for Petroleum Engineering and Geosciences undergraduates. Classroom based research has looked at how instructors and students experience Academic Literacy in this class, and how instructors facilitate student access to the knowledge, skills and dispositions necessary for success with Academic Literacy in the context of an engineering design course. Overall, it was seen a focus on Academic Literacy in this multi-disciplinary design course provided students with a better understanding of what is expected of them as emerging professional engineers and enabled them to think more creatively and critically about the design project presented. These are abilities, knowledge and dispositions that will serve then well as they continue to acquire an ability to think like engineers, act like engineers, and be an engineer. Importantly, it is found that the nature of engineering design course, in which the focus is on the process rather than the product, provides an excellent environment for activities that provide practice in areas of Academic Literacy that can enhance the skills, abilities, and dispositions of students.

It can be argued that it is through awareness of literacy theories and incorporation of them into our teaching practices that we can best begin to bring about the process of transforming engineering education in ways that will better prepare our students to enter the workforce with the full set of skills needed to be a productive member of a global society. In this way, the concept of Academic (Engineering) Literacy can serve as an umbrella for better thinking about how to develop the professional skills so desired in today's engineer.

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