122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #12651

# The Management Tree of Life - An Aid for Undergraduate Engineers to Structure Management Thinking

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**Abstract**
Both members of industry and expert panels continue to call loudly for increasing the ability of engineering undergraduates to effectively lead and work within diverse teams. Yet few engineering programs have a formal approach to providing students with the knowledge of management, human motivation, and organizations essential for understanding how to lead effectively. Instead, programs generally look to electives and general education requirements to fill this gap. This paper examines a path where management material is incorporated into the core curriculum of an Industrial Engineering program and offered to other engineers as a professional elective to meet their degree requirements. For most students, the course is their first exposure to the theoretical underpinnings of management and organizations. Since these materials are quite different than those of traditional engineering courses, students often either: 1) View the material as 'fluff' that is not important to their ability to be an effective engineer and / or 2) Have a great deal of difficulty absorbing the material due its foreign nature.

To combat the second issue, a novel adaptation of a concept map tool was employed to assist students to frame their new knowledge in an engineering context. The approach was deployed in a manner many have seen in other contexts – family trees. The article exams the formative assessment of student performance on the trees and the impact of this intervention on student performance in subsequent summative assessments. Since the map was an optional assignment, the study provides a control group for comparisons.

## Introduction

Due to changes in engineering accreditation criteria,[1] calls from seminal reports such as the *Engineer of 2020*,[2] and evidence from engineering graduates that indicate professional-skills are often what engineers find most important in the workplace,[3] there is an increasing movement toward incorporation of curricular materials that promote the development of more well-rounded engineers. This includes materials such as management theory and practice. Despite this movement, understanding how well students perform in these professional-skill areas is often difficult to assess.[4] One technique that has gained momentum in recent years is utilizing concept maps to not only assist students in structuring their knowledge, but also to assess how effectively they are gaining and retaining that knowledge.[5-7] This study builds on the idea that concept maps can be used to both promote greater student understanding and assess that understanding through the "Management Tree of Life" assignment, an applied concept map assignment. This approach was adopted because concept maps have been shown specifically to help beginning engineering students grasp concepts more easily[8] and the course being utilized is often engineering students' first exposure to the theoretical underpinnings of management and organizations

## Overview of the Concept Map Literature

Concept maps are graphical representations of an area of knowledge, including topics within the area and the relationships between those topics.[9] In education, concept maps can benefit students by showing what they already know and how they represent that knowledge. Since prior knowledge can both help or hinder learning, an understanding of this baseline can benefit instructors by enabling a tailoring of instruction to fit on current student understanding.[10]

Furthermore, since a goal of education is to move students from a novice level of understanding toward an expert level, understanding how student's structure knowledge is also an important piece of information for instructors. The idea of why this structure matters is depicted by Ambrose, et al. in Figure 1 below.[10]

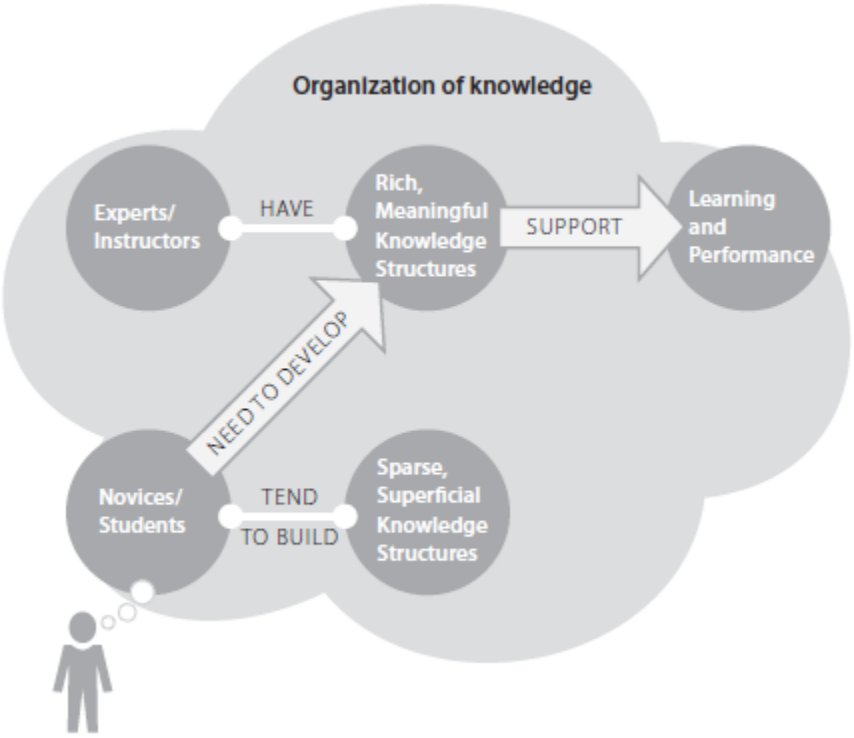


*Figure 1- Differences in How Experts and Novices Organize Knowledge*[10]

In an engineering context, concept maps have been utilized in a variety of ways to both improve pedagogy and measure its effects. These include:

- as an aid to student learning of abstract concepts,[11]
- for in-class constructive learning activities,[12]
- to "quantitize" qualitative data,[13] and
- to better understand engineering students' baseline knowledge.[14]

It appears that the most recent focus has been to utilize concept maps as a measure of student learning.[5-7, 15] A more complete discussion of the applications of concept maps in engineering can be found in the work of Roberts, et al..[6] This study employs the recent focus of using a concept map to assess student learning by deploying and assessing a concept map like assignment. It builds on the assessment by using the results to understand if the use of the concept map impacted future learning.

**Overview of the Course**

The study took place in a junior level, three credit, semester long course that introduces engineering students to the foundations of management and organizational theory. Figure 2 provides an overview of the course organization. As illustrated in the figure, the course builds on a foundation of management theory. This supports a more complete investigation of the work

of managers and theories of motivation and leadership. The topic of ethics is woven throughout these materials.

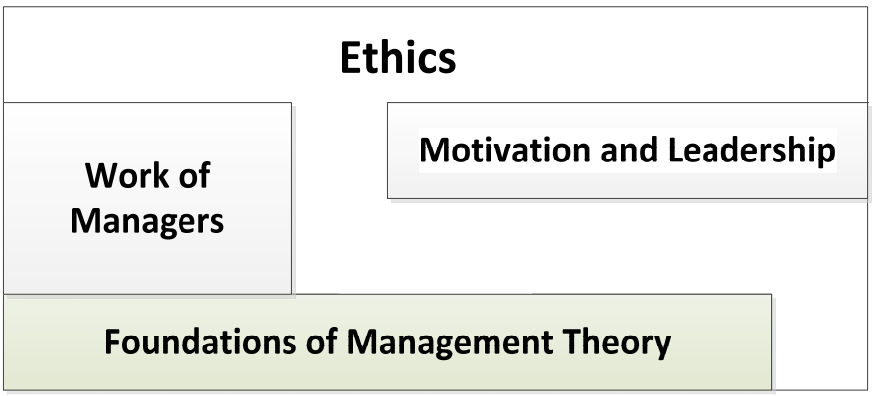


*Figure 2 - The Relationship Between Core Course Topics*

The course employs a highly inductive teaching approach focused on active learning with almost all class sessions utilizing a flipped design. Prior to these sessions, students are responsible for familiarizing themselves with course materials outside of class through readings and recorded lectures. Class meetings are then used in a variety of team based learning approaches including small and large group discussions and debates, and student designed and led presentations. In person sessions are further supported with regular online discussions and debates around key topics. Figure 3 summarizes this approach and the materials and techniques employed.

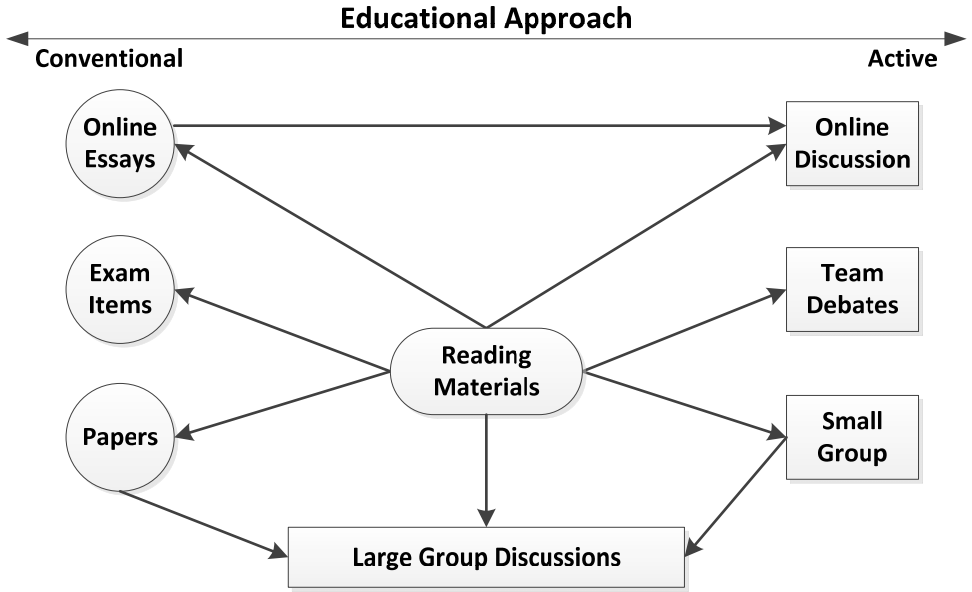


*Figure 3 - Relationship Between Course Materials and Educational Approach*

Previous studies using this course have found statistically significant improvements in students' ethical reasoning and students' perceptions of their ability to perform tasks in line with expected

ABET student outcomes.[1] A more complete discussion of course content and structure along with the result of previous studies into the course's effectiveness in both of these areas can be found in previous publications.[16, 17]

Students in the course come from a variety of backgrounds, since students come to the course for a number of reasons. This includes those taking it as a requirement for students majoring in the school's Financial Engineering or Industrial and Management Systems engineering programs, and for students seeking the minor in Engineering Management; and those taking it as an elective for students seeking the Leadership Certificate with their undergraduate degree, or those in other engineering programs who use the course as part of their degree requirements within their pre-approved professional elective options.

**Study Methodology**

In order to understand any impact from the intervention employed by the study, student performance on course assignments was utilized. In the course, student grades are determined using eight key assignments, summarized as:

- Participation and Homework
- Case Study
- Three Written 'Brief Papers'
- Research Summary and Presentation
- Two 75 Minute Exams

The study introduced an additional assignment designed to observe and measure the impact of using student generated maps as an aid to student understanding of management concepts, which are often viewed as ambiguous by engineering students. The study began by presenting students with an optional assignment to earn bonus points on the first course exam. The assignment asked students to create a "Management Tree of Life" (the tree) of the management theories covered in the course up to that time. Essentially, the tree is a concept map using a structure more familiar to engineering students – tree diagrams in the form of a family tree. Students were asked to use the tree to depict the relationship between the different aspects of management history and management theories from the course materials. This approach was introduced to members of the class in early lectures, which discussed ancient history as providing the roots of management thinking. The instructions for the assignment were to: "Draw and label your own comprehensive management tree of life using the theories and approaches from the course." Figure 4 illustrates how this intervention was incorporated into the course.

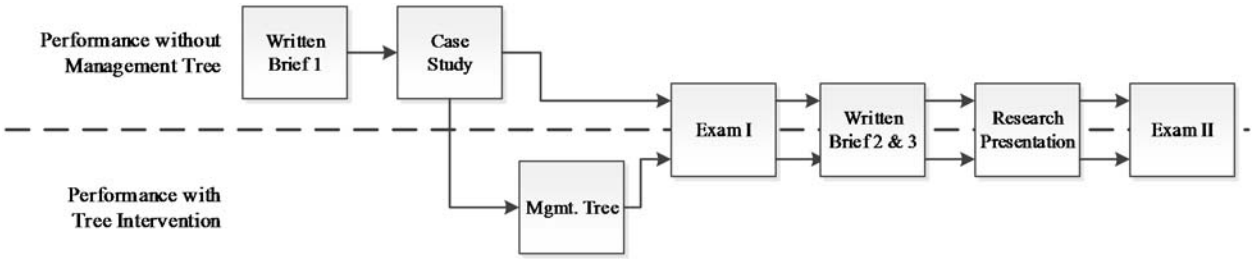


*Figure 4 - Course Assignment Flow and Placement of Intervention*

Once submitted, the trees were evaluated using a framework similar to the one developed by Besterfield-Sacre, et al.[15] to score the quality of the student work. In this framework, concept maps are evaluated using more than numeric methods of comprehensiveness, such as how many

concepts were included or how many relationships were depicted. Instead, a holistic approach is adopted that examines comprehensiveness and considers both organization and correctness. How each of these areas was incorporated into the rubric used to evaluate the trees is summarized as follows:

- Comprehensiveness – How completely did the tree capture the concepts covered in the course materials up to that point? Were all major themes included? How many theorists were depicted?
- Organization – What level of relationship did the tree depict between theories? Linear only? Some relationships between branches? Complex relationships with some branches diverging and reconnecting?
- Correctness – Were the relationships between theories / theorists depicted in the tree logical? Did the relationships show the growth of a thematic area? Were incorrect relationships included?

Based on the recommendations of Besterfield-Sacre, et al., a five point rubric was employed to evaluate each of the trees. The management tree assignment was completed by twelve (12) students, providing an initial comparison group of equal size to those who did not complete the optional assignment. Student performance of the two groups was then compared before and after the intervention of the concept map assignment using the measures outlined in Table 1.

Table 1- Direct Student Performance Measures

| Before Measures[1] | After Measures[2] |
|---|---|
| · Written Brief 1 | · Exam 1 |
| · Case Study | · Written Briefs 2 and 3 |
| | · Research Presentation |
| | · Exam 2 |

1 - Measures used to answer research question 1
2 - Measures used to answer research question 2

**Results**

The course enrollment during the study was twenty-four (24) students, of these, twelve (12) opted into the bonus assignment. The twelve students who completed the assignment generated a wide variety of performance levels on the assignment. Figure 5 shows an example of one of the more exemplary submissions in terms of comprehensiveness, organization and correctness, while Figure 6 provides an example of one of the less complete depictions and also illustrates some clearly incorrect sequencing of how the work of one management theorist provided the foundation for others.

Examining student performance on course assignments before and after the Management Tree of Life assignment was performed by breaking the student population into two groups, those who opted into the assignment and those who did not, and then comparing their scores on individual

course assignments. These comparisons enabled the following research questions to be answered:

1. Prior to the exercise, was there a difference in the performance of students who opted into the tree assignment and those who did not?
2. Following the exercise was there a difference in the performance of those students who successfully completed the assignment and those who did not?

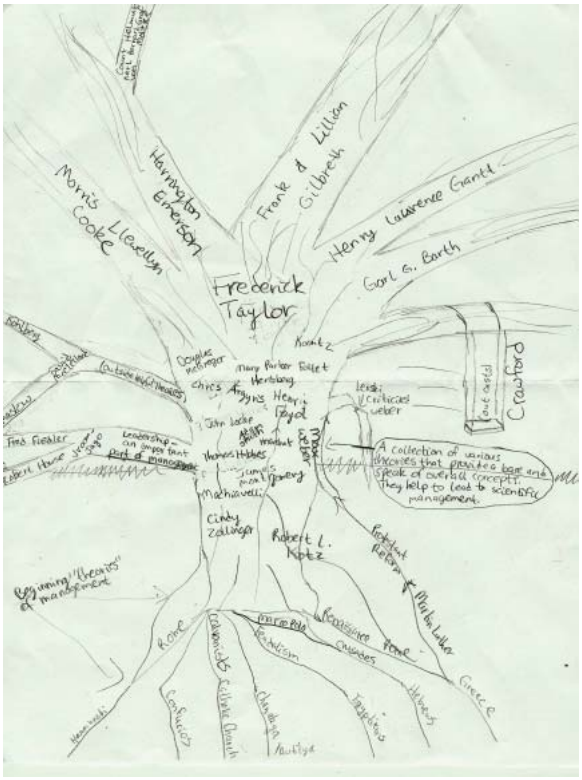


Figure 5 – High Scoring Tree

Figure 6 – Low Scoring Tree

The second research question is the primary focus of this study. Given the results of prior studies discussed in the literature,[5, 6] the expectation is that students who complete the Tree of Life assignment will perform better on graded assignments subsequent to the intervention. The first research question is asked simply to check for selection bias in the sample between those who opted into the assignment and those who did not.

To answer the first research question, a two sample t-test was performed comparing the average performance on the assignments completed prior to the intervention of students who opted into the tree assignment from those who did not. This included two writing based assignments included in the left column of Table 1This comparison found no significant difference ($p = 0.614$ and $p = 0.821$) in performance of those who opted into the tree assignment from those who did not. This finding appears to support the idea that there was not a self-selection bias where students already performing better or worse than their peers were the ones who chose to complete the assignment

The second research question was answered using a series of two-sample t-tests comparing each of the direct measures gathered following the tree assignment, those appearing in the right hand column of Table 1. For this question, the population breakdown was refined slightly and only those students who performed relatively well (earning a score of 4 or higher) on the tree assignment were included in the treatment population (n = 9). This change was made since those who did not perform well on the tree assignment generally did so due to a lack of comprehensiveness rather than errors (see Figure 6). Since their trees did not indicate a reasonable effort to satisfy the requirements of the assignment, it did not seem appropriate to include them in the student population who successfully utilized the tool. Using this subset, the overall results show a strong indication that creating the tree assignment had a material positive impact on student performance. Using an alpha risk of 0.10 for decision making, the specific results for students who opted into the assignment are:

- Performed significantly better ($p = 0.027$) in the course overall, averaging over 6% higher.
- Performed significantly better ($p = 0.048$) on the research outline and presentation, averaging almost 6% higher.
- Performed significantly better ($p = 0.066$) in the remaining short writing assignments, averaging over 5% higher.
- Performed significantly better ($p = 0.069$) on the second exam, averaging almost 9% higher.
- No significant difference in performance ($p = 0.504$) on the first exam, averaging only 3% higher.

Since the students who participated in the tree assignment scored significantly higher on four of the five assignments completed following the intervention the hypothesized impact of the intervention is supported. This conclusion is further strengthen by the fact that these students had no significant differences in performance on the two assignments completed prior to the intervention.

**Conclusion and Next Steps**

The study has shown that use of a concept map like intervention can lead to higher student performance on subsequent course assignments, independent of student performance on assignments completed prior to the intervention. While the broad conclusions that can be drawn from the study are limited due to a small study population, the results of the study seem to indicate that using a novel approach of the concept mapping exercise explored elsewhere in the literature can be a meaningful aid to student performance. For this reason, it is advisable to continue to find ways similar assignments could be utilized elsewhere in the curriculum to promote similar gains. However, the greater contribution might come from determining the extent to which this assignment impacted students' knowledge gain and depth of understanding of course concepts. In order to understand this, further study is needed.

As discussed in the literature review, the findings from studies elsewhere have shown that concept maps can be utilized to assist students to structure their existing knowledge.[7, 10] This has been shown to aid learning new concepts.[6, 10] Given this evidence, it is reasonable to believe that the results of this study also indicate a deeper student understanding of the available knowledge, not simply higher performance on course assignments. In order to more fully investigate this

potential, an additional exploration of the data is planned. First, a similar assignment was utilized with the course in a prior year, which provides an opportunity to increase the sample size for the study. Since those trees were not scored using the methods of Besterfield-Sacre, et al.[15] they were not included in this analysis. However, the author still has a copy of each student submission from that year and can score those submissions using the same approach utilized in this study so that this data can be added to the sample. The second step needed, is to more fully understand whether these results indicate deeper student understanding of course concepts. While differences in the scores of the written assignments and research presentation appear to support this conjecture, utilization of specific exam questions that required deeper understanding of material for additional comparisons could provide stronger evidence. This next round of study will be completed using a team of faculty to ensure consistent application of the tree scoring rubric and exam questions.

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