An Industry-University Partnership to Foster Interdisciplinary Education

Prof. Farrokh Mistree, University of Oklahoma

Farrokh's passion is to have fun in providing an opportunity for highly motivated and talented people to learn how to define and achieve their dreams.

Farrokh Mistree holds the L. A. Comp Chair in the School of Aerospace and Mechanical Engineering at the University of Oklahoma in Norman, Oklahoma. Prior to this position, he was the Associate Chair of the Woodruff School of Mechanical Engineering at Georgia Tech – Savannah. He was also the Founding Director of the Systems Realization Laboratory at Georgia Tech.

Farrokh's current research focus is model-based realization of complex systems by managing uncertainty and complexity. The key question he is investigating is what are the principles underlying rapid and robust concept exploration when the analysis models are incomplete and possibly inaccurate? His quest for answers to the key question are anchored in three projects, namely,

Integrated Realization of Robust, Resilient and Flexible Networks

Integrated Realization of Engineered Materials and Products

Managing Organized and Disorganized Complexity: Exploration of the Solution Space

His current education focus is on creating and implementing, in partnership with industry, a curriculum for educating strategic engineers—those who have developed the competencies to create value through the realization of complex engineered systems.

Email <farrokh.mistree@ou.edu> URL http://www.ou.edu/content/coe/ame/people/amefaculty/mistree.html LinkedIN http://www.linkedin.com/pub/farrokh-mistree/9/838/8ba

Prof. Zahed Siddique, University of Oklahoma

Zahed Siddique is a Professor of Mechanical Engineering at the School of Aerospace and Mechanical Engineering of University of Oklahoma. His research interest include product family design, advanced material and engineering education. He is interested in motivation of engineering students, peer-to-peer learning, flat learning environments, technology assisted engineering education and experiential learning. He is the coordinator of the industry sponsored capstone from at his school and is the advisor of OU's FSAE team.

Prof. Maysam Pournik, University of Oklahoma
Mr. Bryan William Bodie

An Industry-University Partnership to Foster Interdisciplinary Education

The increase in technological change and global competition has led to the natural pairing of colleges and businesses in the United States and around the world. A collaboration of business and education can target and emphasize specific labor markets, skills, and the student to help prepare a highly skilled workforce that increases economic opportunity and competitiveness. This system of learning creates a well-rounded education that fulfills the demand for skilled employees with a knowledgeable and motivated student body. The strongest of these partnerships develop when the local and regional economic and workforce needs are considered on the college level. By joining together, these partnerships can use their combined resources to identify and solve the complicated challenges facing society and business today. In this paper we present an industry-academia collaboration model to enhance student learning and experience.

In 2013 Baker Hughes teamed up with the School of Aerospace and Mechanical Engineering and the Mewbourne School of Petroleum and Geological Engineering at the University of Oklahoma to start a partnership with its students and Baker Hughes known as the 21st Century Co-op. The BHI 21st Century Co-op is a five year accelerated Bachelor of Science/Master of Science degree program in mechanical engineering or petroleum engineering. In addition to the required courses for the disciplinary degree, the BHI 21st Century Co-op curriculum includes customized courses offered by faculty and BHI engineers during summer internships, a senior capstone course, graduate cross-disciplinary courses and graduate theses all relevant to Baker Hughes and its initiatives.

In this paper we present the salient features and lessons learned of this industry university partnership aimed at ensuring the scholars hit the road running when they take up positions in industry.

1. PREPARING ENGINEERS FOR THE 21ST CENTURY - PREAMBLE

1.1 Challenges

The rapid progress of globalization [1] has led to many unprecedented changes in the world in which students are educated and in which graduates will practice. As Friedman [1] puts it, "Globalization has collapsed time and distance and raised the notion that someone anywhere on earth can do your job, more cheaply. Can Americans rise to the challenge on this leveled playing field?" In 2004, the National Academy of Engineering published a report summarizing visions of what the engineering profession might be like in the year 2020 [2]. A follow-up report [3] on how to educate the engineer of 2020 was released a year later. The key message gleaned is that engineering education has to be adapted to the challenges of the future with regard to globalization.

Globalization has put engineering education and the profession at a challenging crossroad [4]. The impacts of rapid technological innovations on the modern societies have been amplified by the globalization of the economy [1]. The competitiveness of the U.S., which is linked to the standard of living, is dependent on our ability to produce a large number of sufficiently innovative engineers [2, 3, 5-7]. Serious concerns have been raised about whether the U.S. is adequately preparing the next generation [8] for the demands of an increasingly high-tech and interdisciplinary workplace, and whether enough scientists, engineers, and highly skilled workers are being produced [9-10]. The post-recession world economy is going to be defined by a New Normal - one that may require us to adopt game-changing strategies for industry to remain competitive in an interconnected world and for academia to equip engineers with the appropriate competencies. That is, engineers must be equipped with the ability to perform a specific task, action or function successfully. These competencies are the result of integrative learning experiences in which skills, abilities and knowledge interact to form bundles that have currency in relation to the task for which they are assembled.

Internships and co-op are two approaches widely used by companies to attract and train engineering students for the work environment, sometimes very specific to the company. Internship and co-op programs also prepare students and make them more "hirable". In the current competitive environment, for both students and companies, new approaches need to be designed that support development of competencies and skills needed by new graduates to be productive from start of their career.

1.2 Industry and academia partnership to develop competencies

Corporations and employers have frequently pointed to a lack of professional awareness and low levels of communication and teamwork skills in engineering graduates [11-14] These issues have led the U.S. Accreditation Board for Engineering and Technology (ABET) [15] to transform their accreditation criteria from a content-based approach to an outcomes-based approach. ABET now proposes to hold engineering schools accountable for the knowledge, skills, and professional values engineering students acquire (or fail to acquire) in the course of their education. Consistently engaging in higher level cognitive activities and achieving the higher level objectives of analysis, synthesis, and evaluation involve more than following a new set of procedures. We do not want merely to adopt a cycle or set of external procedures to follow. We want our learners to develop higher order habits of mind.

There are two levels of competencies in any professional field, field-specific task competencies, and generalized skill sets, or meta-competencies. The task-specific competencies are benchmarks for graduates in a given field, and their level of attainment defines how well-prepared they are to meet job demands and excel in the future [16-17]. The general (meta) competencies are skill sets that enable them to function globally, such as to work with others, function in systems and meet organizational demands, and transfer task-specific skills to new challenges or tasks they have not encountered before [18-19]. Thus, our goal is to revolutionize our learning community to develop an intentional culture of reflection, wherein members (both students and faculty) develop dispositions of metacognition and self-regulation.

The competencies required by future engineers vary from industry sectors and even companies in the same sector. In addition, recent graduates will need to be equipped with more than just specialization skills [20], but be ready to be a productive member of a company without extensive training.

In the literature, Warnick [21] identifies eight categories of global competence for engineers: exhibit a global mindset; appreciate and understand different cultures; demonstrate world and local knowledge; communicate cross-culturally; understand international business, law, and technical elements; live and work in a transnational engineering environment; and work in international teams.

The development of competencies to support engineering is a spiral, with students building on some competencies and adding new ones as they progress through the curriculum. In this paper we focus on the development of meta-competencies to support innovation, with the understanding that technical competencies in domains are a pre-requisite. We build on a set of meta-competencies complied by various educators and researchers [17, 19], to generate a list of meta-competencies that need to be developed by future engineers to support innovation.

Ability to Manage Information

- Ability to gather, interpret, validate and use information
- Understand and use quantitative and qualitative information
- Discard useless information

Ability to Manage Thinking

- Ability to identify and manage dilemmas associated with the realization of complex, sustainable, socio-techno-eco systems

- Ability to think across disciplines
- Holistic thinking
- Conceptual Thinking
- Ability to speculate and to identify research topics worthy of investigation
- Divergent and convergent thinking
- Ability to engage in critical discussion
- Identify and explore opportunities for developing breakthrough products, systems or services
- Ability to think strategically by using both theory and methods

Manage Collaboration

- Ability to manage the collaboration process in local and global settings
- Ability to create new knowledge collaboratively in a diverse team
- Competence in negotiation
- Teamwork competence

Manage Learning

- Ability to identify the competencies and meta-competencies needed to develop to be successful at creating value in a culturally diverse, distributed engineering world
- Ability to self-instruct and self-monitor learning
- Ability to interact with multiple modes of learning

Manage Attitude

- Ability to self-motivate
- Ability to cope with chaos
- Ability to identify and acknowledge mistakes and un-productive paths;
- Ability to assess and manage risk taking

The nature of the competencies mentioned above varies for industry sectors, which creates an educational challenge that is very complex, if not impossible for academic institutions and programs to address. We believe customization of these competencies can be achieved through new collaborative educational models integrating academia and industry.

1.3 Experiential Learning - Foundational Construct

We identified experiential learning as the foundational concept for development of competencies and preparing students for the workplace for this program developed jointly by an industry-university partnership. Kolb [22] provides an often-referenced model of experiential learning. He defined learning as the process of creating knowledge. Kolb proposed a cyclical model for experiential learning with four stages (Figure 1):

- *Concrete Experience:* the learner must be willing and be actively involved in the experience;
- *Reflective Observation:* the learner must be able to reflect on the experience;
- *Abstract Conceptualization:* the learner must possess and use analytical skills to conceptualize the experience; and
- *Active Experimentation:* the learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience.

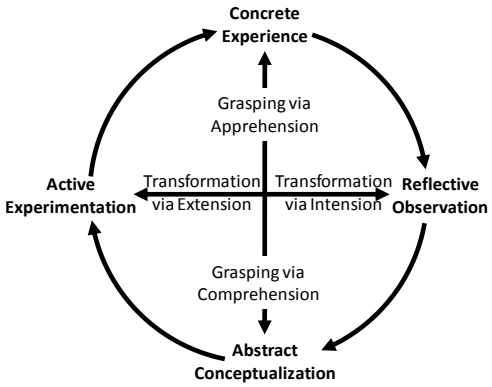

Figure 1. Kolb's Experiential Learning Model

Highlighted in this model are two complementary dimensions: grasping information and then transforming that information. From an epistemological perspective, experiential learning aligns with constructivism, which posits that learners construct meaning from their experiences [23]. However, the *theory* behind the practice of experiential learning has had limited attention in engineering education literature.

During orientation, the BHI Scholars were made aware of this construct and its use particularly in team-based activities.

2. SALIENT FEATURES OF THE BHI 21ST CENTURY COOP

Together with Rustom Mody the champion and sponsor for this program at BHI we developed and implemented a flexible and customized 5 Year BS/MS degree program aimed at developing technical competencies and meta-competencies needed by engineers to hit the road running and succeed in oil and gas industry. Our aim was to craft a program that included the following outcomes:

- Reduce the time taken by an entering engineer to become productive.
- Work with the faculty mentor on projects of relevance to the company.
- Work with underrepresented minority and female students.
- Obtain greater visibility on campus that will help the company recruit engineers in other disciplines.

Early on we recognized that the program must be interdisciplinary, namely, mechanical, industrial and petroleum engineering. We also recognized the importance of experiential learning and incorporated it into our curriculum.

2.1 Overview of the 5 year BS/MS program

The 21st Century Co-Op Scholars are chosen in the Fall Semester of their Sophomore year. Selected students from mechanical engineering and petroleum engineering, the Baker Hughes Scholars (BHS), work as a team with the BH Mentor (BHM) and the Faculty Mentor (FM) for three years. BHS intern at BHI during the summers at the end of their Sophomore, Junior and Senior years.

- Sophomore internship - learn about BHI and identify project to be worked under FM supervision when they return to OU.
- Junior internship – continue to learn about BHI and take a course for credit that is taught jointly by BHI engineer and FM. Identify capstone project.
- Senior internship – take a course for credit that is taught jointly by BHI engineer and FM, plus identify and work on MS project.
- Fifth year at OU – Work on BHI MS project under supervision of FM and BHM / BHI engineers.
- Fourth and fifth years: The BHS's degree plan is jointly worked out by mentors (BHM and FM). Students are provided the opportunity to take customized courses:
  - Three graduate courses from Petroleum Engineering for ME students and a like number from AME for the PE students.
  - Graduate electives - Up to two graduate Industrial and System Engineering courses cross-listed with AME.

2.2 The curriculum

The main elements/components of the program are shown in Figure 2:

5 Year BS/MS Curriculum

Customized course work - electives
Interdisciplinary course work
Senior Capstone

Internships

Site visits

Testing and design of equipment
Course offered during internship by industry partners

Capstone Projects

Multidisciplinary student teams working on understanding different aspects of a large industry concern
Thesis topic selection

MS Thesis

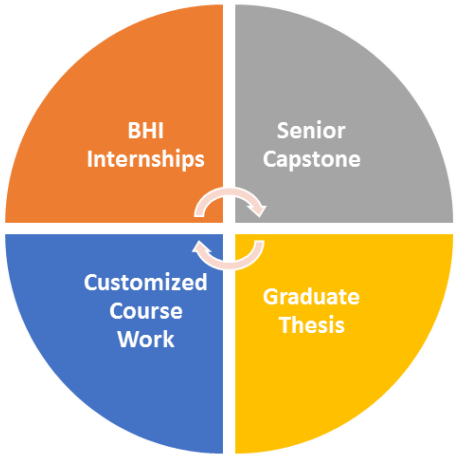

Figure 2: Components of the program

The graduate course options are shown in Figure 3.

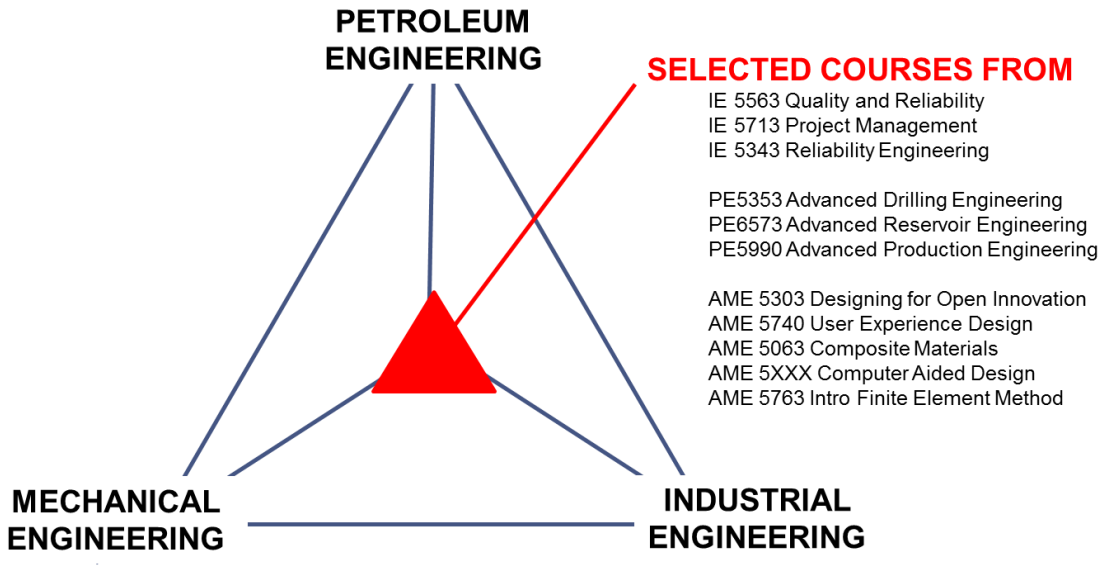

Figure 3: Interdisciplinary Program of Study – Graduate Courses

2.3 Challenge problem[1]

In Fall 2014, Larry Watkins became the designated BHI mentor. He proposed the following challenge problem to be jointly worked on by ALL BHI Scholars, namely, those who joined in 2013, 2014 and 2015.

"The challenge for BHI Scholars is to review and identify the go forward challenges facing development of shale. For this challenge, consider the following dimensions (question areas) for developing shale:

- Technical Issues
- Political Issues
- Economics of Shale Development
- Recovery Factors in Shale"

The BHI Scholars worked on the challenge problem in addition to taking courses. The BHI scholars self-organized into two interdisciplinary teams in order to tackle the challenge problem; see Figure 4. Mechanical and petroleum engineering backgrounds are represented in both groups. By incorporating BHI scholars from each year, the teams were benefitted by various experience and education levels. The team's two team leaders were Alex Smith (petroleum engineer, BHI 14) and Jerry Varughese (mechanical engineer, BHI 14). Bryan Bodie (petroleum engineer, BHI 13) mentored Alex and Jerry because he had the most experience in the program. The BHI scholars on Alex's team include: Brandon McCabe (mechanical engineering, BHI 14), Dallas Milligan (petroleum engineering, BHI 15), and Christopher Sanders (mechanical engineering, BHI 15). The BHI scholars on Jerry's team include: Dana Saeed (petroleum engineering, BHI 14), Pamela Durate (petroleum engineering, BHI 15), Miles Burnett (mechanical engineering, BHI 15), and Wiley Abbott (mechanical engineering, BHI14). Alex's team was responsible for the political and economic perspective while Jerry's team was responsible for the technical and recovery factors perspectives. The perspectives were split on terms of apparent connectivity. Each perspective was framed using the sustainability triangle.

Two Self Organize Interdisciplinary Teams

1. Political/Economics
   - Coordinator: Alex Smith-PE BHI14
   - Bryan Bodie-PE BHI13
   - Brandon McCabe-ME BHI14
   - Dallas Milligan-PE BHI15
   - Christopher Sanders-ME BHI15

2. Technical/Recovery Factors
   - Coordinator: Jerry Varughese-ME BHI14
   - Bryan Bodie-PE BHI13
   - Dana Saeed-PE BHI14
   - Pamela Duarte-PE BHI15
   - Miles Burnett-ME BHI15
   - Wiley Abbott-ME BHI14

Figure 4: Self-organized teams

The sustainability triangle (with Drivers as the three vertices of a triangle) allows the team to organize complexity; see Figure 5. The team assessed the interactions between the three drivers (social, environment, and economic) from four perspectives (technical, political, economic and recovery). The team analyzed the drivers by determining the focus of the driver and the tensions between issues that are present in the industry for each perspective. This involves connecting each issue from each driver to another issue of another driver. This connection is analyzed to determine if there is a tension between the issues. These tensional connections suggest possible dilemmas. The three types of dilemmas analyzed included social/economic, social/environment, and economic/environment. This step is repeated for each

[1] Text and figures attributed to BHI Scholar's Challenge Problem Report, April 26, 2015.

of the issues in each of the drivers connected to each of the other issues in each of the other drivers. Multiple dilemmas can be present. Below is a visual representation of the sustainability triangle.

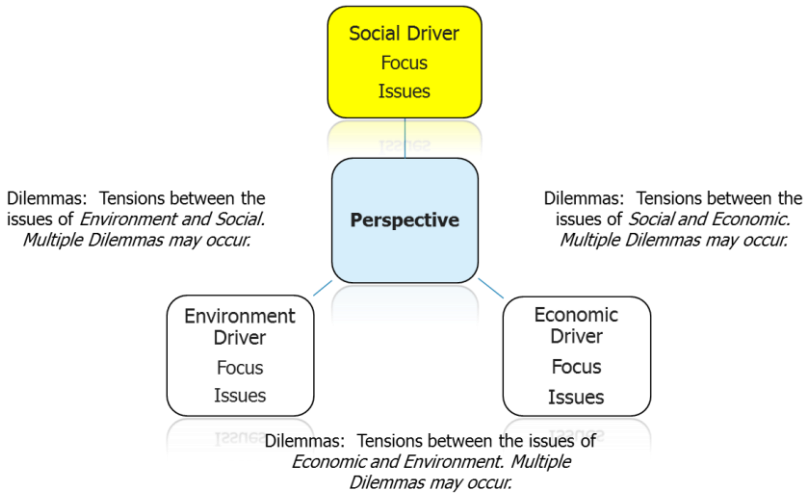

Figure 5: The sustainability triangle – approach to Challenge Problem

After much analysis the BHI Scholars developed a mind map to illustrate the relationship between Drivers, Issues and Dilemmas, see Figure 6. The mind map is color coded in order to reveal the connections. The issues labeled in green are related to cost. The issues labeled in pink are affected by policy and public knowledge. The issues labeled in orange are related to infrastructure needed to be in place. The issues labeled in yellow are those concerned with pollution.

The BHI Scholars, next focused on narrowing the scope of what has been outlined in Figure 6 by prioritizing the dilemmas. In Figure 7, the prioritized list of dilemmas from the Political perspective is shown; the prioritized list for the other three perspectives are not included in the interest of brevity. The BHI Scholars next identified what each would like to focus on exploring in the summer of 2015 and in their MS theses. The topics identified by the BHI14 scholars are illustrated in Figure 8.

During their 2015 summer internships at BHI in Houston the BHI Scholars researched their topics of interest. In Spring 2016 the BHI14 Scholars (who are in the last semester of their BS degrees) have started work on their MS thesis topics. In the summer of 2016, the BHI14 scholars will work with their OU mentors and the BHI mentors on campus with the aim of completing their MS degrees in Spring 2017.

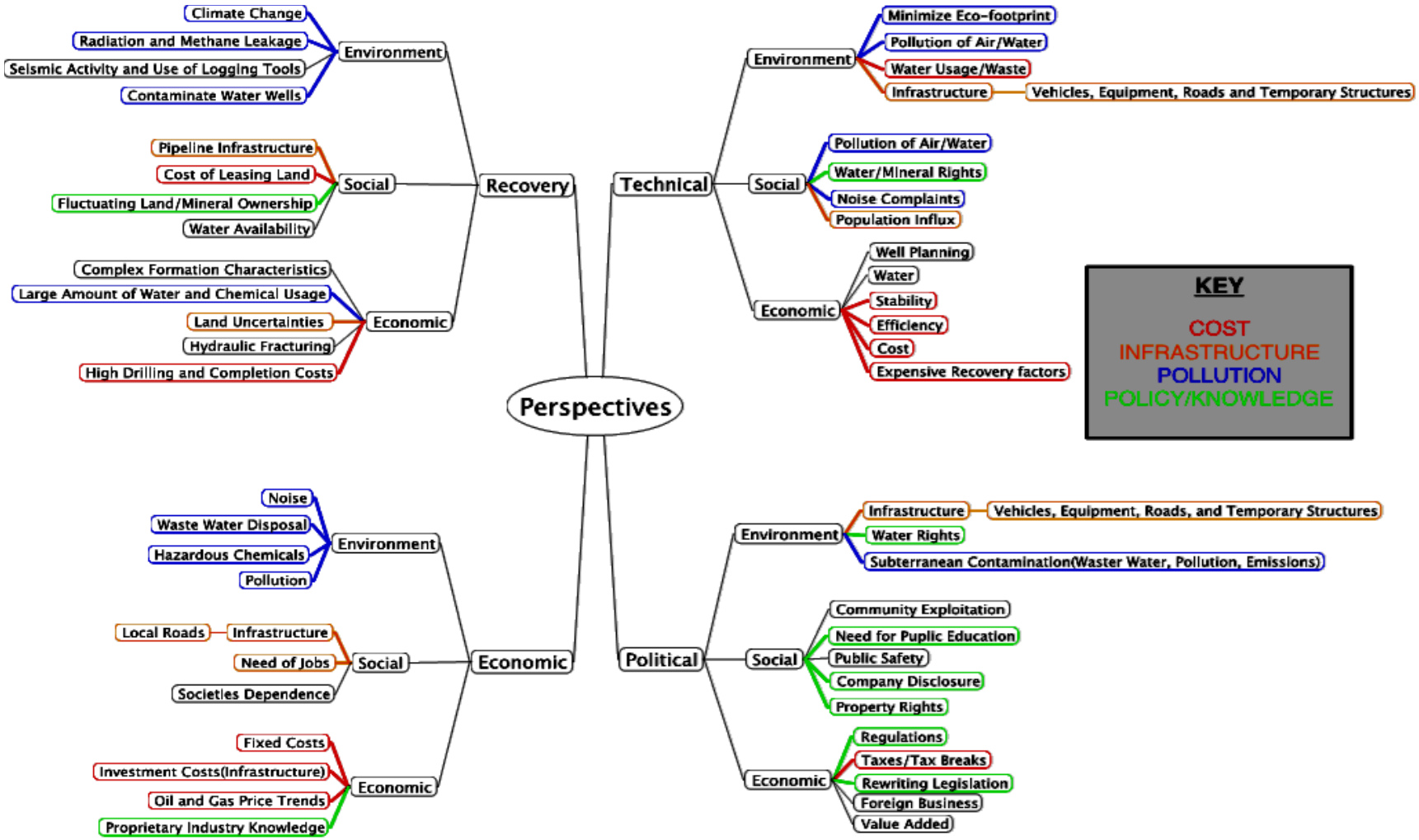

Figure 6: Relationship between Drivers, Issues and Dilemmas

Driver:	Dilemmas:	Reasons for Selecting Dilemma:
Social/ Environment	**Tension Between Public Safety and Sub Terrain Contamination** *Safety of the public from possible pollution in areas where shale development is occurring versus managing the potential risks to the surrounding environment, including subterranean contamination of water, noise, and other pollution, caused by the shale oil industry*	• Availability of reports on water, noise, and other forms of pollution • Many reports have been compiled cataloging damage to environments from past hydraulic fracturing • Personal interest in the public outcry surrounding hydraulic fracturing • Numerous pollution-reduction technologies and innovations exist to counter this issue
Social/ Economic	**Tension Between Public Education and Rewriting Legislation** *The lack of public knowledge of the oil and gas industry versus the public's opposition to legislation in place*	• Personal interest surrounding the policy making issues surrounding hydraulic fracturing • There is quite a bit of published data on community discourse (many communities have banned hydraulic fracturing world wide) • Availability of written legislation (past, current, and proposed)
Economic/ Environment	**Tension Between Regulations and Infrastructure** *Regulations in favor of the environment versus the infrastructure needed to economically produce from shale reservoirs.*	• Environmental regulation data is public knowledge and can be easily accessed • Databases of Congressional hearings focused on the oil and gas industry regulations are available through OU's libraries

Figure 7: A prioritized list of dilemmas (Political Perspective)

Figure 8: Interest of three BHI scholars

2.4 Experiential learning

By undertaking the Challenge Problem successfully the BHI Scholars have developed through an authentic, immersive experience (classes, internships, challenge problem) the following abilities in varying degrees

Ability to Manage Information
Ability to Manage Thinking

Manage Collaboration
Manage Learning
Manage Attitude

Verbatim statements of the value each of the BHI scholars gained from the program and the challenge problem follow[2].

"*Through this challenge problem, I have gained invaluable knowledge about the oil and natural gas industry. I developed the ability to methodically approach topics of interest so as to further develop my understanding. This skill will be helpful to me in future academic endeavors such as capstone and master's thesis.*"
Wiley Abbott, BHI 14 ME

"This challenge problem has advanced my knowledge of the current developments in the oil and natural gas industry. I have learned how important it is to approach the issues facing the industry from various perspectives. I believe this research experience will greatly ease my transition into the Baker Hughes community."
Miles Burnett, BHI 15 ME

"What I have learned from the BHI challenge problem is to communicate and participate as part of teamwork, as well as value the diversity of the people in the group. I believe it has been a good experience to learn and understand more about the challenges present in the oil industry and the development of shale. Also it has helped me prepare for my first summer internship with Baker Hughes."
Pamela Duarte, BHI 15 PE

Through my work with the BHI challenge problem, I got to delve into relevant oil and gas industry problems that I otherwise would not have been exposed to. However, the experience served as more than a learning exercise. I got to work as an interdisciplinary team with petroleum engineering majors who helped me further my understanding of the oil and gas industry as a whole, providing me for a solid foundation for my second summer at Baker Hughes."
Brandon M. McCabe, BHI 14 ME

"This activity has been helpful in broadening my horizon on all of the intricacies of the oil business. Not only is it an industry of problem solving, but there are economic and social issues that have to be addressed in order to move forward. With this new framing of the industry, moving into my internship I know that there will be much more problem solving than just doing math and science."
Dallas Milligan, BHI 15 PE

"My take away is looking at the impact of shale development from different sides such as environment, social, and economic and be aware of the challenges in the shale development. Through continuous researching and meetings with the faculty, Larry Watkins, and my colleagues, the challenge problem helped me stay up to date with the information related to shale development. The challenge problem was a good introduction to what I should expect to work on in my masters and what I should focus on learning in my internship to compensate for the information that can't be gained through researching."
Dana Saeed, BHI 14 PE

[2] From BHI Scholar's Challenge Problem Report, April 26, 2015.

"What I learned from the BHI challenge problem is how to systematically approach research by analyzing the issues through various perspectives. Additionally, I had the opportunity to work with a multi-disciplinary group of mechanical and petroleum engineers. This experience has increased my knowledge of the oil and gas industry, and I believe, has prepared me for my first internship with Baker Hughes this summer."
Christopher Sanders, BHI 15 ME

"Working on the challenge problem allowed me to develop important skills that I will carry with me into my career. I developed leadership, teamwork, and organization skills while expanding my knowledge on shale development. The problem our team was faced with was complicated and required time to fully frame and organize. Being able to look at a problem from four different perspectives opened my eyes to how every problem has a set of connected issues. Having a solid understanding of the problems faced with shale development, I am looking forward to my second summer internship with Baker Hughes.
Alex Smith, BHI 14 PE

"The BHI14 Challenge Problem added value to my academic and professional careers in the following ways: first of all, it provided me an opportunity to develop my problem framing skills (which is essentially in both in academic and industry environment), second, it provided me an opportunity to serve the BHI Scholars as a student coordinator and in doing so it allowed me to develop my team management skills, and finally, this challenge problem allowed me to identify key perspectives in shale development in which I will be able to focus my research in the coming semesters and internships."
Jerry Varughese, BHI 14 ME

3. CLOSING REMARKS

"When I talked to engineers who had worked directly with the students at the end of the summer, they told me that they would be sorry to see the students leave. They are going to miss this group of kids because they have value as a group – that's a strong indicator of their contribution to the program."
Rustom Mody. September, 2015

Clearly, there was much that went right with the BHI 21st Century Coop Program and we have provided an opportunity for a few to hit the road running as they take up their positions in industry in the next few years. Some of the observations and lessons learnt from our experience so far are:

- Commitment and aspiration of students change, especially related to starting the MS degree in their fifth year. Even if the undergraduate students see the benefit for an advanced degree, most of them are not willing to stay for another year.
- The BHI Scholars developed a wide range of competencies while working during their internships.
- Working on the Challenge Problem kept them involved in the company and working towards a common project with students from two disciplines.
- Combining scholarship and internship gave the scholars a sense of belonging to BHI.
- The internship programs, combined with the Challenge Problem, gave the BHI Scholars an excellent understanding and appreciation of their engineering tasks at BHI. The BHI Scholars, during their internship, were treated with extra care because the students were viewed as having a longer term commitment.
- The Scholars have learned a significant amount of knowledge and most importantly gained an appreciation for another field of engineering from each other through their work and communication in their interdisciplinary team.
- Through several interdisciplinary opportunities, student have further enhanced their soft skills, especially ability to communicate and dialogue with people of other disciplines.

When Baker Hughes launched the 21st Century Coop we expected that other oil and gas companies would join the 21st Century Coop Program. Unfortunately, this did not transpire. Hence, the BHI15 Scholars will be the last to graduate from this program. *How could we better market the program to get other oil and gas companies to participate in it?*

A significant number of BHI Scholars who dropped out of the program. This is most disappointing and continues to bother us. What could we have done to prevent that?

1. *How could we have better managed expectations of those who were invited to join the program as BHI Scholars?*
2. *What if we had offered smaller amounts as scholarships at the start increasing the amount as the students progressed in the program?*
3. *What could the OU and BHI mentors done to identify scholars who were indeed committed to getting their MS degrees?*

These questions will perforce need to remain unanswered in this paper!

ACKNOWLEDGMENTS

We gratefully acknowledge the opportunity provided to us by Rustom Mody and Baker Hughes to be part of this experiment. We are most grateful to Larry Watkins for proposing the Challenge Problem, mentoring the BHI Scholars and organizing their summer internships. We are most grateful to the Baker Hughes Foundation for the financial support. Finally, we express our sincerest gratitude to all the students who placed their faith in us and joined us in this exciting journey.

REFERENCES

[1] Friedman, T.L., 2005, *The World Is Flat: A Brief History of the Twenty-First Century*. New York, NY, USA: Farrar, Straus and Giroux.

[2] National Academy of Engineering, 2004, *The Engineer of 2020: Visions of Engineering in the New Century*. Washington DC: National Academies Press.

[3] National Academy of Engineering, 2005, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington DC: National Academies Press.

[4] Tryggvason, G. and Apelian, D., 2006, "Re-Engineering Engineering Education for the Challenges of the 21st Century." *JOM*. October 2006: p. 14-17.

[5] Committee on Prospering in the Global Economy of the 21st Century, 2005, *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington, D.C.: National Academy of Sciences.

[6] Business Roundtable, 2005, *Tapping America's Potential: The Education for Innovation Initiative.* Business Roundtable: Washington, D.C.

[7] Blue, C.E., Blevins, L.G., Carriere, P., Gabriele, G., Leader), S.K.G., Rao, V. and Ulsoy, G., 2005, *The Engineering Workforce: Current State, Issues, and Recommendations. Final Report to the Assistant Director of Engineering*. National Science Foundation: Arlington, VA.

[8] Lang, J.D., Cruse, S., McVey, F.D. and McMasters, J., 1998, "Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers*." Journal of Engineering Education.* 88(1): p. 43-51.

[9] Chubin, D.E., May, G.S. and Babco, E.L., 2005, "Diversifying the Engineering Workforce*." Journal of Engineering Education.* 94(1): p. 73-86.

[10] Felder, R.M., Sheppard, S.D. and Smith, K.A., 2005, "A New Journal for Field in Transition." *Journal of Engineering Education.* 94(1): p. 7-12.

[11] McLaughlin, M., 1992, *Employability Skills Profile: What Are Employers Looking For?* Conference Board of Canada: Ottawa, ON.

[12] Bradford School of Technical Management, 1984, *Managerial Skills and Expertise Used by Samples of Engineers in Britain, Australia, Western Canada, Japan, the Netherlands and Norway*. University of Bradford: Bradford, UK.

[13] Evers, F.T., 2005, *The Bases of Competence: Skills for Lifetime Learning and Employability*. Guelph, Ontario.
[14] Sparkes, J.J., 1990, "Quality in Engineering Education.*" International Journal of Continuing Engineering Education and Life-Long Learning*. 1(1): p. 18-32.
[15] ABET, 2007, *Criteria for Accrediting Engineering Programs*,http://www.abet.org/.
[16] Earnest, J. and Hills, S., 2005, *"*ABET Engineering Technology Criteria and Competency Based Engineering Education," in *35th ASEE/IEEE Frontiers in Education Conference*: Indianapolis, IN. p. 7-12 (Session F2D).
[17] Allan, M. and Chisholm, C., 2008, "Achieving Engineering Competencies in the Global Information Society through the Integration of on-Campus and Workplace Environments." *Industry and Higher Education Journal.* 22(3): p. 1-8.
[18] Wulf, W.A. and Fisher, G.M.C., 2002, "A Makeover for Engineering Education." *Science and Technology*. 18(3): p. 35.
[19] Radcliffe, D.F., 2005, "Innovation as a Meta Graduate Attribute for Engineers.*" International Journal of Engineering Education.* 21(2): p. 194-199.
[20] Christensen, C.M. and Raynor, M.E., 2003, *The Innovator's Solution: Creating and Sustaining Successful Growth*. Cambridge, MA, Harvard University Press.
[21] Warnick, G.M., 2011, "Global Competence: Its Importance for Engineers working in a Global Environment", *118th ASEE Annual Conference and Exposition*, June 26-29, 2011, Vancouver, CA, AC 2011-350.
[22] Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Upper Saddle River, NJ: Prentice Hall.
[23] Doolittle, P. E. and Camp, W. G. (1999). Constructivism: The Career and Technical Education Perspective. *Journal of Vocational and Technical Education*, 16(1): 12-46.