Benchmarking Teaming Instruction Across a Curriculum

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Abstract

Cornerstone and capstone design courses rely heavily on effective student team functioning. Student teaming experiences in these courses is influenced by students' prior experiences on teams in other courses across the curriculum. In the various team experiences students have in a curriculum, they may or may not develop effective team behaviors. As an initial step towards designing scaffolds for student teaming experiences, this paper seeks to document instructional characteristics of student teaming experiences in required courses throughout the current Mechanical Engineering curriculum at Rose-Hulman Institute of Technology via faculty surveys. In particular, the survey asked about size of the team, duration of the project, instruction on teaming, feedback on teaming, methods of dealing with team dysfunction, and impact on individual grades. In the data it is apparent that there is a large lapse of time between consecutive experiences, gaps in teamwork instruction, and lack of scaffolding of teaming. The results of this benchmarking process will be used to focus departmental deliberations and cast a shared vision of how to effectively scaffold instruction and development of each student's teamwork skills. As we focus on the intentional design of a coordinated plan for teaming across our curriculum, we also share our process for this curriculum revision through building shared vision so that others could leverage beneficial elements for their contexts. Our work on teaming is part of a larger curriculum vision effort in our department.

Introduction

Our work to map and coordinate the teaming instruction across the Rose-Hulman Institute of Technology Mechanical Engineering (ME) Curriculum is part of a larger curriculum vision effort within our department. In 2014 the ME department's Curriculum Vision Committee was formed with three primary goals: 1) to cast a vision of what our curriculum could be, 2) to help our department to think more broadly about what we do, and 3) to make explicit our departmental values. In order to develop a longer range aspirational vision, several references were studied including ABET accreditation requirements [1], our alumni survey, Engineer 2020 [2], Trevelyan's ethnography on engineering practice [3], and problem-based learning theory in order to develop the map of desired ME curriculum outcomes shown in Figure 1.

This graphic for desired outcomes showcases the mutual importance of what we have called Basic Engineering Skills and Engineering Mindset. The Basic Engineering Skills are considered parts of the core of the undergraduate curriculum. Engineering Mindset in the outer layer encompasses broader aspects of engineering that impact motivation and the interface with those outside of engineering. We refer to it as the "onion" because engineering is comprised of many layers of knowing and being, just as an onion is layered in its structure.

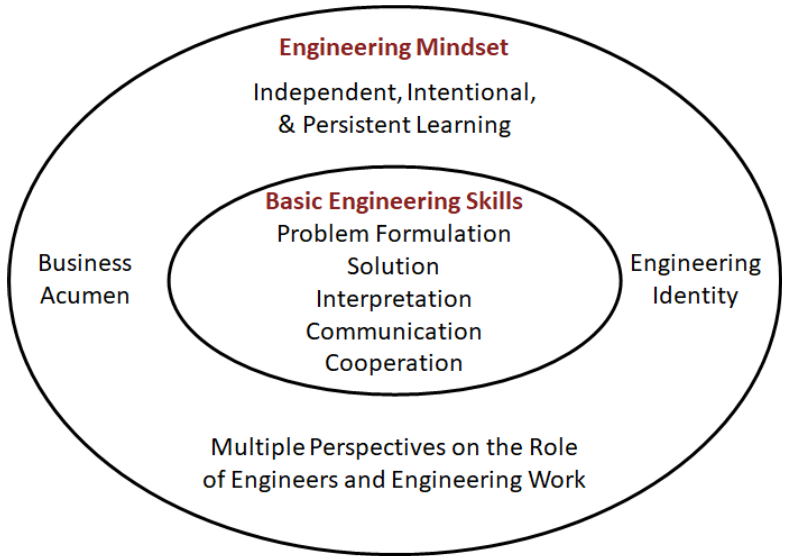

Figure 1. Desired ME curriculum outcomes "onion" defining mutually supportive engineering skills and mindsets

During this process the committee looked to see how well the outcomes in the onion mapped to institutional learning outcomes. Communication and cooperation were both part of the "basic engineering skills" whereas ethics, leadership, and culture and global awareness were all subcategories of "multiple perspectives on role of engineers and engineering work." We also looked at the mapping of the current ME learning outcomes to the onion in Figure 1. Our department outcomes include the following: our graduates will be successful in their careers, our graduates set and meet their own goals for career fulfillment, our graduates will continue professional development, our graduates will engage the international dimension of their profession. The departmental outcomes and ABET a-k, map well to the onion outcomes with the exception of the business acumen aspect missing. Based on Trevelyan's ethnography of engineering practice[3], in general, engineers spend most their work time on the following tasks: coordinating people, business development, procurement, financial, and human resource development, thus adding business acumen seemed appropriate. In addition, according to our alumni survey, one of the current weaknesses cited is the lack of business side of engineering (management, leadership, finance, entrepreneurship).

Along with development of a long range aspirational vision of our entire curriculum, several changes were proposed by the committee to our current curriculum map which were adopted by the department in order to move us towards the vision. This committee also established the development of thread categories – desired department-wide outcomes that require intentional coordination because they transcend a single course or content area.

Initially 15 potential threads were developed and mapped to our aspiration curriculum to illuminate the strengths, weaknesses, and gaps of these themes, shown in Figure 2. The letters at the top of the Figure 2 corresponded to the thread categories listed at the bottom and the courses are listed on the left-hand side. The coloring represents how much a certain thread is covered in a course, according to departmental self-assessment. This preliminary look into topics for cross-cutting curricular threads illustrated the importance of considering the entire curriculum from the beginning to identify strengths, weakness, gaps, and opportunities.

Figure 2. Threads mapped to course offerings showcasing the viability of incorporating the thread into the course

Of the fifteen threads the one developed the least is “multiple perspectives of engineers and engineering work,” whereas themes like “intelligent use of tools” and “hands-on work” were already prevalent. Since it was not possible to focus on all of the threads simultaneously, the Curriculum Vision Committee integrated these suggested threads with the onion to form six themes as shown in Figure 3 [4]. These were presented to the department and it was reiterated that the threads were developed through collective deliberation and are important outcomes that we, as a department, desire to see in our students. Further, developing these threads requires intentional choices and cooperation. Intentional coordination of these themes can: (1) help our students development by allowing them to see these threads explicitly; (2) clarify our teaching/training in these areas (what is it); (3) provide a more consistent message from class to class (coherence) (4) give students repeated practice; and (5) provide departmental feedback showing progress or lack of progress in the student’s development for these areas (assessment along the way). Because of the numerous advantages of the development of these themes, the committee asked for volunteers to form working groups as well as provided potential phases of future work.

#1 • **Business Acumen**	# 4 • Technical Communication (**Interpretation & Communication**)
#2 • Connecting to Strong Fundamentals • Quantitative Problem Solving • (**Problem Formulation & Solution**)	#5 • Experimental Methods • Hands-on Work
#3 • **Ill-structured Problems** / Design* • Intelligent Use of Tools • Verification (Checking Solutions & Trouble Shooting & Debugging) • Programming / Logic / Algorithms	#6 • **Engineering Identity** (including Professionalism & Expectations) • **Multiple Perspectives of Engineers & Engineering Work** • Teaming (**Cooperation**) • **Development as a Learner**

Figure 3. Aggregation of themes into six more manageable themes

Throughout our process, the Curriculum Vision committee engaged the whole department transparently and consistently through End-of-Quarter departmental meetings and some monthly departmental meetings. The voice of everyone in the department was valued and the department gave direction for the next steps in our process. This regular engagement with opportunities for open discussion and refinement was purposeful and has facilitated the development of a shared vision for our curriculum.

The tasks for each working group going forward were (1) agreeing on a cross-cutting theme definition (as is or revised) and documenting all current practices addressing the theme; (2) developing a coordination plan that includes the frequency and placement of engaging students with the theme, the learning objectives for each relevant course in our curriculum, variety of ways to meet learning objectives for each relevant course, and the assessment plan; (3) departmental deliberations and approval of coordination plans; (4) updating the course catalog description and ABET syllabi translating learning objectives to individual course syllabi. Several departmental members volunteered to further develop the thread themes. The currently active thread groups within the department are the business acumen thread, the technical communications thread [4] , the hands-on/experiential learning thread, and cooperation thread. These threads, with the exception of business acumen, are broadly represented in our current curriculum, but are not well coordinated. Therefore, these are good starting points for learning how to coordinate the experiences for a thread before moving to threads requiring more significant content development. The other threads have been tabled for now and will be revisited for development or revision in the future along with other threads that may come up. This is an ongoing process.

The group working on this paper (for the cooperation thread) volunteered to work on theme #6 (Figure 3). After much deliberation, it was decided to focus on the cooperation aspect of the thread as this was seen as the "lowest hanging fruit" since teaming is currently required in numerous classes but could be improved and better coordinated. Throughout this paper we will discuss the steps taken to better understand and document the extent to which teams are used within required courses in Mechanical Engineering at Rose-Hulman Institute of Technology and the broad classification of the instruction students receive in teaming throughout the curriculum. The operational definition of "team" throughout this paper is as follows: "*A team consists of more than one person working towards a common goal (i.e., has at least one team submission that is graded)*". Teaming in the coursework here refers to any type of graded coursework such projects, labs, assignments, or other class related activities which is a combined output produced by two or more students.

Background and Literature review

Teamwork or cooperation emerged as a needed cross-curriculum thread for a variety of reasons. One important motivation for the further development of this thread is the wide use of teams within modern industry practice [5-7], the marketability of teamwork skills [8] and the need for schools to meet accreditation standards which include teamwork [1]. Other studies have also shown learning and retention benefits from teaming experiences during their collegiate career [9-11]. Despite this, in 2004 Chen argued that many students that graduate from college lack these skills upon entering the workforce [12]. Part of this might be attributed to the findings of Oakley et al. which linked student satisfaction with teams and whether the instructor guided them in teamwork skills [10]. Ohland et al. further reinforce the importance of instructors modelling and instructing students on teamwork skills to promote team success [13].

As is noted by Kurfess, teamwork skills have traditionally been considered "outside of the curriculum" and are often taught as topics within design-based courses [14]. As such, in many curriculum teamwork instruction is often only included in cornerstone and capstone courses [15-17]. This is not to say that these are the only teaming experiences in the curriculum, only that little instruction on teamwork skills are typically given in the sophomore and junior years.

Even within capstone courses, teamwork instruction can be limited. A national survey of capstone design courses that included faculty beliefs and teaching practices by Pembridge and Paretti showed that teamwork, as a separate topic from project management, were rarely in the top five topics covered in the course [18]. Much attention in literature has been focused around how to form teams [19-23] and using peer-evaluation to improving teamwork skills [24, 25] but there are still many open-ended questions relating to the best way to manage and mentor teams [15].

One major reason for benchmarking teaming experiences currently in the curriculum is to better understand where students are exposed to teams throughout a curriculum. This allows us to begin the discussion of how and when teamwork skills should be introduced and allows for intentional scaffolding of skills. This approach aligns well with change models and strategies centered around developing a shared vision and reflective teaching practices proposed by Henderson and Borrego [26, 27]. The results of this present study will inform future steps that need to be made in individual classes to achieve the larger shared curricular goals of the department.

Research Approach

In order to collect information about the current state of teaming within the curriculum, a survey was developed to collect existing information about teaming in core ME courses. The main questions asked were to understand if the teaming existed in a specific core course. If it does, then the logistics of the teaming were further investigated. Logistical questions solicited information such as the size of the teams, duration of the project, number of projects in the course, and whether teams are changed within a course. It is also investigated how the teams are formed and if the instructor assigns the teams, then what traits are considered for forming teams. In addition, information was collected about what types of instruction on teaming was provided, namely, formal versus informal, and formative versus summative. Further qualitative information was collected to know if the individual grades on the teams varied compared to the team grade, and how team dysfunction was handled.

Three faculty were surveyed for each of the core course and a total of 21 courses were surveyed. To avoid survey fatigue, deliberate effort was taken to ensure that each faculty member had no more than 3 surveys to fill out. Except for two faculty who had to fill out 4 surveys due to sabbatical leaves or retirements. This information was collected only for past courses and not for ongoing coursework. The faculty were asked to fill out the survey in a department meeting as a working session to maximize the response rate. The first survey question asked for informed consent and if they wanted to proceed which allowed faculty to opt out. The data point in a course collected could not be traced back to an individual faculty member.

The co-operation thread committee used the survey responses to develop a curriculum map to showcase different aspects of the teaming across our curriculum, such as teaming logistics and instruction. The specifics of the curriculum maps are presented in results and discussion section. At a subsequent departmental End-of-Quarter meeting, the cooperation thread committee presented the curriculum maps and asked for corrections. Then opened the floor for discussion and for soliciting observations from the group. At the end, the cooperation thread committee also shared the key findings and observations from the map. The discussion about the current map was guided based on (1) determining if this map captures the current scenarios aptly, (2) helping the committee refine the observations made, and (3) adding additional observations based on the current data. The next section details the observations made from the survey responses.

Results & Discussion

One of the main goals of this work is to understand the current status of teaming that students experience throughout the curriculum. Figure 4 captures instances of teaming throughout the curriculum along with some logistical aspects of teaming including team size, project duration, and the number of projects. Classes that do not have teams are indicated by crossed marking while the data that is not available is grayed out. Overall, ME curriculum has a significant cooperative learning component in 16 out of the 21 core ME courses. The first quarters of the freshman year and the sophomore year are the only quarters with no teaming experience within the ME core curriculum; otherwise, in any given quarter on average, a student would have at least two courses with teams. Amongst the courses that do have teams, the first row indicates whether the cooperative learning occurs in pairs (yellow) or in teams of 3 or more students (green). Significant presence of green indicates that most courses do have teams of 3 or more, a trend that would be appropriate for an "ideal teaming experience". The second row is colored orange if the project lasts more than 6 weeks (more than half of the quarter). Absence of color in the second row indicates teaming in coursework with durations shorter than 5 weeks. As expected, coursework in 400 level courses last for 6 weeks or more while shorter duration coursework is more common in underclassmen courses. The third row is colored in blue if there is a single project in the class while courses offering more than one project are left uncolored in the third row. Again, as expected, senior level coursework requires a single long cooperative coursework compared to underclassmen courses.

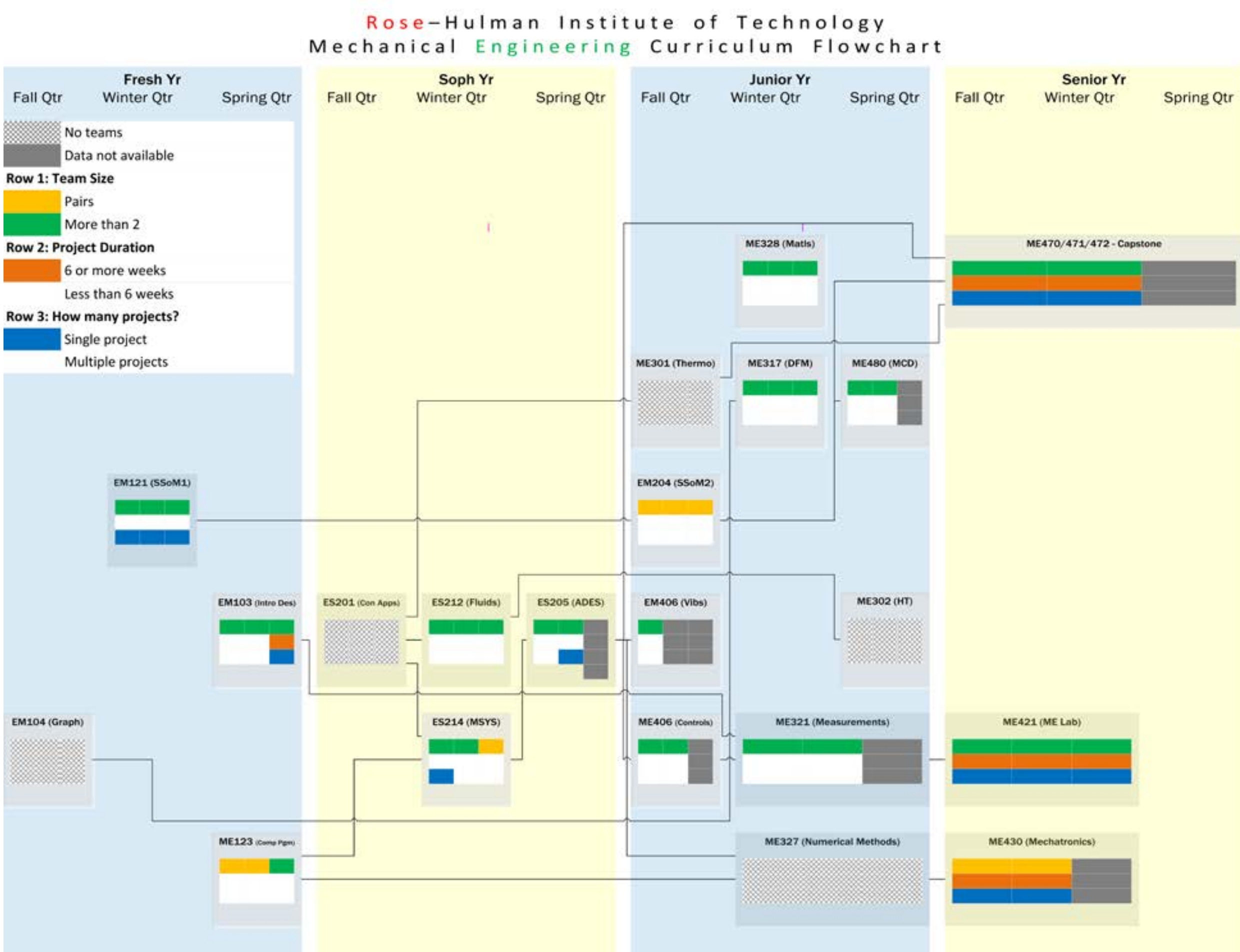

Figure 4. ME curriculum map indicating instances of cooperative learning along with logistics of incorporating it in the coursework.

Given that cooperative learning occurs in a course, it is important to understand if the students receive any training to become better team members. The first row of Figure 5 showcases whether or not students receive any instruction on teaming; dark blue indicates informal instruction and green indicates formal or semi-formal instruction. There is some instruction on teaming in freshman and higher-level classes. There is notable sparsity of instruction in the middle of the curriculum indicated by no color in the first row. If any instruction on teaming exists then it varies amongst sections. The second row of the Figure 5 displays whether students receive feedback on teaming indicated by a yellow color. It is striking that the students do not receive any feedback on teaming behaviors for a continuous stretch of 4 quarters from fall quarter of sophomore year to first quarter of junior year. Again, the feedback on teaming does not seem to be consistent across sections. Addition of intentional instruction as well as feedback on teaming would greatly help students to become better team members and will be investigated in the future.

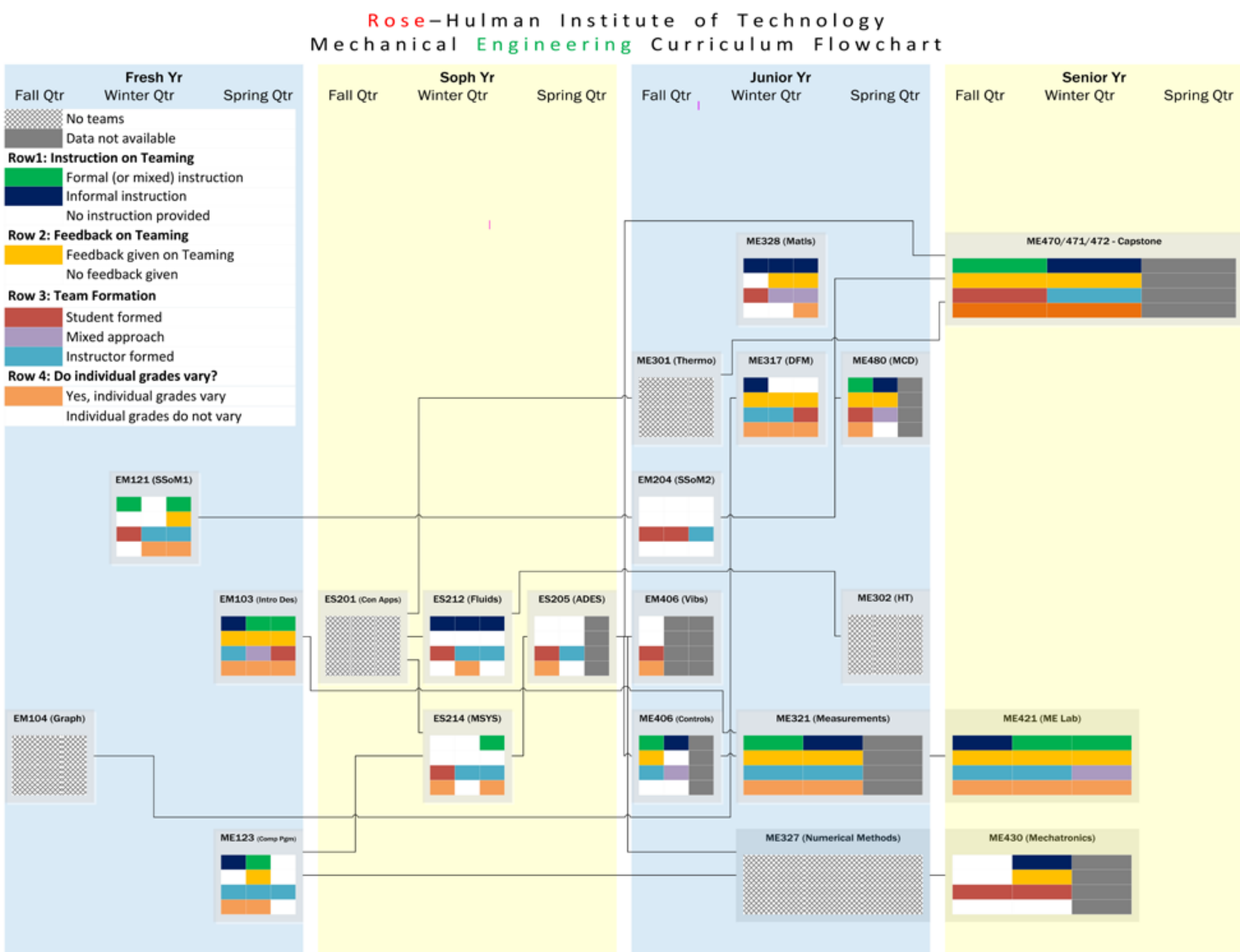

Figure 5. ME curriculum map showing the details of cooperative learning such as presence of instruction, feedback, team formation, & impact on individual grades.

The third row in the Figure 5 indicates the types of team formation methods used with blue representing instructor-formed teams, red indicating student-formed teams, and purple indicating teams formed with a mix of the two approaches. Mixed approach might either mean that instructor forms teams after soliciting student input or the fact that the approach used varies across years. There is no consistency in the approach to team formation within sections or even throughout the curriculum. There is wide variation in which traits were used to assign teams and whether they are grouped based on similarity or differences. There were a few instances where criteria of convenience, i.e., sitting next to each other, were reported and these were typically associated with labs or mini-projects in problem-solving courses. In the other courses where team formation data was available there was evidence of familiarity with dimensions suggested in the literature, specifically: similar or different GPAs, different skills and abilities, similar schedules, similar or different motivation/commitment level, different social groups, and not isolating individuals belonging to under-represented groups. Different instructors used different combinations of these traits. The variations were present across courses and across different sections of the same course. Forming teams based on similar GPAs was prevalent across many courses, as was different skills and abilities and similar schedules. Teams with homogenous GPAs are more frequently used when compared with heterogeneous GPAs, although the literature recommends otherwise [9].

The fourth row in Figure 5 is orange if individual grades vary within a team. Many of our teaming experiences do not have individual grades assigned. Generally, these experiences are for classes where students complete labs or projects in pairs or groups of three. However, even in these cases there is some variation among different instructors of the same course. When individual grades are assigned for teamwork, peer evaluation or peer and instructor evaluation were used in determining the individual grades. All project-focused courses with teams of three or more students (i.e., introduction to design, capstone design, measurement systems, and ME lab) assign individual grades based on peer evaluation or peer and instructor evaluation. Notably, when individual grades are assigned for teamwork, it always included the voice of the students on the team.

In addition to asking instructors about grading teamwork, the survey also included a question regarding 'What types of team dysfunction do you encounter?'. The most common type of team dysfunction reported by faculty across the curriculum is one or more teammates not contributing to the teamwork (i.e. slackers), also described as uneven workload, which is consistent with observations made in Borrego et.al. [28]. Not as common, but also reported often is having a dominant individual on the team. A dominant individual could exhibit behaviors such as asserting primary control over the group decisions, failing to delegate work to others, and disregarding the input of teammates. It is notable that these dysfunctions are observable behaviors that may stem from other non-behavioral dysfunctions that were reported, including, mismatched expectations, lack of communication, presence of cliques, and/or personality clashes.

The survey followed-up by asking 'When you encounter team dysfunction, what do you do?'. Most instructors reported initiating mediation of team dysfunction once they became aware of it. A few instructors reported on dealing with team dysfunction when students initiate mediation. When dealing with team dysfunction some instructors reported facilitating student formed solutions; however, more instructors reported forming the solutions for students. The contents of the mediation and solutions vary widely and are not discussed here.

In the present context of types of team dysfunction and discussion of who initiates mediation and who forms solutions, there is opportunity for improvement. While students' team performance affects individual grades, there is little formal instruction on teaming and how to handle common dysfunctions. In many cases team dysfunction can be addressed proactively. For example, issues of mismatched expectations and lack of communication, which can lead to other dysfunctional behaviors, can be tempered through early interventions aimed at having teams explore and set goals, roles, and processes [29]. It is important to get students to surface differences in their expectations and make adjustments for a common set of team expectations at the start of significant group work. It is also important to teach students how to deal with team dysfunction so that they can intervene constructively and productively on their own in the future - in later courses and in their professional careers. This sort of empowerment requires a consistent and coherent framework for dealing with team dysfunction that students learn and practice consistently. If instructors prescribe solutions for student teams this takes away from an opportunity for students to grow their mediation skills and can affect student motivation [30-32] to follow through on the solution; however, it is important to acknowledge the instructor formed solutions often involves student input with instructor direction.

The final step of closing the loop of this study was to present the results of the survey to the department at an end-of-quarter department meeting. The purpose of presenting the results at this meeting was to verify the accuracy of data synthesis and interpretation of the results. Faculty members were given the opportunity to identify any errors in flow charts (Figures 4 and 5) and share observations. After the department shared their observations, the committee members shared their observations (those presented in this paper). The goal of this activity was to build a shared understanding of the state of teaming experiences and instruction within the curriculum. The results of these preliminary discussions helped to validate the survey results and interpretations. Only minor corrections were noted in this meeting. The observations centered around the opportunities for improvement in the consistency in teaming instruction and feedback in the sophomore and junior years and a desire to have more help understanding teaming best practices found in literature. The type of teaming experience that the students are exposed to in the sophomore and junior year might shape their perceptions about cooperative learning in intended or unintended ways. A careful consideration of such experiences might add to the learning experience and will also be discussed in future departmental meetings. Performing and sharing this benchmarking study was an important first step to making larger coordinated changes across the curriculum in the future based on the shared vision approach. As a department, we were also able to begin the discussion of the needs of the students to develop teamwork skills as well as the needs of the faculty in the department to teach these skills.

Conclusions

We set out to collect data and prior research results to inform departmental deliberation on how to coordinate our teaming experiences and instruction throughout our curriculum. Importantly, this work is situated across the change models of Reflective Teachers and developing Shared Vision [27]. Our curriculum currently contains a lot of varied teaming experiences. Students experience a mix of shorter team projects, e.g., labs and smaller projects, in the freshman and sophomore years and build to longer team projects, e.g., half-term, full-term, and multiple-term design projects, in the junior and senior years, which provides scaffolding to the longer and more substantial project teaming experiences. Most of the teaming experiences are at least three or more students working together. The data shows a lack of formalized instruction in the middle years of our curriculum and formative feedback, which ties to student anxiety and missing opportunities to promote further student growth in this professional area. Further, even when we are providing formal or informal feedback and instruction there is a lack of coherence and consistency of teaming messages and tools. The data also demonstrates that there are opportunities to improve handling of team dysfunction and helping students build tools to deal with it. These findings will form the foundation for further departmental deliberations and actions to reinforce the strengths of the teaming experiences and take advantage of the identified opportunities.

Future Work

After the discussion on the current map concluded, a follow-up meeting is planned with the focus on the question “where we would like to be?” This discussion will hopefully lead to the formation of “the ideal teaming experience”. This ties in with the shared vision approach to encourage faculty buy-in and to make sustainable changes to the curriculum. After this future meeting, the co-operation thread committee plans to draft the ideal teaming experience map and present it faculty in a departmental meeting that follows.

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Appendix: General Form for surveying course instructors

The purpose of this survey is to better understand and document the extent to which teams are used within required courses in ME department at Rose-Hulman Institute of Technology. Please complete the form for the course listed in the title. Operational team definition for this survey: A team consists of more than one person working towards a common goal (i.e., has at least one team submission that is graded).

1. Informed Consent
Yes
No *Stop filling out this form.*

2. Do you use teams in your course? (refer to operational definition of teams in survey instructions) *
Yes
No *After the last question in this section, stop filling out this form.*

3. What size are your typical teams?

4. How are your teams formed?
Students self-select teams *Skip to question 6.*
You, as the instructor, select teams *Skip to question 5.*
Other: *Skip to question 6.*

5. What traits do you look for in order to form teams (e.g. different gpa, similar schedules, etc.)?

6. How many team projects do you have in the quarter (could be same teams)?

7. What is the duration of a typical team project (round to the nearest # of weeks)?
8. Do you switch teams in the quarter?
Yes *Skip to question 9.*
No *Skip to question 10.*

9. When do you switch teams and how many times do you switch teams?

10. Do you give instruction on teamwork performance (i.e. good team function/behavior)?

11. Do you give feedback on teamwork performance (i.e. good team function/behavior)?

12. Do individual grades vary based on teamwork performance (i.e., good team function/behavior)
on a team project?
Yes *Skip to question 13.*
No *Skip to question 14.*

13. How do you determine/differentiate between individual grades on a team deliverable?
14. Do you use CATME for teamwork performance (i.e., good team function/behavior) assessment?
Yes *Skip to question 15.*
No *Skip to question 16.*

15. When do you use CATME and how many times?
Not used - Skip to question 17.

16. Explain what you use/do for assessment of teamwork performance?

17. What types of team dysfunction do you encounter?

18. When you encounter team dysfunction, what do you do?