ABSTRACT
This is the second paper in a four-part series focused on a competency-based approach for personalized education in a group setting. In the first paper, we focus on identifying the competencies and metacompetencies required for the 21st century engineers. In this paper, we provide an overview of an approach to developing competencies needed for the fast changing world and allowing the students to be in charge of their own learning. The approach fosters "learning how to learn" in a collaborative environment. We believe that two of the core competencies required for success in the dynamically changing workplace are the abilities to identify and manage dilemmas. In the third paper, we discuss our approach for helping students learn how to identify dilemmas in the context of an energy policy design problem. The fourth paper is focused on approaches to developing the competency to manage dilemmas associated with the realization of complex, sustainable, socio-techno-eco systems.

The approach is presented in the context of a graduate-level course jointly offered at University of Oklahoma, Norman and Washington State University, Pullman during Fall 2011. The students were asked to identify the competencies needed to be successful at creating value in a culturally diverse, distributed engineering world at the beginning of the semester. The students developed these competencies by completing various assignments designed to collaboratively answer a Question for Semester (Q4S). The Q4S was focused on identifying and managing dilemmas associated with energy policy and the next generation bridging fuels. A unique aspect of this course is the collaborative structure in which students completed these assignments individually, in university groups and in collaborative university teams. The group and team structures were developed to ultimately aid individual learning. The detailed answer of the Q4S are elaborate in the other three papers which address identifying and managing dilemmas, specifically related to Feed-In-Tariff (FIT) policy and bridging fuels.

The fundamental principles of our approach include a shift in the role of the instructor to orchestrators of learning, shift in the role of students to active learners, providing opportunities to learn, shift in focus from lower levels to upper levels of learning, creation of learning communities, embedding flexibility in courses, leveraging diversity, making students aware of the learning process, and scaffolding. Building on our experience in the course, we discuss specific ways to foster the development of learning organizations within classroom settings. Additionally, we present techniques for scaffolding the learning activities in a distributed classroom based on systems thinking, personal mastery, mental models, a shared vision, and team learning. The approach enables personalized learning of individuals in a group setting.

1. HIGHER EDUCATION STRUCTURES
Many graduate engineering design courses are merely a continuation of the content and structure found in undergraduate courses. The structure of these graduate engineering courses fail at allowing students to be independent thinkers, thus, creating a lack of accountability of their own learning. With modern globalization, traditional courses do not always prepare individuals to be competitive, and consequently may have little value or relevance to an individuals. In this paper, we demonstrate an approach for educators to help students take charge of their education, and create more value and relevance that many traditionally structured classes may fail to do. The foundations of this approach are presented in [3]. This approach is heavily based on students developing competencies needed for the increasingly fast world in which they live. The fundamental differences between the course
discussed in this paper and the traditional course found in many engineering programs is shown in Figure 1. The restructuring of design courses converts the hierarchical structure of many traditional courses into a collective structure. To address these differences, students develop competencies by using an approach that fosters “learning how to learn” by placing students in a collaborative environment, which many will experience in academia and industry once they graduate. The course facilitated students to focus heavily on two competencies, namely, the abilities to identify and to manage dilemmas. These competencies are required for the dynamically changing workplace. More information on dilemmas can be found in the papers which follow in this four paper series [1, 2].

Figure 1 – Key differences between traditional courses and the collective approach discussed in this paper

In Fall 2011 two courses were offered concurrently:
- AME5740 – Designing for Open Innovation @ OU
- ME503 – Systems-Based Design Approaches for Sustainability @ WSU.

The course was designed and orchestrated to help students learn how to develop competencies necessary for identifying and managing dilemmas; see [3]. This orchestration took place in the context of a Question for the Semester (Q4S) that dealt with the design of energy policy.

The paper is organized as follows. An overview of AME5740/ME503 is presented in Section 2. An overview of mass collaborative learning in the context of this course is provided in Section 3. The outcomes of this course along with student testimonies are discussed in Section 4. Lastly, closing comments are provided in Section 5.

2. OVERVIEW OF AME5740/ME503

The following is from the first lecture of AME5740/ME503:

“This course is offered to the individual in a group setting. It has been designed to facilitate personalized learning that includes the honing of the following abilities...”

a) Ability to identify the competencies and meta-competencies you need to develop to be successful at creating value in a culturally diverse, distributed engineering world.

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

c) Ability to continue learning through reflection and the associated creation and articulation of knowledge.

d) Ability to account for sustainability considerations in formulating, partitioning, and executing multidisciplinary, systems-design problems that are characterized by the open innovation construct.

e) Ability to speculate and to identify research topics worthy of investigation.”

The relationship between the team organization and the class content is displayed in Figure 2. Early in the semester students were given the question for the semester (Q4S). This was given to the students in the context of their semester competencies they wished to develop along with their supporting learning objectives. There were lectures focused on higher level topics related to “learning how to learn” along with content-based lectures focusing on energy policy and bridging fuels. The class content also focused on answering the Q4S through dilemma identification and management. Finally, students reflected upon their semester learning through a semester learning essay.

All of the class content was focused on dilemmas resulting from economical, sociological and environmental aspects which arise in energy policy and bridging fuels. The team organization was supported through the class content and the assignments related to this content. There were several levels of the team organization. Firstly, there were assignments early on in the semester (see Section 3.1) designed for students to identify the competencies they wished to develop throughout the semester (A0, A1, A2). This allowed for individual learning. Next, there were assignments which allowed students to get experience working in groups (A2, A3). Groups of around 4-5 individuals formed at each university. This level of team organization allowed group learning. A higher level of team organization included teams which were formed between students across universities. These teams included a group from each of the universities. The assignments involved allowed the support of collective learning through the use of technologies to address to geographical differences (A3, A4). The Q4S was finally a compilation of A3 and A4 and was answered in the AME5740/ME503 team setting.
The uniqueness of this course stems from the collaborative structure in which students worked in group and team settings in order to answer a question for the semester (Q4S). Students were required to speculate about the world of engineering in 2030 and then to identify competencies needed to be successful at creating value in a culturally diverse, distributed engineering world. These students developed the competencies by completing a sequence of scaffolded assignments. Students completed these assignments individually, then in groups at OU and WSU groups and then in teams that required collaboration between students at OU and WSU. The group and team structures were developed to ultimately aid individual learning while working in an environment which mirrors many structures found in academia and industry. It was found that if students were able to identify key competencies early on in the course, they had the accountability and independence of their own learning, which is needed to be competitive in a highly globalized world.

2.1. Approach

AME5740/ME503 is unique in several respects. First, the concept of Senge’s Learning Organization [4] was present throughout the lectures and the assignments. This allowed a fluent development of both competencies and learning objectives. Second, each lecture delivered in the context of a question for the day. This question for the day allowed students to engage in the lectures and to be constantly analyzing the content presented; see Section 2.1.2 for additional information.

2.1.1. Learning Organization

In Senge’s book titled The Fifth Discipline: The Art of the Learning Organization, Senge introduces improvement through the continuous study of five disciplines [4]. These disciplines include personal mastery, mental model, team vision, team learning, systems thinking. Throughout this course, the assignments were framed with these five disciplines. By way of illustration overviews of assignments are included later:

**Personal Mastery:** Introduce yourself and what you can contribute to the group / team. Include the competencies you wish to develop and the associated learning objectives.

**Mental Model:** Review the postings of your team members. Suggest two competencies you wish to develop as a result of doing this assignment.
Team Vision: This consists of two parts, namely, a contract as to how the team is going to function and an agreed on plan of action. The plan of action includes what needs to be done, by when and who is responsible, etc. The plan must facilitate each team member developing his / her chosen competencies. This may necessitate having to modify individual Mental Models.

Team Learning: What did we learn collectively?

In this course students were asked to decide upon competencies and learning objectives which would add learning through the course. “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” [5].

In the context of the course, the students were asked during the first lecture: “What competencies do you need to develop to be successful at addressing dilemmas associated with the realization of complex, sustainable, socio-techno-eco system in a distributed engineering world?” They were also posed a more specific question, “What competencies do you wish to develop in AME5740/ME503 so that you are competitive in the world of 2030?”

To answer the question proposed above students are given examples of what these core-competencies could look like:

Understanding of the Product Realization Process
- Ability to apply a systematic design method
- Ability to design while accounting for the lifecycle
- Ability to design design-processes
- Ability to Formulate Design Problems
- Ability to identify needs from diverse users
- Ability to convert users’ needs into engineering specifications

Analysis
- Ability to apply modeling and simulation
- Ability to multidisciplinary systems
- Ability to model uncertainty in design

Synthesis
- Ability to generate ideas individually and as a group
- Ability to apply computational methods for design

Selection
- Ability to apply decision making methods

These competencies represent a starting point for students to begin thinking about what their own competencies and learning objective. An example from a student in AME5740/ME503 included the following as his competencies at the end of the semester along with justifications in Table 1.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Justifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn how to learn</td>
<td>I believe that this is the most important competency because it is the most fundamental which all others are based upon. In the world of 2030 it will be even faster pace than our current world. Technologies will advance at a faster rate and it will be more difficult to stay current with your knowledge base. To be competitive you will need to know how to learn, and be able to learn at a pace in order to stay current.</td>
</tr>
<tr>
<td>Ability to deep read and internalize</td>
<td>In the highly globalized-flat world of 2030 we will be overloaded with information. Having the skill set to be able to deep read and internalize will allow us to convert this information into knowledge. To be able to internalize this knowledge and use it in an applicable way will be critical in solving the problems of 2030.</td>
</tr>
<tr>
<td>Ability to apply computational methods for design</td>
<td>In our current world we are faced with many complex problems which depend greatly on computational methods to determine solutions. However, in the world of 2030 these complex problems will be even more complex and will rely even more on computers to find solutions. With many systems becoming decentralized like the energy infrastructure the design of these systems will rely heavily on computational efforts to make more informed design decisions.</td>
</tr>
<tr>
<td>Ability to analyze multidisciplinary systems</td>
<td>In the world of 2030 many systems will not be single disciplinary systems. These systems will be complex and multidisciplinary. An example of this will be the energy infrastructure. No longer will energy infrastructure solely be based on topics of electrical engineering as they were in the past. The energy infrastructure will be a multidisciplinary system where designers will need to be knowledgeable in topics such as economics, game theory, policy, sociology, environmental engineering, etc.</td>
</tr>
<tr>
<td>Ability to speculate the future, be a visionary thinker</td>
<td>In the world of 2030, to not be a visionary thinker would be similar to driving a car blindfolded. Designers and engineers will need to be visionary thinkers in order to solve current and future problems. They will need to be able to predict these problems and determine solutions before they are even encountered. With large population growth the human race cannot afford to waste limited resources on manmade disasters and environmental impacts.</td>
</tr>
</tbody>
</table>
Based on the competencies in Table 1, this student stated that the learning objectives, and justifications, found in Table 2, would help to obtain these competencies.

Table 2 – Example of a student’s learning objectives along with his justification

<table>
<thead>
<tr>
<th>Learning objectives</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn how to determine and justify what knowledge is worth obtaining</td>
<td>In the world of 2030 information and knowledge will be everywhere. I feel that this is an important learning objective because it will give me the ability to know what I need to know. No one person can know everything, therefore it is important to be able to filter out what you do not need to know and learn so you can focus on what you do need.</td>
</tr>
<tr>
<td>Learn how to compare what I have learned against what I already know</td>
<td>By being able to compare what I have learned against what I already know will give me the ability to connect the dots and fill in missing puzzle pieces of knowledge. This will also give insight as to weaknesses that I did not realize I have, and will give me the power to fill in these gaps.</td>
</tr>
<tr>
<td>Learn how to improve upon the information and knowledge which I receive</td>
<td>By having a deep understanding and internalizing knowledge which I am acquiring will allow me to take this knowledge to the next step and improve upon it. This will allow me to contribute my own knowledge to help solve important engineering problems.</td>
</tr>
<tr>
<td>Learn how to evaluate and recommend the design of multidisciplinary systems</td>
<td>By being able to evaluate and recommend the design of multidisciplinary systems this will mean that I will have a good understanding for these systems which I hope to design. This will be a very challenging task but will also be one that is very important.</td>
</tr>
<tr>
<td>Learn how to assess the current state of a system</td>
<td>By looking at the holistic state of a system I will need to have a strong understanding and knowledge of the system itself. This learning objective is important because if a state is failing or needs to be improved a designer must take immediate action in order to fix the system before the problem gets worse. By being able to assess the current state of a system these problems can be avoided.</td>
</tr>
</tbody>
</table>

2.1.2. Lecturing with a Purpose

Each lecture of AME5740/ME503 started with a question for the day. The question for the day was designed to give meaning to each lecture and to frame each lecture with a purpose. In addition, the question for the day made students think about one aspect which was designed to help answer the Q4S. These questions were labeled in sequence in order to relate to the flow of information through the lectures. An example of a question for the day is as follows:

QD6 – September 06, 2011
- What are the key characteristics of my world of 2030?
  - Globalization 3.0
  - Mass Collaboration

QD7 – September 06, 2011
- What are the challenges associated with sustainable design for 2030?
  - Dilemmas, Tradeoffs, Compromises

2.2. Course Goal (Q4S)

The primary course goal was to develop competencies and learning objectives by answering a question for the semester (Q4S). By answering these questions the objective was for students to develop and improve upon their competencies and learning objectives which they set for themselves early on in the course. The Q4S was a two part question and was stated as follows:

a) Bridging fuel: What are the technology, policy and communication dilemmas associated with utilizing natural gas as bridging fuel for next 25 years, while minimizing the adverse impact on quality of life?

b) Policies for distributed generation technologies: What are the technology, policy and communication dilemmas associated with implementing the Feed-In-Tariff (FIT) policy while maximizing the adoption of distributed generation technologies?

3. MASS COLLABORATIVE LEARNING

One of the main differences between this course and that of a traditional nature came from the mass collaborative learning. As previously stated, there were three levels of the team organization. Individual learning, group learning, and AME5740/ME503 team learning. This structure was supported by how each assignment was to be completed. The team assignments and group structures emerged from the quality of work presented by each group. These AME5740/ME503 teams were the core of answering the Q4S and an important part in the end of semester deliverables.

3.1. Assignments

In addition to the end of the semester deliverables, this class contained four assignments and one pre-assignment, see http://csl.wsu.edu/AME5740_ME503. These assignments were scaffolded, built on one another and promoted collaborative learning. Each assignment had an element that was designed to help answer the question for the semester. These assignments were as follows:

a) Assignment 0: Self Evaluation. This assignment was completed individually. This was considered a pre-assignment which was designed to help students deter-
mining the competencies they wished to develop in this course. Although this assignment was the first to be submitted it was updated throughout the semester. This assignment was eventually turned in as an end-of-semester deliverable. The preamble for this assignment is stated as,

Value: By completing this assignment you will establish your Learning Objectives and the Competencies you wish to develop by taking this course this semester. You will be using this information throughout the semester. It is best to get the Learning Objectives and Competencies nailed down ASAP.

Context: Your response must be in the context of Bloom’s Taxonomy. Hence, it is imperative that you familiarize yourself with it.

Scaffolding: In this course, we expect you to touch upon all six domains of knowledge embodied in Bloom’s Taxonomy. Evaluation is a particularly important construct in Bloom’s Taxonomy. It is foundational to learning how to learn. In the interest in helping you learn how to evaluate your own work – includes judge, critique, justify, verify, assess and recommend.

b) Assignment 1: Define the world of 2030 through Deep Reading, Observe-Reflect-Articulate (ORA) and Critical Thinking. This assignment was completed individually. The expected outcomes of this assignment were:

1. Have a vision for the engineering world of 2030.
2. Have a vision of the energy infrastructure in the world of 2030.
3. Refined competencies and learning objectives.

c) Assignment 2: Collaborative and collective learning. This assignment was completed collaboratively within the students’ own university and had two primary objectives:

1. Experience using a virtual environment to collaborate in a G3 world.
2. Understand the efficacy and limitations inherent in the Learning Organization proposed by Senge.

The deliverable of this assignment was presented as the following:

In the context of a Learning Organization, you are required to propose a plan of action to develop an outline for a paper titled Product Realization Processes for Open innovation in the G3 World.

1. Personal Mastery: Introduce yourself. Include the competencies you wish to develop and the supporting learning objectives.

2. Mental Model: Review the postings of your team members. Suggest two competencies you wish to develop as a result of doing this assignment.

3. Team Vision: Collectively develop a Team Vision that includes a team contract and a plan of action: What needs to be done, by when and who is responsible, etc. This may involve your having to modify your Mental Model.


5. Learning and Evaluation

Team Learning: What did you collectively learn by doing this assignment?

Team Evaluation: In tabular form provide the following information

i. What worked.
ii. What did not work.
iii. What changes you plan to implement in undertaking the next assignment.

6. Individual Learning: Reflect on your performance in this assignment. In tabular form, please identify:

i. Your contribution to the outcomes embodied in this assignment. Justify.
ii. Degree to which you attained your competencies and learning objectives. Please justify.
iii. Degree to which you learned what you would do differently and why.
iv. The changes (if any) you propose for your personal competencies and learning objectives and why.
v. The competencies / learning objectives you plan to improve in the next assignment? Justify.
vi. Please enter this information in the table in A0.

d) Assignment 3: Dilemmas in energy policy design. This assignment had three parts. The first part of the assignment was completed individually. Second, the assignment was compiled together in groups formed within each university. Third, the assignment was compiled collaboratively from groups at both universities. Students were invited to “Understand how to analyze the impacts of different energy policies from a sustainability standpoint (engineering, environmental, economic, and social objectives).” The outcomes of this assignment included the following:

1. An understanding of the different types of policy tools used for increasing the adoption of renewable energy technologies
2. An appreciation of the scope, benefits, and challenges associated with designing energy policy
3. An understanding of the dilemmas associated with the analysis of Feed-In-Tariff (FIT) policy and energy policy in general

e) Assignment 4: Dilemmas in bridging fuels: This assignment was completed collaboratively with groups from both universities. The students were invited to, "Understand how to determine the suitability of bridging fuels from a sustainability standpoint (engineering, environmental, economic, and social objectives)." The outcomes of this assignment included the following:

1. An understanding of the requirements and dilemmas associated with the choice of the bridging fuels
2. An understanding of the suitability of natural gas and/or other fuels as sustainable bridging fuels

3.2. Group Structures

Group structures were a large factor of how this course functioned. By framing this course in the context of Friedman's The World Is Flat [6] students used this course as a practical experience of working in a collaborative environment in order to compete in the flat world of 2030. Although this concept was present from the first day of lecture students were eased into the idea of how to work collaboratively within groups from their own universities and in groups across universities. Although Assignment 0 and Assignment 1 were completed by each student individually, these assignments were to insure that students already had an idea of what competencies and learning objectives they wished to develop individually by completing collaborative assignments. Assignment 2 was given to introduce the concept of collaborative learning by having students form groups (at random) at OU and WSU to complete this assignment. Assignment 3 was different because it started as an assignment for the individual and then had students combine this assignment in members of their group at OU or WSU. Based on the quality of submissions of this combined work, groups were paired with groups from OU and WSU. This AME5740/ME503 team then had the task of combining the two groups' assignments before submission. After submitting Assignment 3, the AME5740/ME503 teams were to collaboratively work on Assignment 4. This was a unique experience for the students because it allowed for each member to directly give their input in contrast to the structured communication process introduced in Assignment 3.

To insure that each member of the group contributed equally, group contracts were introduced. The following is an excerpt from one team’s Assignment 4:

In order to perform the task of responding to the questions posed in this assignment while ensuring that each group member further progresses through their development of their semester long competencies, our team created and followed the following procedure to accomplish Assignment 4 (A4):

a) Each group member from Team Beta (Team 2 from University of Oklahoma (OU) and Team 1 from Washington State University (WSU)) completed Part 1 Task 1: Deep read the assignment. This was accomplished with the mindset of how the team will collectively complete A4 and how each member will improve their personal competencies.

b) Each member from Team Beta then considered the connection between the questions for the semester (Q4S) and their personal semester long competencies with associated learning objectives to pose two competencies to focus on and develop during the duration of A4.

c) A brief team meeting was scheduled to discuss the rules of engagement, plan of action to complete the assignment, and the strategy to help each member achieve their competencies they wished to achieve.

d) The rules of engagement were re-established and agreed upon.

e) An extensive, face-to-face team meeting was scheduled to discuss the important parts and details of A4 to ensure that each member will agree and develop a cohesive thought for which the team will accomplish the rest of the assignment as a learning organization.

f) The extensive, face-to-face team meeting was held between the two university groups. This was accomplished by the group members from each state coming together in person and communicating to the other group via Skype. In this meeting, the points stated previously were discussed.

g) After extensive discussion on the main subjects and matter in the assignment to ensure a coherent thought between all the group members, tasks were distributed evenly to complete the assignment. These tasks selected per group member to not only help complete the assignment at hand, but also to help develop their desired competencies they are focusing on.

The completed document including the work accomplished in the previous task was then reviewed and commented on by each student to ensure a full and complete thought was established in regards to the team’s coherent thought.

In addition to the team contracts, each team made a comprehensive list of tasks which would assist in the development of competencies and learning objectives at the individual level. Once this list was developed, each individual identified which of these tasks they would accomplish in order to personally develop the competencies and learning objectives by accomplishing this assignment. The following is an excerpt from one team’s Assignment 4:

In accordance with the task of responding to the questions posed in this assignment and the competencies listed above, the following tasks were developed and then assigned to each member to help develop their desired skills. It should be noted that some of the tasks listed below are the same as the ones previously stated in this document.
T1: Individually deep read A4 to understand the purpose at hand and to consider the connection to the Q4S.
T2: State the competencies with associated learning objectives each person wished to learn this semester and specifically for this assignment.
T3: Establish and agree upon the rules of engagement.
T4: Individually complete Parts 2 and 3 of the assignment to develop personal thoughts and ideas accomplishing each task.
T5: Develop an outline/agenda for the document that will be filled in with details by the group during the group meetings.
T6: Schedule an extensive, face-to-face team meeting to discuss the important parts and details of A4 to ensure that each member will agree and develop a cohesive thought for which the team will accomplish the rest of the assignment as a learning organization.
T7: Collectively assign and evenly distribute specific tasks to each group member to help complete A4 and help develop their desired competencies they are focusing on for this assignment.
T8: Analyze and review the work completed by Team Beta with emphasis on the selection method used to ensure that scheme was used properly and effectively. Provide detail comments and suggestions for improvement.
T9: Analyze and review the work completed by Team Beta with emphasis on the reasoning and justification on the selection method used to ensure that uncertainty in the process and results are described effectively and thoroughly. Provide detail comments and suggestions for improvement.
T10: Individually state the degree of learning for the competencies focused on, assess personal and group dynamic during the completion of the part (What worked? What did not work? What do should be improved on?).
T11: Structure a check system for accountability purposes to insure that each member is developing the competencies in which they want to develop.
T12: Comprehend and synthesize the comments and suggestions posed by each member to update the document with uniformity.
T13: Analyze matrices and tables focusing on potential future dilemmas with selected fuel source(s).
T14: Compare, review, and update alternative fuels to be used as a bridge focusing on future dilemmas associated with requirements of Team Beta.
T15: Read over the assignment at various points of completion, and ensure that it is adequately communicating the teams’ thoughts and ideas.
T16: Present suggestions for formatting that optimizes the ease of reading the assignment.
T17: When appropriate, head communications between the 2 groups in Oklahoma and Washington
T18: Categorize requirements our team used in assignment 3 into those that are applicable to those that are applicable to assignment 4, and those that are not.
T19: Present suggestions for the organization of the requirements into a hierarchy.
T20: Analyze and review the work completed by Team Beta as a whole with detailed comments and suggestions for improvement.
T21: When completing this assignment, emphasize Part:3 #6 (Analysis of Results) and present my thoughts and justifications to the group.
T22: Analyze and review the work completed by Team Beta as a whole with detailed comments and suggestions for improvement.
T23: Analyze and justify the assignment based on the previous assignments and Q4S to present an applicable systematic process to answer to A4.
T24: Review, determine and classify different references to use in answer to A4 that which one is valuable and useful.
T25: Synthesize the group’s individual parts into one cohesive document that shares the team vision while giving a voice to each individual.

3.3. End of the Semester Deliverables

At the end of the semester there were four deliverables each student had to submit to the course orchestrators. These deliverables are also discussed in the first paper of this series [3]. These included:

a) Assignment 0 - End of the Semester (A0-EOS):

Assignment 0 was presented to students on the first week of lecture. This was a living document which was for students to analyze and develop their competencies and learning objectives. Throughout the semester, students were required to update this document and keep track of their changes and leanings in a journal format. Students then submitted this document at the end of the semester with the other deliverables.

b) End of the Semester Learning Essay:

The End of the Semester Learning Essay was designed to be a source of reflection and self assessment; see SLE at http://csl.wsu.edu/AME5740_ME503. This assignment had an open structure and students were not given a formal guideline in order to encourage creativity. Students were given the following as a structure:

“We are looking for Creativity - Thought - Insight … Ability to make the strange familiar and the familiar strange … see and communicate relationships …

ANALOGY/METAPHOR Choice of metaphor/analogy. Appropriateness. How well it is explained. How creative it is.

THEME Relationship between metaphor and text. Metaphor needs to support text and text needs to add value to the metaphor. Systematic development of theme.

RELATED TO COURSE/A0/COMPETENCIES/LEARNING OBJECTIVES Quotes and citations from earlier essays / best practices. Clearly tied to Assignment 0 and work done throughout the semester. Clearly tied to core-competencies and learning objectives.
CREATIVITY / THought / Insight
Creativity in choice of metaphor and creativity associated with outcomes. Thought – is deep thinking evident? Insight – have observation, reflection, and the articulation of new thoughts taken place?

Presentation
Level of originality wrt layout, cartoons, etc…

Lessons Learned
Extent and depth of learning based on ALL work undertaken in this class. Identify lessons learned from lectures, assignments, project, Q4S, etc… To what extent have you achieved the competencies and learning objectives.

Tie-in to Assignment 0 Competencies / Learning Objectives
Critical evaluation of what you set out to achieve in the course and what you really did achieve.

Self Assessment
In the context of the previous items, critically evaluate and assign yourself a grade. Justify.“

Within this document students also assigned a grade to themselves. They were given an Wxcel spread sheet which they included within this document. An example is presented in Figure 3.

4.1. Semester Learning

Figure 3 – A screen shot of a student’s self-evaluation

c) The answer to the questions for the semester:

In Section 3.1, we provided a description of Assignment 3 and Assignment 4. Each of these Assignments was completed collectively with AME5740/ME503 teams. The compilation of these two assignments answered the Q4S. This required AME5740/ME503 teams to work together one last time in order to combine these documents and make a final submission of their semesters’ work.

4. Outcomes

Figure 4 – An example of a student’s end of the semester competency development
Throughout the semester students were invited to update the progress they had made in developing their competencies and corresponding learning objectives; see AOEOS at http://csl.wsu.edu/AMES740_ME503. Before starting assignment students were required to propose and then to discuss (with their group/team members) which competencies they wished to develop out of the competencies that they had identified in A0. An excerpt from one students Assignment 2 is as follows:

“The competencies I wished to develop through this assignment were 1) Learn how to learn, and 2) The ability to speculate the future/be a visionary thinker. I feel that this assignment was relevant for these two competencies. For this assignment we had to work in a team and be able to share our thoughts and ideas. By doing this assignment it helped me learn how learning is not something that is strictly done in a class room yet is done in almost everything you do. I thought that this assignment would be easy to complete and I would not get much out of it. This was not the case. We struggled originally coming up with ideas because this assignment was more in-depth than I originally thought. After doing this assignment I felt that I was able to get insight as to others thoughts and ideas. This helped shape my own opinions and ideas. After completing this assignment I was amazed at this new idea of learning that now seems so obvious. By thinking about product realization in 2030 I was pushed in my creativity to speculate the future and be a visionary thinker. I feel that speculating the future is much like working out. One cannot just jump into their thoughts of what the future will be like. These thoughts need time to develop and to strengthen.

This assignment also helped with my learning objectives. By doing this assignment I was able to learn how to compare what I have learned against what I already knew. As we discussed what product realization would be like in Globalization 3.0 I was forced to compare what I was learning from others ideas against what I already knew. Some of the information we discussed I already knew yet other topics were new to me and I was able to process this information into knowledge. Another learning objective that this assignment helped me develop was learning how to improve upon the information and knowledge which I received. The information which I was receiving was the ideas from my teammates. I was able to take this information process it and improve upon it for the collective knowledge of the group. Lastly, another learning objective which I developed through this assignment was learning how to assess the current state of a system. Before I could have an opinion as to product realization in the year 2030 I first needed to assess what product realization looked like today. By assessing this current state I was able to think about where product realization would be in 2030.”

For each assignment students were asked what they would do differently knowing what they know now. For Assignment 3 one student replied:

“I feel that we could have found a better way to work truly collectively. I feel that it worked well with the WSU group but when we added more people and our document grew larger with more complex figures we needed a different tool to work collectively. This added pressures for individuals to combine the multiple documents. We used wiggio for our team meeting but I feel that there are other technologies which would have allowed for better phone conferences. If given more time I think we could have done things a little bit differently. Our organization lacked structure in our meetings and we should have made formal document stating what we were to address in our meetings. Likewise, each group should have done this alone before combining our two groups.”

When asked to assess the selection of competencies wished to develop for Assignment 4, one student replied:

“I feel that the competencies and learning objectives I chose were very good for this assignment. At first I was not too convinced that I had chosen the best ones. I feel that FIT policy both involve speculating for the future and also analyzing multidisciplinary systems. By doing this assignment I feel that I developed these competencies at a high level. However, if I were to change a competency I would add “working with a group”. I feel that the group dynamics of the WSU group and OU were very different. This was not a bad thing, yet it did open my eyes to how the group dynamics affected how work was assigned and how it was completed. I feel that I acquired a good competency of how groups work based on of this assignment.”

When asked to self assess the development of the chosen semester competencies with the following prompts, at the end of the semester, one student replied as follows:

“Degree to which you attained your competencies and learning objectives and why.

I feel that I put in as much effort into this class as I could, given my time constraints. By doing this, I also got a lot out of this course including developing many of my competencies and learning objectives. Therefore, I feel that I attained my competencies and learning objectives at a high level.

Degree to which you learned what you would do differently and why.

I feel that in every assignment I was able to give a comprehensive list of what I would do differently. The biggest thing I learned was that I should have had working in a team as one of my learning objectives. This class was another example of why working in groups no matter what stage of life you are at gets frustrating. There are always free riders and also ones that want to control everything.”

4.2. Student Testimonies

When the semester was completed students were asked what their overall impression of the course was. One student responded with the following:
“While I am looking backward, I find the true merit of this course. I summarize it as “self-motivation”. I believe it is the drive force of pursuing anything, not only the learning objectives in one class, but also your own objectives in your whole life. What do you want? The answer cannot be given by any others, but only from the bottom of your heart. You know what you want. The reason you don’t know is just because you are not willing to dig it out. Once you get your answer of your objective, you can steer yourself towards it. In the progress, you will find your own method of how to arrive the other shore that you are dreaming of. Like in this class, instructors seldom tell you the specific method, but only give you some meta-methodologies which can direct you to the right way. By answering the Question for Semester (Q4S), I identified my 5 learning objectives and 5 core competencies that I wanted to develop through the whole course. Step by step, with the well designed assignments from A1 to A5, I gradually fulfilled my proposed learning objectives and competencies from both individual thinking and collaborative working. On the road of learning, I learned by motivating myself, learned by creating curiosity and learned by participating team activities. The whole process is self-organized, self-activated and self-introspective.”

When asked if the format of this course could be extended to additional courses one student replied:

“The whole approach of the class style can be transplanted to other courses Extending this course to another domain would be fairly easy since the foundations of the approach are already laid out. Although the mentality of graduate students, when it comes to learning, may be different compared to that of undergraduates, I believe that a course similar to this should have been offered early on in my college career. I feel that I would have been a more focused student as a result. I would have learned that the path I take to learn may be more important than the specifics in the long run.”

When asked what the advantages of this course were compared to that of a traditional course one student responded with the following:

“In my experience I have never taken a class like AME5740/ME503. In today’s fast passed world there is a necessity in learning how to adapt and evolve with the world. Those who are more successful, it seems, are the ones who have learned early on to adapt. AME5740/ME503 has taught me just this. This class was entirely different than I thought it would be based on the course description. However, this difference may be a game changer later on down the road. I first thought this class was going to be about sustainable design, but I soon learned that it used sustainable design as an example of how to develop competencies. I discovered that sometimes it is far more useful to learn how and what you need to learn oppose to learning specifics, which you will most likely never encounter in industry and therefore most likely will never need to remember.

AME5740/ME503 was structured differently than most design courses I have taken. It gave a foundation to learning which I have never seen before. I feel that most of the higher level information in which I encountered should have been exposed to me long ago, perhaps even middle school and high school. I feel that I would have had a completely different approach on learning and what it means to learn. In the age of the internet, information is at your fingertips and it is no longer as important to be concerned with specific facts and reciting details at will. Instead, it is far more important to be able to retrieve these facts, and the process in which you use to do so. Similarly, this class helped open eyes to this and helped us develop competencies which allow us to sort through an endless noise of information to consider what is important and how to turn this information into knowledge. This is something so fundamentally basic but it is a skill which anyone needs to be successful. This is what is lacking in most traditional graduate level courses.”

For the most part this course received positive feedback According to student testimonies, one of the downsides to AME5740/ME503 was the technology barriers. This class was not structured to be a formal remote class, and therefore had technology barriers including problems with audio and video. Although this did not take away from the overall learning of students, which was primarily focused on developing competencies outside of lectures, it was a distraction during these lectures on occasion.

Finally, one student summarized AME5740/ME503 with the following:

“Learn how to learn” – the core of this course: AME5740/ME503 Systems Design Approach for Sustainability. It sounded so strange to me during the first class when I heard it. What should I really learn after all? – This was my natural reaction towards this learning objective. I guess most of my classmates had the same feeling at that time. We were confused, unclear and even disliked this topic at the very beginning. The main reason for the misunderstanding may have been from the uniqueness of this class from my point of view. It was so different and not structured like any class that I had taken previously. In other classes, the instructor assigns the learning objectives to you. What you need to do is just follow the class schedules. The whole process is that you passively receive what the teacher imparts upon you. However, in this class, we were encouraged to develop our own list of learning objective and competencies which we used to develop throughout this class. The focus during the semester was on the progression and value added towards these goals. This was both at an individual and group level in order to develop an answer to the overarching Question for the Semester, which we were presented in the first lecture. I can see that the whole process is that we actively learn what we want to learn. Therefore, for such a transformation from traditional learning pattern to a totally new one, those initial confusions and misunderstandings are eradicated.”
5. CLOSURE

In this paper, we described pilot course implementing the approach discussed in [3] to develop competencies for the 21st Century Engineer. This course was orchestrated in a distributed learning setting as a joint course offered to students at Washington State University, Pullman, along with students from the University of Oklahoma, Norman, in the Fall semester of 2011.

This paper is the second of a four-part series. In the first paper competencies and meta-competencies are discussed in more detail, and how they relate to being a successful engineering in a changing environment [3]. In the third paper, we discuss how this course helped to identify dilemmas using the context of this course, namely, bridging fuels and energy policy [1]. Lastly, the fourth paper discusses how to manage these dilemmas [2].

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REFERENCES

5. 2002, "Defining and Assessing Learning: Exploring Competency-Based Initiatives", National Postsecondary Education Cooperative,