WIP: MCA: Development of concept map activities to improve undergraduate technical writing in chemical engineering courses

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Abstract

This work-in-progress paper discussing a project funded by the National Science Foundation's (NSF) Division of Undergraduate Education (DUE) describes the refinement and planned implementation of a concept mapping intervention designed to improve the technical communication skills of senior-level chemical and biological engineering undergraduates. Concept mapping offers a promising framework for helping students structure, synthesize, and communicate complex information, which is often underdeveloped in undergraduate curricula.

During this Mid-Career Advancement (MCA) project, several activities using concept maps were integrated into a junior-level course including in-class concept maps using magnets and whiteboards, and a concept map based on a four-page technical writing project. The overall feedback was positive, and students liked how they had to tie their results to the overall project objectives. Key revisions to the classroom activity were informed by student feedback and faculty collaboration, including more explicit instructions, scaffolded group and individual components, and clearer expectations for connecting ideas. A mixed-methods research design was finalized to evaluate the intervention's impact, featuring pre- and post-surveys, scored concept maps, and focus groups. The survey instruments and focus group protocols were developed with support from a mentor and collaborators in engineering education at Clemson University.

This paper and poster will summarize the activity revisions and present the study design to be implemented in Fall 2025. Anticipated results and implications for broader STEM education contexts will be discussed, with an emphasis on enhancing student agency and communication through concept mapping.

Motivation

In the engineering discipline, professional skills, including problem-solving, project management, team management, and communication, are essential for success in industry.[1-3] Despite the clear importance of written and oral communication in the workplace, as skilled communication is tied to higher levels of career advancement,[4] it can be difficult to motivate students to see the importance of written and oral communication in their future careers. Additionally, the importance of technical communication skills is reflected in the engineering ABET outcome of developing technical writing and oral communication skills and to have *"an ability to communicate effectively with a range of audiences."*[5] However, incorporating these skills effectively into the engineering curriculum remains a challenge.

At this Montana State University (MSU), as is common in engineering disciplines, technical communication is taught primarily through lab and design courses. Students prepare short (individual) and long (group) technical reports, as well as group technical presentations as final deliverables to their experiments. The proposed project aims to enhance the technical communication skills of chemical engineering undergraduates by adapting and incorporating evidence-based practices of concept mapping. Concept mapping has been shown to improve students' understanding and retention,[6] as well as problem-solving and critical thinking skills.[7]

Concepts are included within nodes, represented by circles or boxes, connected to each other using lines, usually with arrows indicating direction, and descriptive words near the line describing the relationship between the concepts. The nodes are then placed in a hierarchical structure that starts broadly with more specific, detailed concepts branching out and/or below. If connecting lines are made between hierarchies, those are known as crosslinks and typically indicate a deeper understanding of the material.[8] Figure 1 shows a representative concept map developed by a junior-level student in the mass-transfer course based on their written report.

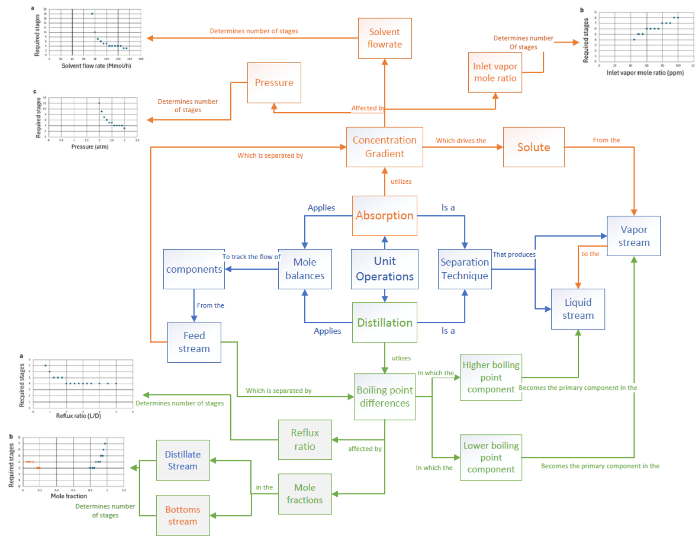

Figure 1. Example concept map created by a student.

While concept maps have been integrated into laboratory classes previously, the goal was not to improve written and oral communication, but for students to better understand the concepts.[9, 10] Outside of laboratory classes, concept maps have been used to improve technical writing[11-13] with a previous study on 9th grade biology students finding that concept maps improve the content of written reports.[12] The current study looks to evaluate the effect concept mapping has on the technical communication skills of senior-level undergraduate students in a laboratory setting, which has not been previously reported. By doing so, the project will help address the challenges of teaching effective communication skills and provide students with the necessary skills and motivation to succeed in the workforce.

Methodology

This project involves validation of data collection strategies, comparison of scores from previous year's students without concept mapping to students that did use concept maps, refinement and implementation of a rubric to ensure consistent grading, survey data collection, student interviews, analysis, dissemination, and refinement of tools and guidelines based on the results. Due to being the second year of the project, this paper will focus on the development of the concept mapping project and rubric, as well as the initial feedback from the students on the activity.

Course Structure As with a typical chemical engineering curriculum, the senior-level laboratory courses and the capstone design series at MSU are the primary courses that provide assessment for the communication ABET outcome. The sequential laboratory courses are taken by senior-level chemical engineers typically in the last two semesters of their curriculum. Since the courses are sequential, the learning between the courses can be scaffolded so that the multimodal composition assignments build on the student's previous knowledge. The first lab course is taught by the author and focuses on the technical communication learning objectives of: 1) the ability to identify genre, 2) ensuring informal oral and written communication is appropriate for the audience, and 3) communicating data through visible display of quantitative information.

Assessment In order to assess the concept maps consistently and accurately, a comprehensive rubric was created that focuses on key constructs and levels of mastery. The current technical communication rubrics in the ECHM 442 course are heavily weighted towards analysis with 20% consideration given to holistic factors, as the goal is providing students with a clearer understanding of their readiness to communicate effectively in the professional community. Figure 2 shows some of the constructs that are evaluated with the technical rubric; however, for the concept map a more holistic rubric was desired.

Figure 2. A portion of the rubric used to evaluate the executive memo report in both classes.

Literature Review and Theory	**A = 2** Has all and only those pieces of theory needed for/relevant to the assignment and audience; completely accurate		**C = 1.5** Has some of the needed theory; includes a good amount of unneeded or commonly known material; some errors; missing eqns
Results and Discussion (e.g., the "why?")	**A = 8** All useful results are presented and discussed; apropos chart and table use; excellent text to explain how results were obtained from data; references to equations when needed; critical assumptions or approximations made in obtaining results are stated; *whys* discussed for all results; no significant conceptual errors; logical recommendations tied to theory and results	**B = 7** Most key results are presented and discussed, or all results presented but only some *whys*; OK chart/table use; some text to explain how results were obtained; key accompanying uncertainty; might include reference to equations, critical assumptions or approximations; relatively few conceptual errors; reasonable recommendations	**C = 6** Some key results are presented and/or discussed; adequate chart/table use; little text explaining how results were obtained; marginal accompanying uncertainty; few references to equations, critical assumptions or approximations; some technical conceptual errors; weak recommendations
Conclusions/ Recommendations	**A = 4** Purpose/objective is restated in a new way; major finding and recommendations are clearly stated;	**B = 3.5** Purpose/objective is restated; major finding is stated, but not clear; revisits hypothesis; recommendation could be improved	**C = 3** Purpose/objective or major finding is incorrect or missing; unknown hypothesis; recommendation is weak

Concept Map Activities Concept map activities were developed and implemented in a junior-level mass transfer course in the spring of 2024 and fall of 2025. In class, students developed a concept map framework on different aspects of unit operations using magnets and dry erase markers. Following the in-class activity, students had to create a concept map on the technical report and results based on the project objectives. Following implementation and subsequent submission of their technical report, students were offered a survey (with a $20 incentive for completion) to provide feedback regarding the learning outcomes and concept map activity. Using this feedback, a concept activity was developed for the senior laboratory course that was implemented in the fall of 2025.

In the senior laboratory course, for each of the two labs ran during the semester, students developed a concept map. First, as a group using the experimental protocol and objectives as their initial resources. The concept maps were collected and scored to provide feedback for the students regarding the content and structure. The second concept map was based on the second lab results and completed individually. This concept map should demonstrate the student's understanding of the material and represent the data and information presented in the lab report.

Results

Survey Development In order to get feedback on the concept map activity, a survey was developed to give to the students after the project was completed and a set of survey responses were collected. Most of the feedback was positive with 73% (of 19 student responses) of students saying that the concept map activity led to a better understanding of the course topic and 90% of students saying the concept map activity helped them see the connections between the topics and results.

Rubric development A rubric to grade the concept map activity was developed that encapsulates the major points of a concept map and added to the project/report rubrics (Figure 3) and was adapted from M. Besterfield-Sacre, J. Gerchak, M.R. Lyons, L.J. Shuman, and H. Wolfe.[11] The rubric focuses on the comprehensiveness, organization, and accuracy of the concept map compared to the technical report. While adequate to evaluate the concept maps, future changes will focus on clarity of the levels of performance as description of the "but is limited" was vague and did not include when major aspects were lacking.

Figure 3. Rubric used to evaluate the concept map activity in both classes.

	A = 8	**B = 7**	**C = 6**	**D = 5**	**F = 0**
Concept Map	**Comprehensiveness** – The map completely defines the subject area and all of the variables presented in the simulation; includes multiple hierarchies, represented by nodes, and crosslinks, represented by link lines **Organization** – The map is arranged systematically and has good branch structure and connectivity **Accurate** – Reflects the report and information presented and indicates a good understanding of the subject matter with no misconceptions, spelling/grammatical errors	The concept map is adequate in comprehensiveness, organization, and accuracy, but is limited in one of the areas. For example, some main aspects are missing, integration of branches is lacking, and there may be a few grammatical errors.	The concept map is adequate in comprehensiveness, organization, and accuracy, but is limited in two of the areas. For example, some main aspects are missing, integration of branches is lacking, and there may be a few grammatical errors. The concept map suggests a somewhat narrow understanding of the subject matter.	The concept map is adequate in comprehensiveness, organization, and accuracy, but is limited in all of the areas. For example, some main aspects are missing, integration of branches is lacking, and there may be a few grammatical errors. .	Missing or lacking many of the aspects required.

Activity development An introductory in-class concept mapping activity was implemented using magnetic word sets. Students worked in small groups to organize and connect separation-related terms and were asked to incorporate two additional terms of their own. This activity served as students' first exposure to concept mapping; guidance was provided, but the exercise was ungraded and followed by a class discussion.

Building on this introduction, a graded concept mapping assignment was integrated into the course project. Students, working individually or in pairs, created concept maps based on their technical reports. The objective was to help students visualize connections among report sections and reflect on how effectively their results, discussion, and conclusions were aligned. In this activity, students translated their written reports into concept maps, explicitly mapping relationships between results and their interpretation. Survey responses indicated that this process helped students identify gaps and strengthen connections both within their writing and between their work and course concepts.

The concept map activity and survey have been prepped to be implemented in Fall of 2025 in a course at MSU. There were several modifications to the previous concept map activity with the biggest being more details as to what to consider including and explicitly stating to make as many connections as they can. The first concept map activity will be a group activity for their experimental proposal for Lab 2 in the course and the second activity will be individual and based on the results of the lab (mirroring the executive memo they need to write).

Future Work

In the spring 2026 semester, focus groups moderated by a collaborator from Clemson University took place to gain insights into their experiences and perspectives on using concept maps. The questions were developed, and the focus groups took place in late March of 2026. The focus groups allowed for more dialogue to occur, and since the students were no longer being evaluated for a grade, more honest comments may have resulted. This data will be analyzed through a series of coding and analytical memos.

Acknowledgement

This material is based upon work supported by the NSF under Grant No. 2321428.

References

1. Dannels, D. P., "Learning to Be Professional: Technical Classroom Discourse, Practice, and Professional Identity Construction." *Journal of Business and Technical Communication* **2000,** *14* (1), 5-37, 10.1177/105065190001400101
2. Grant, C. D.; Dickson, B. R., "Personal Skills in Chemical Engineering Graduates: The Development of Skills Within Degree Programmes to Meet the Needs of Employers." *Education for Chemical Engineers* **2006,** *1* (1), 23-29, https://doi.org/10.1205/ece.05004
3. Paretti, M. C.; McNair, L. D.; Leydens, J. A., Engineering Communication. In *Cambridge Handbook of Engineering Education Research*, Johri, A.; Olds, B. M., Eds. Cambridge University Press: Cambridge, 2014; pp 601-632.
4. Sageev, P.; Romanowski, C. J., "A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills." *Journal of Engineering Education* **2001,** *90* (4), 685-693, 10.1002/j.2168-9830.2001.tb00660.x
5. Commission, A. E. A., Criteria for accrediting engineering programs. ABET, Inc.: Baltimore, MD, 2019,
6. Novak, J. D.; Gowin, D. B., *Learning how to learn*. cambridge University press: 1984.
7. Novak, J. D., "Concept mapping: A useful tool for science education." *Journal of research in science teaching* **1990,** *27* (10), 937-949,
8. Novak, J. D.; Cañas, A. J., "The theory underlying concept maps and how to construct and use them." **2008**,
9. Muryanto, S. In *Concept Mapping: An Interesting and Useful Learning Tool for Chemical Engineering Laboratories**, 2006.
10. Özmen, H.; DemİrcİoĞlu, G.; Coll, R. K., "A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry." *International Journal of Science and Mathematics Education* **2009,** *7* (1), 1-24, 10.1007/s10763-007-9087-6
11. Cañas, A.; Reiska, P.; Åhlberg, M.; Novak, J., "Using concept map to facilitate writing assignment." *Life long learning* **2008,** *2*, 5.9,

12. Conklin, E. Concept mapping: impact on content and organization of technical writing in science. Walden University, 2007.
13. Roy, D., "Concept Maps for Teaching Technical Writing to Computer Science Majors: A Case Study in a Japanese Technical Institute." *International Journal of Learning* **2010,** *17* (1),