INTRODUCTION

An information resource web-page has been constructed to support an experimental freshman engineering course at the USAF Academy (USAFA)\textsuperscript{1,2}. The intent of the course is to use Problem Based Learning (PBL)\textsuperscript{3} to begin developing problem solving skills while concurrently introducing engineering fundamentals to cadets. The course does not have a textbook or a syllabus. Instead, the cadets are given learning objectives, a tasking (to develop a plan for a manned research mission to Mars)\textsuperscript{1}, and access to an information resource containing data and references on engineering, Mars, and problem solving skills and tools. A series of mini-workshops and the information resource are used to initiate the problem solving skills-development. Initially, the information resource was a collection of computer folders. Before long, however, the accumulation of information in the folders made them hard to use, and during computer downtimes, they were inaccessible.

To improve the utility of the information resource, a web-page has been created. The Homepage is shown in Fig. 1. Designed as a network of concept maps containing hyperlinks to information categories, finding specific information has become a relatively easy and fun exercise for the cadets. Analogous to the Help function found in many software applications, *Search* nodes on the maps allow students to enter descriptive words for specific information sought. For instance, entering “orbits” connects the students to information on the fundamentals of orbital mechanics. If the information sought is not available, or if a hyperlink does not currently exist, the student is invited to post comments on the *Bulletin Board*. As well as being an information repository for the students, entries on the bulletin board are reviewed and responded to by the course director. The information resource web-page is new and dynamic, and upgrades are still being made.

BACKGROUND

Engineering 110Z (Engr-110Z), the experimental freshman engineering course mentioned above, has been developed at USAFA to meet the educational outcomes\textsuperscript{4} shown in Table 1. Started in 1995, this academic experiment has spanned three years. The pedagogy and process are presented elsewhere\textsuperscript{1,2}, so only the key elements are presented as background for the information resource web-page.

**The USAFA Core** - USAFA is a military service academy offering the Bachelor of Science degree. Within the BS curriculum, cadets specialize in one of 19 discipline-
Table 1. USAFA Educational Outcomes

<table>
<thead>
<tr>
<th>Number</th>
<th>Educational Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Officers who can frame and resolve ill-defined problems.</td>
</tr>
<tr>
<td>2.</td>
<td>Officers who are intellectually curious.</td>
</tr>
<tr>
<td>3.</td>
<td>Officers who can communicate effectively.</td>
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<tr>
<td>4.</td>
<td>Officers who possess a breadth of integrated fundamental knowledge in the basic sciences and engineering, and in the social, political and military sciences.</td>
</tr>
<tr>
<td>5.</td>
<td>Officers who can work effectively with others.</td>
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<tr>
<td>6.</td>
<td>Officers who are independent learners.</td>
</tr>
<tr>
<td>7.</td>
<td>Officers who can apply their knowledge and skills to the military profession.</td>
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</tbody>
</table>

majors spanning four academic divisions, Basic Sciences, Engineering, Humanities, and Social Sciences. Regardless of discipline, all cadets complete a core of courses comprising nominally 65 percent of the BS degree requirements. The Engr-110Z experiment is part of this core. Cadets complete their academic program by taking about 16 additional courses in their chosen major. The five engineering courses in the core introduce fundamental concepts in aeronautical, astronautical, civil, electrical and mechanical engineering; they are not offered to recruit engineering students. The freshman cadets randomly selected for Engr-110Z do not necessarily major in engineering. Thus far, 43 of the 142 cadets completing Engr-110Z (about 30 percent) are majoring in engineering.

**Why the Mars Mission Problem** - USAF graduates are Air Force Officers who, during their careers, participate in and have responsibility for a variety of systems-programs. Such programs often present interdisciplinary ill-defined problems involving engineering, economics, politics, sociology, medicine, psychology, and law. Accordingly, USAFA cadets need school-experiences working on multifaceted interdisciplinary situations as opposed to device-oriented problems. The ill-defined aspects of a manned mission to Mars presents the cadets a challenging and timely interdisciplinary problem that requires them to interact with instructors from various engineering and social science departments as well as external agencies such as NASA.

**Problem Solving** - Among the USAFA educational outcomes, developing problem solving skills, especially with regard to *framing and resolving ill-defined problems*, is the priority. From the inception of Engr-110Z, the traditional recitation-classroom was rendered inappropriate for producing student growth in problem solving. Since PBL has produced successful results in engineering programs elsewhere, it was chosen as the pedagogy for Engr-110Z.

Experience shows that skills-development in problem solving is successful when a three-step process is used: (1) **Introduction**: The skill or tool is introduced in a traditional lecture manner. (2) **Bridging**: Utility with the skill or tool begins by practicing it on a generally familiar situation. (3) **Application**: Confidence and competence strengthen by extending the use of the skill or tool to a new situation. In Engr-110Z, Steps (1) and (2) are used in the first 25 percent of the course to establish foundations in the 13 problem
solving skills and tools shown in Table 2. For Step (3), the cadets apply these skills and tools to the Mars mission project.

**Table 2. Problem Solving Skills and Tools Introduced in Engr-110Z**

<table>
<thead>
<tr>
<th>Skill or Tool</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mars Facts</td>
<td>Basic Scientific Knowledge on Mars as Known from Viking, Mariner and Pathfinder NASA Probes</td>
</tr>
<tr>
<td>2. Concept Maps</td>
<td>Concept mapping architecture and design: Concept mapping is used to convey information, graphically display brainstorming, and help frame ill-defined problems.</td>
</tr>
<tr>
<td>3. Project Planning</td>
<td>Project planning is an essential step in problem solving. Students learn to formulate problem statements, task lists, resources available and needed, and timelines. Project planning is the executable format of problem solving.</td>
</tr>
<tr>
<td>4. Research</td>
<td>Research includes use of the WWW and the traditional sources of libraries, teachers, and practitioners.</td>
</tr>
<tr>
<td>5. Figures &amp; Charts</td>
<td>Students learn how to convey information using proper formats for figures and charts. This skill is a fundamental communication skill.</td>
</tr>
<tr>
<td>7. Ill-defined Problems</td>
<td>Students learning to recognize ill-defined problems from those that are deterministic. Framing involves identifying unknown information. An important ingredient is providing for timely analysis of information and updating problem solving approaches.</td>
</tr>
<tr>
<td>8. Teamwork</td>
<td>Teamwork involves leadership and elements of project planning. The students learn that their team is no stronger than its weakest link, and that cooperative participation of all members is required to complete a project effectively.</td>
</tr>
<tr>
<td>11. Computer Nets</td>
<td>A Tool: Foundations in using the USAFAnet and the WWW.</td>
</tr>
<tr>
<td>13. Spreadsheets</td>
<td>A Tool: Foundations in using MS-Excel to create and use spreadsheets to catalog data and to make calculations.</td>
</tr>
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**Mini-Workshops Format** – Mini-workshops are used to perform Steps (1) and (2) for the skills and tools developments. The process begins with Assignment Sheets such as that shown in Fig 2. This particular Assignment Sheet is for Skill-Tool 2, Concept Maps. Each assignment sheet contains five parts: (1) **Discussion**: The skill or tool plus its use are briefly described. (2) **Engr-110Z Goals**: The educational outcomes (Table 1.) targeted by the assignment are identified. (3) **Objectives**: The capabilities sought by completing the assignment are stated. (4) **Task**: A specific exercise is given to practice and demonstrate utility with the skill or tool. (5) **References**: Sources for additional information and guidance are provided.

The task defined on each Assignment Sheet is graded and returned to the student with a Feedback Sheet (Fig. 3). The Feedback Sheet is the instructor’s evaluation of the
student’s performance with regard to the stated objectives. The direct correspondence between assignment and feedback is crucial for each student to see his/her level of performance and to benefit from the instructor’s suggestions for improvement.

For each mini-workshop assignment, the information resource web-page is the usual starting point for the student. From the Homepage (Fig. 1), double clicking Skills & Tools, activates the skills and tools page which is another concept map (Fig. 4). Now the student has 10 categories (nodes) to search for information pertaining to the assignment. The concept map exercise is presented below as an example.

INFORMATION RESOURCE WEB-PAGE

Architecture
The information resource web-page is designed as a three-dimensional global concept map in which the peripheral nodes present the topics and information compiled for the course. All files are hypertext machine language (html). The branches are hyperlinks that allow the students to access that subject page simply by double-clicking the node. Once in that domain, sub-layer concept maps allow students to navigate easily to the information sought. Double-clicking any node now directs the student to a more specialized level of information.

The Homepage defines the eight broad categories of the information resource web-page. The central node is Project Falcon Base. Double clicking it presents the student information on the mock Air Force System Program Office established for the Mars mission program, plus the mock Air Force directive tasking them to develop a project plan to deploy a manned mission to Mars\textsuperscript{1,2}. Deadlines for the oral and written reports are also defined. The PBL node contains background information and insights on this different classroom pedagogy. The Members node presents two directories, one containing brief biographies on the faculty mentors, the other containing biographical data on the cadets in the course. The Administration node contains course specific information on grading policies, expectations and learning outcomes, course structure, and the skills and tools assignments. The Reference node contains Uniform Resource Locations (URLs which are WWW addresses) for information on Mars, plus a variety of topics relevant to the course. The Search node allows the students to enter descriptive words for information. Search nodes exit on all concept maps, and each provides hyperlink connections to URLs, or to nodes where more information is available. If the information sought is unavailable, the student is invited to use the Bulletin Board to present a request for information, or to make suggestions for improvements. The Bulletin Board is also directly accessible from the Homepage.

Double clicking the Skills & Tools node activates perhaps the most popularly used element in the information resource web-page (Fig. 4). The 10 nodes in this map identify the skills and tools categories of Engr-110Z.

The Cadet Technology Page node (Fig. 5), accessed from the Skills & Tools map, is
especially useful to students needing help on operating application software routines, or needing help with WWW research. Each of the first level branch-nodes are **viewers** meaning that clicking on them automatically opens that application software package thereby providing the student guidance on its use. The *How to do Research on The WWW* node is an html presentation containing sub-levels “Quick Overview,” “Bookmarks,” “Searches”, and “References.” The information is presented in bullet format with each bullet being a hyperlink to other resources, some being html files, URLs, or applications.

Clicking the *Search Engines* node allows the user to enter a question in the “search-box,” after which the search begins and returns a list of URLs for further investigation. For example, when “what is the gravity on Mars” is entered, one of the URLs returned states that the gravity on Mars is approximately 3/8 of that on Earth. From here, the student can click-on this URL to find out more about this value, or back-click to move upwards in the concept map, or return directly to the *Homepage*.

**Example**

Using Assignment 2 as an example, clicking the *Concept Maps* node activates the map shown in Fig. 6. The nodes on this page allow the student to acquire background information, or to access URLs, or to page-flip through an example on concept map construction. Identified by the course director as helpful information, the URLs have been placed in the *WWW Resources* node as “ready-references” for the student. Double clicking the *Mini-Workshop Assignment* node branches to the assignment sheet for this skill-tool development (Fig. 2). The *Search* node allows the student to ask for help on a particular concept map item, and *Return to Homepage* provides an immediate return to the Homepage.

The *Example* node presents a step-by-step example of concept map construction. The subject, “Living Things,” is used to introduce hierarchical and global concept map architectures. This example is an MS PowerPoint slide presentation, so clicking *Example: Living Things* automatically opens a PowerPoint presentation of the slides shown in Fig 7. With this as a background guide, the student begins developing the concept map skill by completing Assignment 2.

**CONCLUSIONS**

Still in development, the information resource web-page is a valuable addition to the experimental freshman engineering course. The graphical presentation, concept map architecture, and search and help capabilities make it user friendly. Plus, it’s fun. Students can easily navigate through a large amount of data to get the particular information they seek. The hyperlinks connecting the files allows student inquiries to be directed to different URLs where the topics they are researching are located. Often, the URL’s are outside the Academy, so the searches are genuinely global. And for the student, perhaps the most convenient feature is the leisure process of search the “world
from my room.” As time progresses, new features, new hyperlink connections, and more foundation principles in both engineering and non-engineering disciplines will be added.

REFERENCES


Fig. 1 Information Research Homepage
ENGR-110Z:
MINI-WORKSHOP FOR SKILLS DEVELOPMENT
USAFA ACADEMY, COLORADO 80840

Assignment 2  Foundations in Skills & Tools for Problem Solving  Concept Mapping
Problem Framing

**Discussion:** A concept map is a tool that can be used to help frame a problem, organize thoughts serve as a basis for project planning, and be used as a visual aid to convey information.

Concept maps have three essential elements:
1. Nodes that present the key components.
2. Branches that connect nodes to show directional association.
3. Descriptors on the branches that define the directed association between nodes.

**Engr-110z Goals:** This Skills-Tool day exercise seeks to provide:
1. Improvement in framing Ill-Defined Problems.
2. Improvement in Communication Skills.
3. Improvement in Critical Thinking.
4. Improve Independent Learning.
5. Improve Teamwork.

**Objectives:** Given a topic, you are to create a concept map that:
(a) Clearly identifies the central idea/topic/concept.
(b) Clearly identifies at least 3 sub-categories or sub-elements.
(c) Exhibits proper directional association between the categories and elements.
(d) Exhibits proper use of concept map elements: nodes, branches, descriptors.
(e) Exhibits levels of elaboration and association.
(f) Exhibits “inter-node” branching and coordination between sub-categories.
(g) Exhibit task completion in a neat professional manner  (an AF Hallmark).

**Task:** Develop a concept map for your widget project. Submit your concept map to your instructor by COB Lesson-4. Each team member signs the concept map thereby testifying to equal participation in its construction.

**References:** Information Resource Web-Page: Skills & Tools: Concept Maps

Fig. 2  Skills & Tool Assignment Sheet 2, Concept Maps
ENGR-110Z
SKILLS & TOOLS FEEDBACK SHEET

ASSIGNMENT-2: Communication Skill: The Concept Map

I. OBJECTIVES:

(1) Identifies Concept Map Elements: ☐ ☐ ☐ ☐ ☐ ☐
   a. Identifies central idea/topic/concept.
   b. Identifies at least 3 sub-categories or sub-elements.
   c. Exhibits proper use of nodes, branches and elements.
   d. Exhibits proper directional association between the categories and elements.
   e. Exhibits levels of elaboration and association.
   f. Exhibits “inter-node” branching and coordination between sub-elements.

Comment: ________________________________________________________________

(2) Task Completed in a neat and professional manner: ☐ ☐ ☐ ☐ ☐ ☐
   Comment: ______________________________________________________________

Score: ☐ ☐ ☐ ☐ ☐ ☐

Strengths:
______________________________________________
______________________________________________
______________________________________________

Things to Work on:
______________________________________________
______________________________________________
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Fig. 3 Skills & Tools Feedback Sheet, Concept Maps
Fig. 4 Skills and Tools Web-page

Fig. 5 Cadet Technology Page
Fig. 6 The Concept Map Page

Build a Concept Map Showing an Association Between The Items Shown Below

Fig. 7 Example of Concept Map Construction: “Living Things”
Fig. 7 Continued
Fig. 7 Continued (end)