# Board 146: Work in Progress: Incorporating Learning Strategies and Theory into a Multidisciplinary Design Capstone Course

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# WORK-IN-PROGRESS:
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## Introduction

This work in progress paper explains modifications made to the senior-level multidisciplinary design capstone course based on student learning theories and strategies. In the summer of 2022, the Multidisciplinary Design Capstone (MDC) instructional team at The Ohio State University attended a 3-day departmental workshop to evaluate and discuss improvements to the course based on several different student learning strategies and theories. The workshop included reviewing learning theories and developing modifications to the current MDC curriculum to enhance student learning. There were four major learning strategies and theories that were focused on for the 2022-23 academic year. These strategies and theories included sense of belonging, stereotype threat, calibration, and retrieval. MDC course assignments and activities were developed or modified to support student learning based on these strategies and theories.

The combination of these learning strategies and the student perception of the learning outcomes is evaluated through a triangulation method of assessment. The feedback of students on self, of students on peers, and of advisors and industry sponsors on students is compared throughout the course. Pieces of this work have been added into MDC over the years with these listed pieces integrated beginning in Autumn of 2022. The first full year of data will be evaluated after Spring of 2023 and then repeated for the upcoming academic years 2023-24 and 2024-25.

## Background

The Ohio State University College of Engineering's Multidisciplinary Design Capstone (MDC) program is a year-long cross-discipline senior-level design course for students across various engineering majors (EM) and non-engineering majors with an Engineering Science Minor (ESM). The MDC instructional team consists of a director, an engineering senior lecturer, and a technical communications senior lecturer. The 2-semester course starts in autumn semester and continues through spring semester. MDC annual enrollment includes 60-80 students from both engineering (~80%) and non-engineering ESM (~20%) completing 13 – 20 sponsored projects. The students are placed into teams of 4-6 students to follow a design process that includes problem identification, research, conceptual design generation, detailed design, prototyping, evaluation, and documentation.

Since its conception, the MDC course has collected weekly timesheets from each individual student. The timesheets are not for a grade; they are for data on workload balance between and amongst teams as well as the course overall. In the 2022-23 academic year, these have now been expanded to also include a weekly check-in. The weekly check-in consists of a few Likert scale questions around the individual perspective on their work within the learning outcomes. There is also an open-ended field for any comments, questions, or feedback.

In the 2020-21 academic year, MDC began administering an 'ABET-EMLO Learning Outcomes' survey to assess student perceptions at the beginning of autumn semester and at the

end of spring semester. The bookend survey focuses on their perceived preparedness to complete the identified tasks in a professional workplace environment and track overall improvements from the beginning to the end of the course. The level of preparedness is on a scale of 1-5 with 1: Not Prepared at All, 2: Minimally Prepared, 3: Somewhat Prepared, 4: Adequately Prepared, and 5: Very Prepared. Feedback from this survey has helped inform the instructors on areas to improve course materials and/or assignments. The engineering tasks in the survey align with the Student Outcomes identified by ABET (in gray) and Entrepreneurial Mindset Student Learning Outcomes (EMLO) (in green), which align with the MDC course learning outcomes (in orange) as illustrated below in Figure 1:

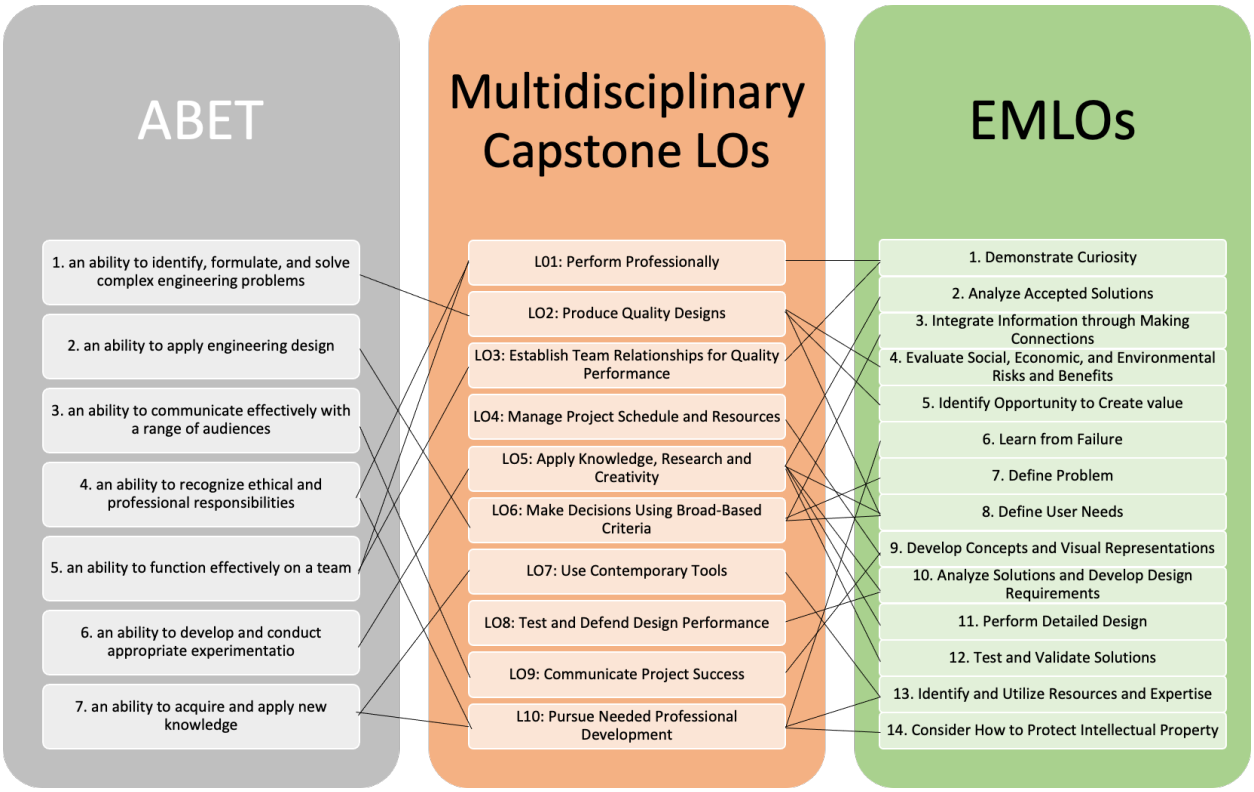


*Figure 1: Connection of ABET Student LOs and Engineering Mindset LOs to MDC LOs*

In the 2022-23 academic year, MDC began administering surveys to all project sponsors and advisors for each team. These are completed at the middle and end of both semesters, totaling 4 data sets.

In the 2020-21 academic year, MDC began using the CATME tool from Purdue University for team evaluations. These are completed at the middle and end of both semesters, totaling 4 data sets. This gives students an opportunity to practice giving and receiving feedback while allowing them time to improve their performance before the graded evaluation at the end of the semester.

Two of the focuses from the workshop were to increase a **sense of belonging** [2 – 14] and reduce **stereotype threats** [15 – 22] within the student capstone teams. This is very important due to

having diverse student teams involving both engineering and non-engineering majors with diverse backgrounds and experiences from across the university. The MDC instructional team incorporated the value affirmation strategy by requiring student teams to develop team values that are related to each individual student's values. In addition to team values in their team charter, the instructors incorporated empathic decision making into the design process [23]. The intent of this process is to increase team inclusivity and efficiency.

**Calibration** is the relationship between a student's perceived performance and their actual knowledge of cognitive level [24 – 29]. In the MDC capstone projects, students tend to identify a solution to a given problem early in the design process. In fact, some students tend to "jump" to a solution before completely understanding the problem that has been proposed to them. In the MDC course, the instructors have the students spend 4 weeks at the beginning of the project identifying the problem and root causes before beginning work on possible solutions. This process was emphasized for students to reflect and modify their problem identification as they gain knowledge progressing through the design process. The instructors reinforced this relationship between their performance and knowledge gained through revisions to past written reports that were used to build on their project.

**Retrieval practice** helps students to monitor their learning by encouraging them to retrieve prior knowledge [30 – 46]. The MDC instructional team implemented this practice by giving written feedback to students on their written reports and oral presentations and allowing them to incorporate this feedback on future extensions of their reports and presentations to improve their communication skills.

The MDC instructional team is employing a triangulation method of feedback to review impacts of these changes [1]. This method includes receiving responses from students, student peers, and experts (MDC instructors, faculty advisors, and capstone project sponsors). This information will be used to evaluate these changes in curriculum. The assessments are collected through various formats and include the ABET-EMLO Bookend Survey of Self, the Weekly Timesheet Survey of Self, bi-semester CATME Survey of Peers and Self, bi-semester Sponsor/Advisor Surveys of Students, and instructor evaluations of the project milestones.

Ferdiana (2020) demonstrated a triangulation assessment model, outlined in Table 1, in a software engineering capstone to address subjectivity and non-standardization of the assessment model between projects. The author stated "…there should be an opportunity to use the triangulation assessment model in the non-software engineering capstone project model" and MDC has begun that process for multidisciplinary capstone projects.

*Table 1: Triangulation Assessment in the Software Engineering Capstone Project [Ferdiana, 2020]*

| Assessment Instrument | Measurement Description | Assessment Method |
|---|---|---|
| Student outcome rubric | Measuring the student outcome by looking at the capstone design project product | Direct |
| Capstone logbook assessment | Measuring the process of engineering design | Direct |
| Capstone design project survey | Measuring the feedback | Indirect |

## Methods of Implementation

The implementation of the four learning theories includes sense of belonging, stereotype threat, calibration, and retrieval practice. These four learning theories are connected to both MDC LOs and EMLOs in multiple ways, as illustrated below in Figure 2:

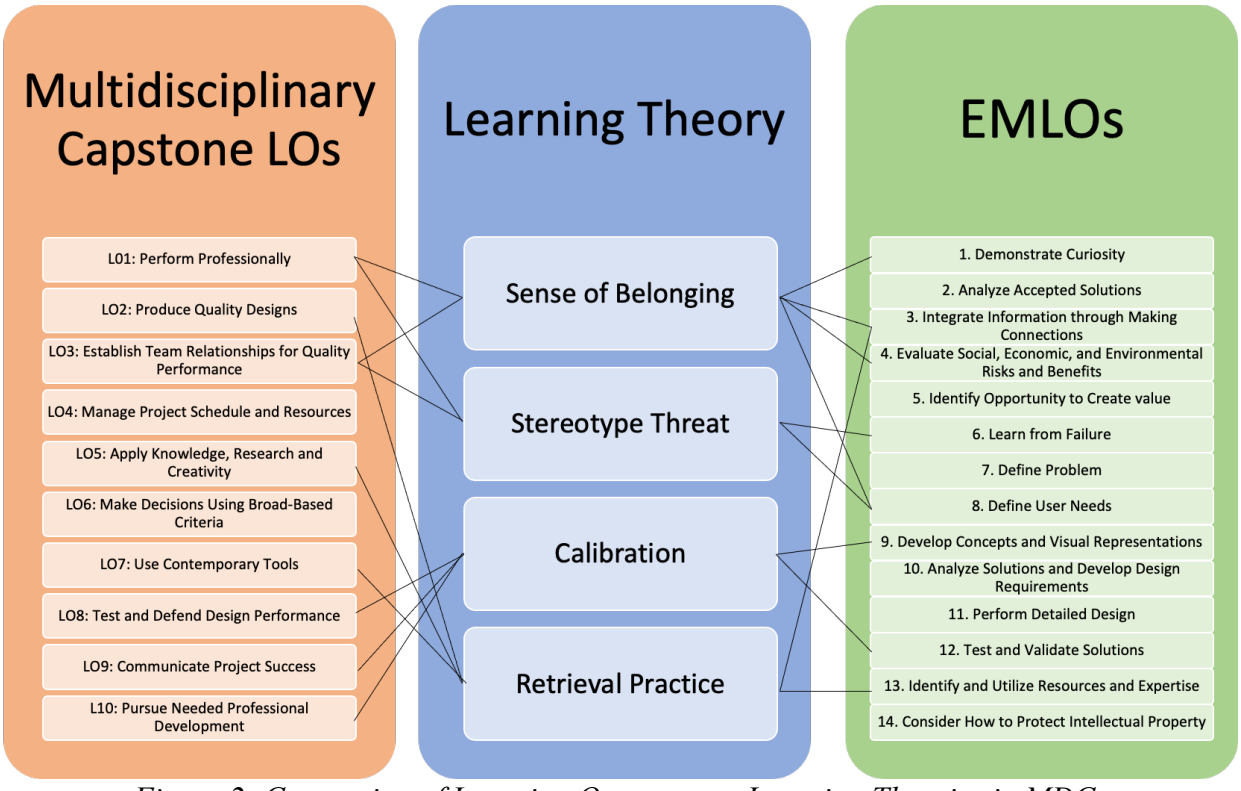


*Figure 2: Connection of Learning Outcomes to Learning Theories in MDC*

**Sense of Belonging** was incorporated as a value affirmation process in the student team development of their team charter. This involved individual students identifying their own personal values and discussing them as a team to create a set of team values within their team charter. This helped each student better understand their team members while seeing their personal values represented in the team values.

**Stereotype Threat** was presented as empathic decision-making to the capstone students to increase inclusivity within the student teams. This was introduced and practiced with the team charter and then reinforced in their project with a focus on the user needs to begin problem identification.

**Calibration** was incorporated in the initial phase of the MDC design process that involves identifying the problem that the student team is assigned to complete. This phase is given 4 weeks for the students to define in detail the project objectives, root causes and requirements before moving into the conceptual solutions phase. As the teams progress through the design process, teams review and revise their problem statement as a way to introduce new knowledge gained and to reevaluate and redirect the project direction. Validation of their final design and research/prototype requires a plan that connects back to the user needs and original problem identification.

**Retrieval Practice** is incorporated in the MDC program as the students build a report over the two-semester sequence. The report is broken into four major chapters that include problem identification, preliminary design, detailed design, and final design. The instructors require the teams to submit updated prior sections of the report as they progress through the design process phases. The students are instructed to incorporate feedback on these prior sections and front-end matter, including an executive summary, when submitting a new chapter of the report. This allows students to reflect on prior work and to include new knowledge in their report and presentations.

## Impacts of Implementation

As this is a work in progress, this paper includes qualitative observations from the instructors' general evaluations of these impacts from one semester of modifications (Autumn 2022) which is one-half of the first year of implementation. The instructors are using the triangulation method of feedback over the academic year to fully evaluate impacts. A more in-depth analysis of the collected data will be completed in future works.

At the end of the autumn semester, students were surveyed to evaluate their self-performance and team performance based on five MDC learning outcomes. The learning outcomes included:

- Perform Professionally
- Manage Project (and Teamwork)
- Apply Knowledge (to Design Development)
- Make Decisions (and plan Next Steps)
- Communicate Project Status

The students were asked to evaluate their performance or demonstration of these five areas using the following Likert scale:

1. None at all
2. Minimal
3. Somewhat
4. Adequate
5. Exceeds Expectations

Figure 3 displays the average of the Likert score for the learning outcomes from the student evaluation of their team (Student – Team) and themselves (Student – Self). In addition, the same survey was given to the team's sponsor and faculty advisor to evaluate the team (Sponsor/Advisor).

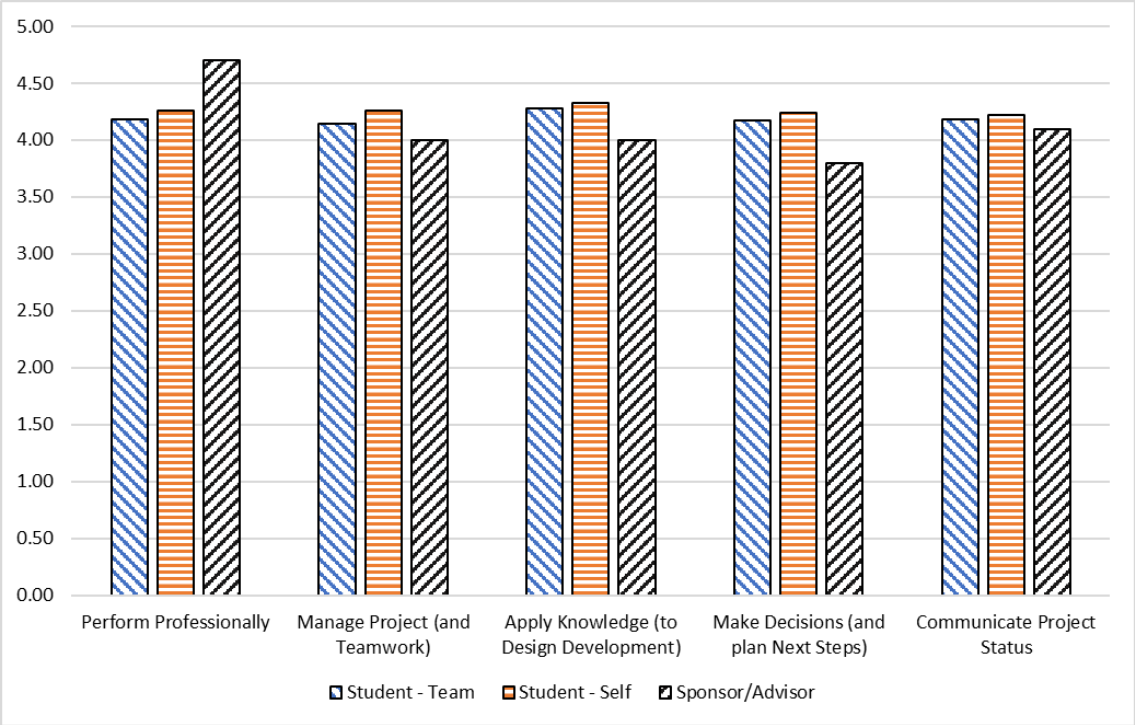


*Figure 3: Student & Sponsor Perceptions in Performance*

These results show similar scores from the student's perspective and sponsor/advisor's perspective. Future research will be compared to the end of the second semester survey results to identify trends and impacts.

The qualitative observations from the instructors throughout the year resulted in the following lessons learned:

- The value affirmation activity appeared to be valuable and the teams incorporated the items in the team charter in thoughtful ways.

- Students' self-evaluations of their preparedness related to the MDC learning outcomes were observed to be somewhat or adequately prepared at the beginning of the course sequence.
- Students' perceptions of their preparedness for the ABET Criteria 3 items 1 through 7 were similar to the MDC learning outcomes.
- In general, most teams struggled with the first submission of each chapter of the report. Therefore, the revision process that was implemented proved to be very valuable.

## Future Work

Data will continue to be collected through Spring of 2023 and will provide a full year of data on each student and team. The information collected from the various assessments will be triangulated to better contextualize the student perspective. This current 2022-23 academic year has 75 students working across 17 projects. Surveys and data collection methods may be updated for next academic year, as needed, where additional data will be collected for the full year. The instructors plan to analyze the data to improve the delivery and impact of implementing these changes.

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