Instructor-Developed Concept Map for a Survey Course

Elizabeth MH Garcia, Daniel H. Cost
Department of Engineering
U.S. Coast Guard Academy

Instructor-Developed Concept Maps have proven to be useful tools for helping students understand the global picture of the course material. Previously, one author presented three concept maps that improved cadet's "big picture" understanding of three engineering courses at the U.S. Coast Guard Academy. There are fundamental differences in the development of a concept map for a core prerequisite (such as Dynamics and Fluid Mechanics) and a survey course preparing students for several courses to come, as is the Principles of Naval Architecture course as the U.S. Coast Guard Academy. Instructors that teach Naval Architecture and Marine Engineering recognize it to be a systems-engineering major focused on the study of various engineering systems that must be then successfully integrated onto a ship or other maritime structure. Yet students rarely enter the major with this same appreciation and, as such, are often confused by the wide variety of topics they must study. Further, the U.S. Coast Guard Academy plays a key role in developing future officers who are able to successfully oversee the design and maintenance of CG cutters, as well the oversight for the safety and security of foreign and domestic commercial shipping in U.S. waters.

The authors have developed a fourth concept map, this time to the introductory junior-level survey course, Principles of Naval Architecture. This paper presents the unique development of this survey course concept map, and outlines not only how it is being used in the survey course, but referred to frequently in the follow-on courses, culminating during the senior capstone ship design. The development began with looking closely at the course content, course textbook, and the design spiral from the Evans "Basic Design Concepts", ASNE Journal, Nov. 1959. Integration of the content, textbook, and design spiral, allowed for integration of the topics surveyed in the course.

Implementation of the concept map during the fall 2015 semester included providing a handout of the concept map on the first day, and having a poster of the concept map in the classroom. As each topic was introduced and reviewed, the instructor referred to the design spiral indicating the progression of the course, as well as emphasizing when they would see it again in more depth or for application in their senior capstone ship design. The result was students feeling more coherence in the course and less sentiments of a lack of flow or jumping around in content.

Corresponding Author: Elizabeth MH Garcia, Elizabeth.M.Garcia@uscga.edu

Introduction

Previously, concept maps were incorporated into several major requirements (Dynamics, Fluid Mechanics, and Ship Structures) for the Naval Architecture and Marine Engineering major at the U.S. Coast Guard Academy (Garcia 2015), modeling after the concept map developed for Mechanics of Materials at the U.S. Coast Guard Academy (Egelhoff et al. 2010; Egelhoff and Burns 2011). These concept maps allowed students to see the big picture for those courses starting on day one, and also to see how they were progressing in comprehension of those topics throughout the semester.

Concept maps, introduced by Novak and his research group at Cornell University in the 1970s, are a visual representation of how individual concepts are related to one another to create the "larger wholes" (Novak, Fang). Additionally, instructor-developed concept maps avoid the pitfalls of student-developed concept maps where there are many misconceptions and misunderstandings presented (Egelhoff et al. 2010; Egelhoff and Burns 2011; Garcia 2015) .

Engineering educators recognize Systems Engineering to be an interdisciplinary field of engineering for the design and management of complex engineering systems. In the NASA Systems Engineering Handbook, systems engineering is designed as a "robust approach to design, creation and operation of systems. In simple terms, the approach consists of identification and quantification of system goals, creation of alternative system design concepts, performance of design trades, selection and implementation of best design, verification that the design is properly built and integrated, and post-implementation of how well the system meets (or met) the goals." The use of concept maps as an easy means to organize, communicate, and validate information

during a system study was presented at the IEEE International Conference on Systems, Man and Cybernetic in 1990. The idea that fundamental concepts could be graphically represented and that their relationships could be clearly defined has become very valuable as a way to present complex systems to others.

In relation to systems engineering, naval architects and marine engineers view a ship as a system to be studied, analyzed, optimized, designed, maintained, repaired and salvaged. When viewed from a distance, a ship can be seen as a single system; however, as one looks more closely, it becomes readily apparent that a ship itself is comprised of several different systems. Students earning a naval architecture and marine engineering degree will learn about these systems as they study the shape of the hull for hydrodynamics purposes, the structures of the vessel for weight and centers, the machinery plant for propulsion, the electrical plant for power, the auxiliary equipment to manage human comfort and waste collection and the arrangements of the vessel to provide fire boundaries and sufficient egress paths. In addition, students recognize that vessels operate in the marine environment and as such must have sufficient stability and seakeeping abilities. While studying each of these systems by itself is a challenge for sure, the educated naval architect must not only have an appreciation for each individually, but must also be able to understand that they must be considered together in order for a ship to meet its intended purpose.

The introductory junior-level survey course, Principles of Naval Architecture sets the initial foundation for the students. Its primary goal is to present the various topics in Naval Architecture to the student so that they will be prepared to discuss these topics in more detail in subsequent courses. A concept map that links these topics together and provides the "big picture" to the student is invaluable in achieving this goal.

One author was preparing to teach the junior-level survey course, Principles of Naval Architecture, which prepares students for the rest of the degree program and senior capstone. Having never taught this course before, it was important for the author to develop a big picture understanding of what the course was about. Additionally, senior exit interviews had indicated that many students did not understand the purpose of this course. Students often felt that they jumped from topic to topic, as is common in a survey course but unbeknownst to the students. They also did not understand that this was preparing them for their senior capstone, a full iteration of a ship design.

Understanding the power of concept maps and developing a big picture understanding alongside the individual lectures and topics, the authors took it upon themselves to create an instructor-developed concept map that would not only outline the big picture for this survey course, but also demonstrate to the students the use of this information in ship design both in their senior design and in their careers as U.S. Coast Guard Officers.

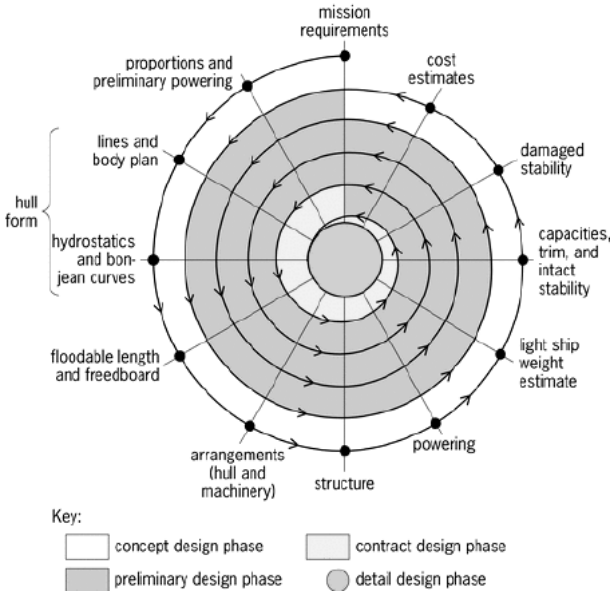

Figure 1: Evans' design spiral for ship design, first introduced in 1959.

Development

The development of the concept map for Principles of Naval Architecture was very different from other textbook courses. Ship design by nature is a systems engineering problem. There are many things that must be considered in the final design, and although all are part of the same design, they are conceptually different. Therefore, making a flow chart or grouping like concepts for a concept map would not work for a survey course presenting the many facets of ship design.

Fortunately, the process did not have to start from scratch. In 1959, Evans presented a "Design Spiral" that showed the iterative nature of integrating the many different systems and design parameters into the ship design process (Figure 1). This design spiral had traditionally been show to students as part of the first lecture for both Principles of Naval Architecture and for the senior capstone design the following year. However, this design spiral is more valuable than just part of the first-day lecture.

Additionally, the lecture schedule and textbook also provided input into what is presented during this course (Tables 1-2). Overlaying the textbook and lecture topics with the design spiral provided a good outline for the course, but as a survey course that builds upon previous knowledge to prepare students for their follow-on courses, it was quickly realized that this concept map needed to make reference to several courses throughout

the Naval Architecture and Marine Engineering curriculum.

Therefore, each course that is directly tied to the development of Ship Design was integrated into this concept map. Namely, the sophomore-year Ships and Maritime Systems, a required general education course for all students at the U.S. Coast Guard Academy, is the first introduction into many of the topics listed previously.

Principles of Naval Architecture, a junior-level course, is the first in-major course on ship design. This fall-semester course is then followed by two other junior-level courses integral to the preparation of the students for their senior design: Marine Engineering and Ship Structures. Then, during the senior year, there are three courses that are focused on the senior capstone design using one iteration around the design spiral: in the fall, Principles of Ship Design, Ship Propulsion Design, and in the spring, Ship Design and System Integration.

With the assistance of all instructors in Naval Architecture and Naval Engineering, it was identified which courses covered which topics. Of equal importance was the verbiage used to discuss each topic. Therefore, in order to place into context for the students how each design component was covered, the topic verbiage from each course became the way to refer to what students had seen or would see in those courses.

The design spiral was now morphing from just a ship design system spiral, to one that was limited in scope to just the survey course, to now a spiral that showed the integration of the various courses tied to that survey course.

Next steps included "visualizing" each component of design with some sort of graphic that allowed students to connect the words to their true meaning. Graphics were found that would help students to recall visually the significance of each component. Finally, with software being such an integral part of the ship systems design, the software logos were placed at strategic locations around the design spiral as well.

With a little finessing to allow for the best use of space possible, the final version of the Principles of Ship Design concept map was developed and approved by the various faculty who had participated in drafting the map. The final concept map is presented in Figure 2.

Implementation

On the first day of class, the syllabus and schedule included a copy of the concept map developed. Additionally, a poster of the concept map was framed and placed in a prominent position in the front of the classroom. The map was then discussed by the instructor during the first lecture, explaining how each part might not make sense right now, but it provided a visual of the topics for the course.

As each new topic was introduced in class, the concept map was briefly reviewed. If the students had seen the topic before in Ships and Maritime Systems, it was discussed what they should already know, and then the reasoning for the importance of the topic was reviewed in the context of the follow-on courses and senior capstone ship design.

This same review of the concept was done the lecture prior to any exams and again at the end of the course. The regular referencing and use of the in-class poster allowed students to see they progression of topics in building their repertoire of Naval Architecture and Marine Engineering Systems.

Table 1: Lecture Topics and Lecture Hours. This course is taught with two 1.5 hour lectures each week and one 3 hour lab each week.

Lecture Topic	Lecture Hours
Hull Form	4.5
Hydrostatics	3
Transverse Stability	4.5
Trim	3
Flooding	6
Structures	4.5
Resistance	3
Propulsion	3
Ship Dynamics	3
Cost Estimation	1.5

Table 2: Zubaly's Applied Naval ArchitectureTextbook Chapters

Chapter 1. Cargo Ships
Chapter 2. Hull Form
Chapter 3. Static Equilibrium and Stability
Chapter 4. Stability at Large Angles
Chapter 5. Trim and Longitudinal Stability
Chapter 6. Flooding and Subdivision
Chapter 7. Ship Strength
Chapter 8. Ship Resistance
Chapter 9. Ship Propulsion
Chapter 10. Ship Dynamics

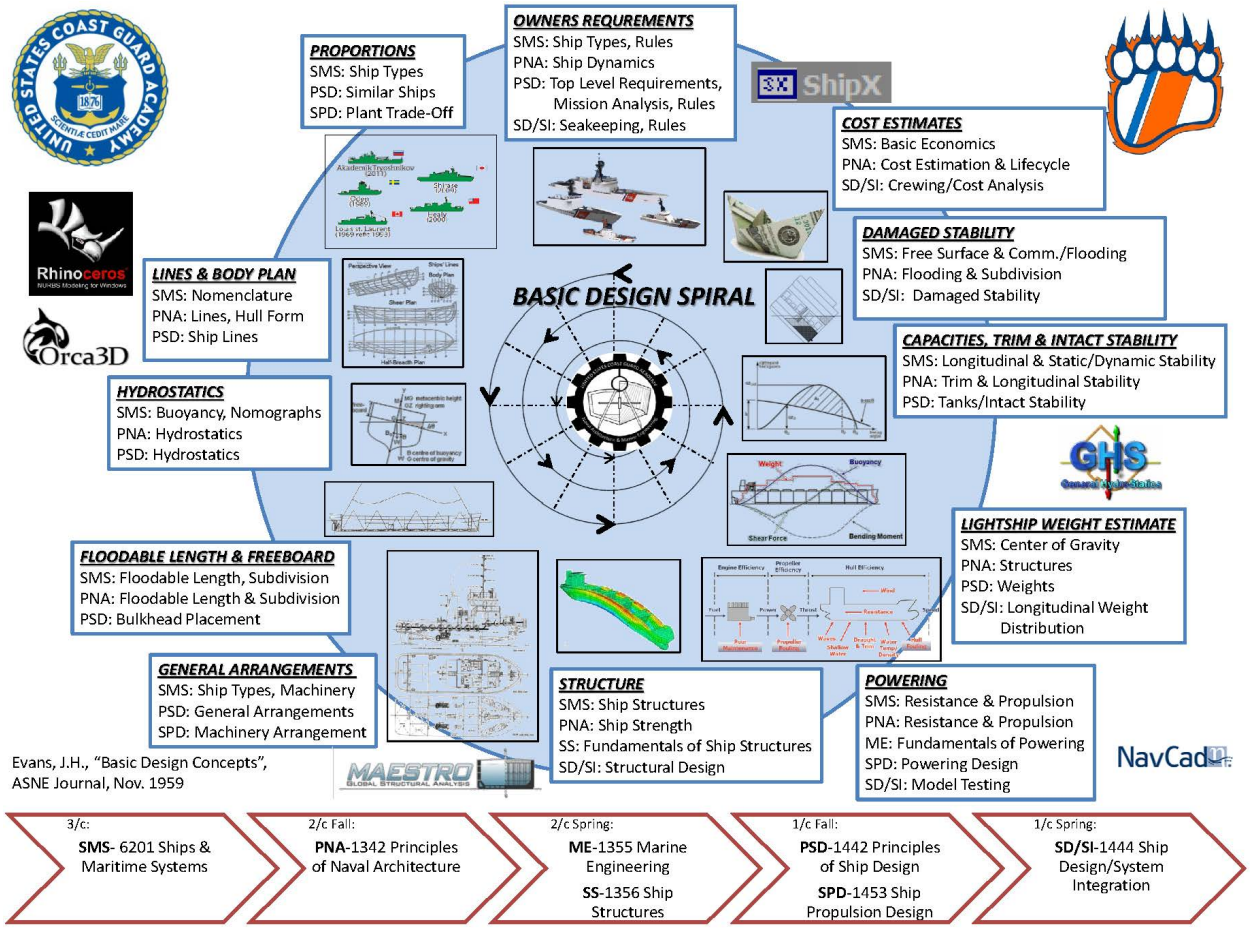

Figure 2: Principles of Naval Architecture course concept map.

Implications for Student Careers

A Concept Map helps develop the Naval Architecture skill set required to support Coast Guard missions. The Coast Guard operates and maintains its own ships, and is also responsible for the safety, security and environmental stewardship of all commercial vessels that operate in the U.S. marine transportation system. As technology has advanced, so have the ships we design, and as such, the need for properly educated naval architects and marine engineers in the Coast Guard is clear. But while ship design has gotten more complex, the concept map discussed remains an effective tool for helping to maintain the "big picture" of how these large complex systems come together.

Coast Guard Naval Engineers are responsible for the oversight in design, construction, maintenance, and repair of Coast Guard vessels. In recent years, the Coast Guard has begun replacing its aging fleet with several classes of new vessels. Currently, ongoing construction of the National Security Cutter and the Fast Response Cutter are keeping Coast Guard naval engineers busy with the oversight of the construction of these vessels to ensure they are being built to the approved design. At the same time, the Coast Guard is in the midst of reviewing second stage design proposals for the Offshore Patrol Cutter, which when approved will be the largest acquisition project in Coast Guard history. And soon, the Coast Guard will have to start looking at preliminary design proposals for new Coast Guard icebreakers. For sure, these are challenging undertakings and often students will feel overwhelmed with the future work that they see in front of them. The concept map is a great way for the teachers to help the students refocus on the process and show them how these large projects can be broken down into smaller steps that are then related to each other.

On the other side of the house, Coast Guard Marine Safety Engineers are responsible for evaluating new construction commercial ship designs; everything from small dinner cruise harbor vessels, to new replacement U.S. flagged containerships that are being fueled by Liquefied Natural Gas (LNG), to offshore oil and gas

drill ships that will be working in the U.S. Outer Continental Shelf. The Coast Guard must be able to not only understand the designs that are coming in for review, but must also be capable of reviewing the designs against applicable international and U.S. rules, regulations, policies and guidance and then provide a reply back either approving the design or requiring revisions prior to approval. Again, it is a challenging job, often overwhelming for new engineers; however, it is also something that we must teach our students about so that they have an understanding of the importance of their education and its value to the organization. As an example, the use of LNG to power vessels is a new challenge facing both designers and regulators, being driven by changes in environmental emission regulations. While there are risks that must be accounted for, the process of using LNG onboard a ship to power the vessel does not change the design process outlined in the concept map as designers must still tackle general arrangements, structural design, powering estimations, tank capacities and weight estimation. As such, the concept map serves as an outstanding tool to help our students stay focused on the various components involved in ship design and allows us to still present them individually while also appreciating the interconnectivity between them.

Feedback

Although no formal metrics were applied to survey the students on the use of the concept map during its first semester of use in fall 2015, anecdotal feedback would suggest that it was a useful tool to the students.

Students were asked throughout the semester if they felt that they were jumping around with the topics, a common complaint from past years. The students unanimously agreed that they did not feel like they were jumping around as they understood it to be a piece of the design spiral. Additionally, with the poster in class being referred to often, students became very aware of the design spiral process. In past years, students would only see the design spiral on the first day of class, and have no reinforcement of the concept the rest of the semester.

In the end, the students seemed to appreciate the visual aide of the concept map and its use, and it will be continued to be implemented in future iterations of the course.

Future work

One thing is that all concept maps are subject to continuous improvement. Errors may be corrected, or a new way to present the material may be found that may lead to a more streamlined, simple concept map. After the first year of use, there are no changes yet to be introduced, but the map will be revisited each year.

Another issue that is difficult to ascertain in measuring the efficacy of concept maps. Nesbit and Adesope (2006) have presented a comprehensive study demonstrating learning with concept maps. The hope is to review the many processes presented in this analysis and apply some metrics to surveying students on the use of the instructor-developed concept maps within the course, and perhaps beyond the course as well.

Conclusions

A concept map is a great way to develop a big picture understanding of a semester-long course, forcing students to see beyond each lecture. Additionally, an instructor developed survey allows the instructor to impress upon students a correct big picture, rather than a distorted or amateur understanding of the whole course. In a survey course that presents many disconnected topics in order to prepare undergraduates for follow-on courses, a concept map becomes very useful to show how seemingly disjointed topics are in fact interrelated to the larger subject, in this case, ship design.

The development and implementation of a concept map into Principles of Naval Architecture at the U.S. Coast Guard Academy in Fall 2015 proved successful in providing students with the understanding of how the many topics are in fact connected and part of a larger process, taking individual systems and integrating them into the whole systems engineering topic of ship design. It is anticipated that this better understanding of the whole will not only encourage retention of the topics going forward to the senior capstone design, but also allow them to better understand their future careers as U.S. Coast Guard Officers, looking either at U.S. Coast Guard cutters or commercial ships.

References

1. Egelhoff, C.J., and K.L. Burns, “A Heuristic to Aid Teaching, Learning and Problem-Solving for Mechanics of Materials,” *Proceedings of the 118th ASEE Annual Conference*, Vancouver, 2011, AC 2011-1261.
2. Egelhoff, Carla J., Nathan Podoll, and Kassim Tarhini. "Work in Progress–A Concept Map for Mechanics of Materials." *Proceedings of the 40th ASEE/IEEE Frontiers in Education Conference*, Washington, DC. 2010.
3. Evans, J. Harvey, “Basic Design Concepts.” *Journal of the American Society for Naval Engineers*, vol. 71, issue 4, pp. 671-678, Nov. 1959.
4. Fang, Ning, “Enhancing Students’ Understanding of Dynamics Concepts through a New Concept Mapping Approach – Tree of Dynamics,” *Proceedings of the 119th ASEE*

Annual Conference, San Antonio, 2012, AC 2012-3345.

5. Garcia, Elizabeth MH, "Instructor-Developed Course Concept Maps Used to Contextualize Material," *Proceedings of ASEE Northeast 2015*, April 30-May 2, 2015.
6. *NASA Systems Engineering Handbook*, National Aeronautics and Space Administration, Washington, D.C., December 2007.
7. Nesbit, John C., and Olusola O. Adesope, "Learning with Concept and Knowledge Maps: A Meta-Analysis," *Review of Educational Research*, vol. 76, no. 3, Autumn 2006, 413-448.
8. Novak, Joseph D. "Concept mapping: A useful tool for science education." *Journal of Research in Science Teaching* 27. No. 10, 1990, 937-949.
9. Zubaly, Robert B., *Applied Naval Architecture, Cornell Maritime Press*, 1996.