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Launching for Success: A Review of Team Formation for Capstone Design*

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In practice, engineering capstone project teams form through any of a variety of methods, including random assignment of students, assignments based on existing or desired skills of students, student preference-based assignments, having students bid for projects, using computer-aided team formation, and others. This paper discusses tradeoffs of different approaches for forming teams at the launch of engineering capstone projects, drawing from literature about team formation and from shared experience in running capstone courses. Building on a literature review, we present a summary of team formation approaches with mechanisms for performing team formation. We recommend that capstone directors consider desired learning outcomes and pedagogical perspectives as well as industry expectations when considering tradeoffs for different team formation approaches. Team formation is the first step in the full project lifecycle and overall team success. As such, a desired outcome of team formation is the opportunity of engendering a sense of ownership in students of their project from "cradle to grave."

Keywords: team formation; capstone design; teaming approaches; teaming

1. Introduction

For many engineering programs, capstone design is the culminating experience for senior students to demonstrate their newly acquired skills in a simulated real-world setting [1]. Implementation of capstone design is widely varied, yet programs tend to focus on authentic professional practices situated in the academic setting, collaboration as a team, and meeting real-world project needs [1]. One of the key objectives for capstone design is to emulate the industry experience as closely as possible in an academic environment, including ensuring that students can perform effectively on a team. A critical first step in the capstone experience is the team formation process. While the capstone program directors and instructors play a key role in this process, there are currently a wide variety of approaches used in various capacities, with no single consensus on a single, correct methodology. Meanwhile, for newly developing capstone programs, the task of creating a systematic approach to team formation can be difficult to navigate, while often yielding mixed team performance and project results.

Team formation thus represents both a challenge and an opportunity. A challenge is that the variety of possible approaches support various learning outcomes, though capstone design outcomes may not be directly associated with decisions about team formation. At the same time, team formation offers an opportunity for beginning the interaction between capstone faculty and the incoming student cohort, establishing a mentoring relationship of support.

The objective of this paper is to systematically review the current methods commonly employed in formation of student teams in capstone design programs, drawing from literature and from experiences at our various institutions. The methods span a range from purely faculty-chosen approaches to fully self-formed student teams, as well as various combinations in between. While each method presents potential advantages and disadvantages, it is possible to balance multiple aspects of the methods to enable students to gain *ownership* of their experience while faculty maintain influence over setting up and supporting the team dynamics. It is important to establish and be mindful of the expected learning outcomes in the team formation process but to also

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recognize it is only the beginning of the overall development of the students and the teams.

This paper presents background on team formation from literature, followed by a summary of team formation approaches. We consolidate these approaches into a list of team-compiling mechanisms that sustain the process and encourage focus on teaching philosophy and desired learning outcomes of the capstone design experience.

2. Literature review and background

2.1 Scope of literature review

Team formation strategies exist outside of the capstone design context in literature, such as in the field of business education [2]. Nelson presents a managed group formation approach that involves steps such as obtaining a personal value profile, initial partitioning and assigning short cases, solving cases in heterogenous groups, debriefing, and collecting sociometric nominations [2]. While Nelson's approach comes from a context other than capstone design, it addresses some of the high-level factors that influences team formation and behavior.

Paretti et al.'s work explores balancing self-selection versus systematic assignment of team, product vs process, and technical practice versus professional practice [3]. Pimmel et al. discusses team skills, presentation skills, project management skills, and design skills considering co-operative learning as applied to capstone design [4]. Team skills and project management skills may be influenced by the team formation approach. Dutson et.al emphasizes the importance of working effectively as a member of a team and improving interpersonal and leadership skills as the main goal for using teams in project-oriented courses [1]. Brickell et al. discusses the effects of team formation methods on grades and student attitudes in the course [5]. The literature reviewed in this paper does not include prior research on freshman or sophomore-level design courses. The scope is limited to possible team formation methods and potential learning outcomes of team selection, though the effects of team selection strategies on capstone project outcomes remains unexplored.

2.2 Team formation tools

Paretti et al. provides a very good discussion on team formation approaches and sets the importance of tools for instructor-led team assignments [3]. CATME Team Maker is one such tool to facilitate instructor-led team formation in a large program setting [6]. Meanwhile, another such tool is Computer-aided Team Maker tool by Bacon et al. [7]. Zhou et al. summarizes team formation approaches and recognizes that instructors must evaluate strengths and weaknesses of each strategy before selecting one that is applicable to their program [8]. Ohland et al. discussed how to remediate a dysfunctional team leading to further discussion of the fact that choosing the right team formation approach might reduce the possibilities of dysfunctional teams [9].

2.3 National surveys of capstone design

Dutson et al. outlines and summarizes team formation methods as either the instructor assigning team members or students selecting their own team [1]. They also discuss some of the instruments instructors can use to form teams such as Hermann Brain Dominance Instrument and the Myers-Briggs Type Indicator. While this paper presents a good and quick summary, a better guidance to select a team formation method outlining pros, cons, and learning outcomes targeted would be beneficial to other capstone instructors, which is the main goal of this paper. Clear et al. presents a guide to the capstone instructors teaching courses in computing [10]. Their paper mentions three approaches to team formation, namely, instructor-formed, student self-selected, and instructor-appointed leader who then recruits team members [10].

The literature presenting national survey results or reviews of capstone programs only provides data on the size of the team and the number of teams assigned to each project [11–14]. However, there is a lack of data on how teams are formed in different programs and how it effects the overall team success. Of note, there is some literature that addresses program specific information on capstone courses and addresses how teams are formed in their program with no data relating to the effectiveness of the team [15, 16]. A thorough investigation of such papers does not necessarily capture the best practices for team formation, hence it is not pursued for this manuscript.

2.4 Team formation in professional settings

In industry settings, matrix organizations result in project team assignments which are separate from employment decisions [17]. Employees are grouped by function under personnel managers, as software engineers separate from mechanical engineers, etc. [17]. When a project is approved, the assigned project manager (PM) works with functional managers to determine and negotiate availability of staff, resulting in a team drawing from across the functional matrix of possible employees [17].

Anecdotally, we have observed some capstone instructors [18] referencing this industry practice to justify purely instructor-formed teams (e.g., "employees in industry are assigned to teams and

they go and work for that project''). In industry settings, however, employees also seek and accept employment that aligns with their professional values and identity [19]. Functional managers and project managers both accept guidance and interests from employees and attempt to align project opportunities to them. At the end of the discussion, if there is too much discrepancy between an employee's professional identity and the roles they are given on projects, the employee has the option of seeking alternative employment.

The industry setting for projects differs from academic team formation in other ways as well. Industry teams tend to be longer running, with greater ebb and flow allowing for team members to be added or depart. Capstone teams work together for one or two semesters [1, 14], and all enrolled students must have opportunity to contribute to a team, regardless of how well they have completed course prerequisites. Finally, capstone projects tend to emphasize educational objectives over sound business outcomes, meaning that a capstone project can support worthwhile learning outcomes while not necessarily being economically justifiable for industry.

It may be helpful for capstone instructors to understand these differences in structure and purpose between industry team formation and educational team formation, especially in setting student expectations for their experience on the team.

2.5 Differences and similarities with co-operative learning

Project-based courses with teams such as the capstone sequence are a subset of the overarching co-operative learning approach [20, 21]. The main challenge with a capstone course is that an individual end-of-the-term exam cannot be administered, instead a final report or final presentation by the team culminates the tasks completed during the term. The inability to administer individual exams for capstone makes it challenging to capture the individual accountability and positive interdependence. Some important recommendations from Felder's research on co-operative learning encourages instructor-formed teams of 3–4 students with heterogenous ability levels, and with common blocks of time [21]. If self-selected teams are allowed they recommend setting guidelines such that only one student with a high grade in the pre-requisite course is allowed on a team, again ensuring heterogenous ability levels on a team for effective co-operative learning.

Finally, literature captures the classic team formation stages, such as, forming, storming, norming and performing [22, 23]. These stages are important for a team to experience to become effective team members. It would be useful, in the future, to investigate how the team formation impacts these stages of team development, but such a study is beyond the scope of this paper.

3. Summary of team formation approaches

In practice, several different strategies are used by capstone faculty and coordinators to assign project teams. These strategies range from those involving no instructor input and almost no time commitment to strategies involving considerable time and input from capstone instructors and/or coordinators (Fig. 1). The following sections will briefly outline the unique characteristics of each of these approaches.

3.1 Randomly assigned

Beginning with the strategy involving the least amount of time or effort from instructors, randomly assigned teams is an approach used by a minority of programs. While randomly distributing students in teams certainly prevents students from clustering based on friendships or familiarity, lacking in this approach are deliberate efforts to promote student ownership, allowance for instructors to assign teams based on student preferences and competencies, or consideration for particular client preferences and project needs. Random assignments have been shown to correlate with bad teaming experience [24]. It is also difficult to convince students the benefits of random assignments especially if they feel like their year-long team assignment relies on chance and is completely out of their control.

3.2 Student-led: self-formed teams

Placing the responsibility on students to form teams is another approach to team formation that can save instructor time and effort. In this model students are intentionally made aware prior to the start of senior design that they will be working in teams of a set number of students in the capstone course. They can either choose to form a team before the first day of class or they can choose to wait for the instructor to assign them to a team. In this method, usually a high majority of students are on a team before capstone begins and the instructor has to place the remaining students on teams. This method requires very little effort by the instructor, and self-selecting students have complete autonomy of selecting their team, so they take the ownership in the project early on. This system works most effectively if the program has a pre-established culture of self-selection and students are seeking their capstone team members as early as their sophomore or junior years. One downside of this approach is that students may not get a teaming experience comparable to post-graduation

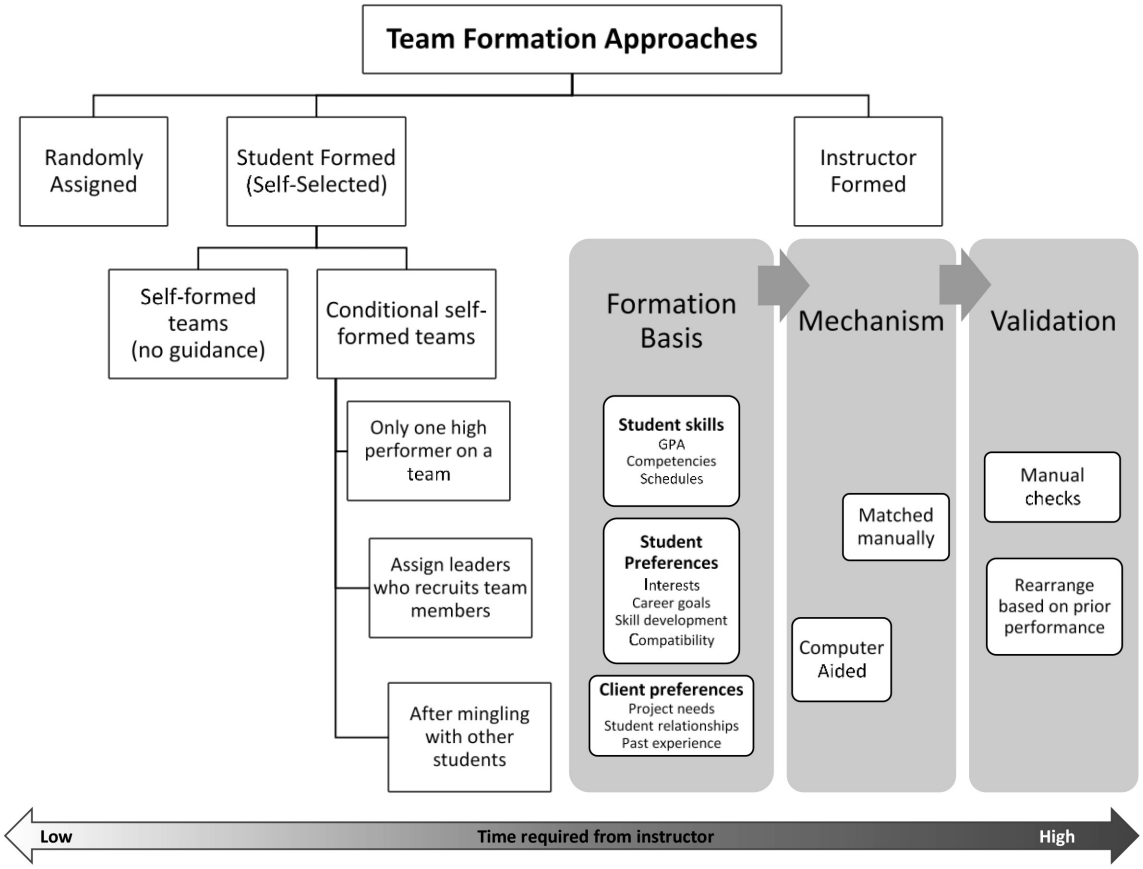

Fig. 1. Overview of Team Formation Approaches.

environments where they do not get to choose their team. Another downside is that a remaining team may be formed of students who did not get selected on any team due to a variety of reasons such as personality issues, low GPA, or other factors. Such a team may require a lot more mentoring. However, in some situations, a team of low performers can learn quickly that they either sink or swim and manage to pull it together and meet expectations of the course.

3.3 Student-led: conditional self-formed teams

This approach is similar to the self-formed team approach except the students have to meet conditions that are imposed by the instructor. For example, each team may only have one student who received high grades on prerequisite courses [21]. Such a condition may enforce formation of heterogeneous teams compared to pure self-selection. Another condition may be for capstone instructors to select a finite amount of student leaders who are tasked with recruiting team members. Within this conditional approach, the program needs to allow students to have the opportunity to meet and mingle with each other to enable team formation. Aller et al. applied mingling as a team formation approach to improve team performance by targeting shared interest and motivation [25]. Mingling was then followed by bidding and project assignments leading to better team performance. Smyser and Jaeger emphasize the importance of students defining their own project and recruiting team members who have skills to complete the project [26].

While the student-formed team approaches are likely to encourage student buy-in and ownership, student-selected teams may be more influenced by existing friendships or social circles than using any analysis of skills individual members can contribute. Instructor-led approaches towards team formation may be worth the additional time and effort required in order to ensure teams are formed that balance students' interests and skills with project needs. Projects using the instructor-led approach often divide that approach into three steps: identifying the basis of formation, using a team compiling mechanism, and then validating team membership.

3.4 Instructor-led: based on student skills

One way to gather student competency is to conduct a mini competency project before the actual project is assigned. Students get their top choices of projects based on their performance in the competency

project. The competency grades allow the instructor to measure the student interest level without relying on GPA and the students get to have a fresh start, in case their prior performance was not up to the mark. The project assignments are then potentially more "fair", with students feeling more in control of their team assignment outcome. The downside of this method includes some time investment in the beginning of the term and extra grading by the instructor, although the buffer time may allow instructors to gather capstone projects while students are working on their competency project. Some students may perceive this as irrelevant work or waste of time.

An instructor-led team formation approach that may more closely model industry involves forming teams based around identified skill sets needed for specific projects. This method includes using student resumes or portfolios to make judgments about individuals' skills and in doing so, may allow for students to have some say in the process through "applying" to be on a particular project. The emphasis on students documenting their own skills and prior experiences includes a side benefit of motivating students to spend time updating and polishing their resumes and portfolios. Depending on the number of students in the capstone program, the volume of student skill documentation to review may present a daunting task for capstone coordinators and faculty. A less procedural but more fundamental drawback to this approach is that it doesn't promote the idea of learning and developing new skills; instead, it more heavily emphasizes project choice based on skills and experience students may already have.

Instructors can also collect students' schedule information to identify cases of schedule compatibility. Depending on the size of the program, this model can require significant time to sort through student preferences. In addition, there may be high interest in a select few projects resulting in instances where instructors can't accommodate some of the preferences students rank and need to intervene to more evenly distribute team membership.

3.5 Instructor-led: based on student preferences

As a way to allow more instructor control in the process but also allow for student ownership, a common approach used by capstone programs is to provide capstone students with project descriptions in advance and allow them to rank preferences. The number of preferences students must rank varies depending on the size of the program and the number of available projects. This formation approach encourages student buy-in, allowing students to gravitate towards projects meeting their interests, matching their competencies, or providing opportunities to grow their skills. This approach can also serve as a mechanism for capstone faculty to identify projects with the strongest student interest and possibly eliminate those lacking strong student interest (if there is a need to narrow down projects that will be greenlighted). In addition to reviewing student preferences, instructors can also collect students' schedule information to identify cases of schedule compatibility. Depending on the size of the program, this model can require significant time to sort through student preferences. In addition, there may be high interest in a select few projects resulting in instances where instructors can't accommodate some of the preferences students rank and need to intervene to more evenly distribute team membership. Several capstone programs have incorporated elements of this approach using a Project Fair format (example in [27]) to introduce students to their project options and enable them to bid for their project preferences. The faculty then use the student input as a basis for forming the teams.

Another method to gather information from students is through inventorying their interests in the particular areas in which they'd like to grow their skills. Such an approach helps cultivate a growth mindset approach towards learning (reminding students of the value in working on a project that will challenge them and allow them to develop new skills). It is possible that this approach will be met with resistance by some students, as students with a fixed mindset approach towards learning will likely shy away from projects that aren't situated within their current skillset. Student preferences can also be used to help ensure compatibility among team members. Some programs allow students to indicate who they do NOT wish to be placed on a team with, allowing students who may have had negative experiences working together to avoid repeating those experiences.

3.6 Instructor-led: based on client preferences

Accepting input from project proposers (based on sponsor fair or student survey data) is another strategy supporting team formation based on project needs. Through mechanisms such as an industrial sponsor event (i.e., fair or expo) or through student survey data, sponsors could evaluate students and have the chance to request individuals on their teams. This approach would certainly favor top-notch students who make a good impression (either in person or on paper) with sponsors. A limitation of this approach is that it may leave capstone program coordinators with tough cases of students that no sponsors are requesting. In addition, involving inputs from external parties adds a layer of logistics to the team formation

process and would likely require more time than an internally-based approach.

4. Team compiling mechanisms

Once the student and or project information is collected, the next step is to use that information to form teams. Some of the strategies to match students to projects are explained here.

4.1 Team formation: matched manually

Manually sorting through student or client preferences, something that may be required depending on the kind of data collected, can be a sizable task for capstone instructors and coordinators. Depending on the program's size and number of students and projects, this approach may be worth the effort, as it offers the best way for faculty to account for their knowledge of student dynamics and project nuances while controlling the outcome of team membership.

4.2 Team formation: computer-aided

The main advantage for using computer-aided team formation is the fact that the complexity of manual assignment grows proportionality with the class size [6, 7, 28]. Such tools are expected to reduce the time required from instructors while making informed team assignments.

Computer-aided tools such as CATME Team Maker allow the instructor to pick the strategies for forming teams [6]. For example, CATME Team Maker enables the instructor to optimize diversity with respect to demographics, or interests. Instructors can also choose to add schedule compatibility. Additionally, they can ask multiple choice questions and assign weights to each question, then score and fine tune the team formation to their liking. It is important to note that CATME Team Maker utilizes factors that affect teaming, but it does not prescribe a strategy for forming teams. In other words, capstone instructors still have to make informed decisions on what factors to use for making the team. Of note, the tool only assigns students to teams, but not teams to projects, which is left up to the capstone instructor.

While computer-aided tools help make the process more efficient, many capstone faculty report that the tools are often accompanied by individual review of preferences as well. The downside of tools is that they can't account for knowledge (about the students, the projects, the dynamics of students working together) the way manual sorting by the instructor or capstone coordinator can. Additionally, not all tools may lend themselves well towards diversity considerations or be as conducive for programs with multi-disciplinary projects.

Some individual programs use tools they created uniquely for their own programs, using Python to optimize scoring [18]. This approach obviously includes time spent on actual tool creation; however, the creation of such a tool may lend itself well as an actual design project for some programs with a computer science and engineering emphasis. Additionally, for students to rank preferences and for those preferences to be considered—whether through a tool or manually or both—programs must have a list of projects determined early enough so that there is time to review preferences and then form teams.

4.3 Validation of team assignments

Once teams are formed using any instructor-led approach, many programs use a final step of validation before finalizing team assignments. Within programs with class sizes small enough so that faculty get to know individual students, faculty validation is another approach towards team formation. Asking faculty for input on individual students (as well as students placed together on a team) can elicit valuable information.

Faculty validation of team assignments of course requires them to spend time reviewing information, often prior to the start of the semester or at the start of the semester, a time that is often already very busy for them. In addition, because this approach introduces the possibility of bias, it is most effective if it involves perspectives from more than one faculty member.

Considering student GPA is another way to help validate team membership. Capstone faculty and coordinators may adjust team membership to strike a balance so that high or low GPA students are not all grouped together. While GPA may be a good proxy for developed skills in specific technical areas, problematic with this approach is the fact that a high GPA is not necessarily correlated with effective collaboration or leadership potential.

If computer-aided tools are used to make team assignments, it becomes critical to check the assignments or re-arrange the teams, particularly if prior knowledge is involved which cannot be entered into the tool's algorithm. For example, if a repeating external client has recently worked with several less productive teams, the capstone coordinator might choose to bias the team assignment for that sponsor toward a team expected to be more highly productive.

4.4 Resources required

It is important to understand the different resources that may be required for different teaming approaches. Table 1 summarizes the resources required such as time from the instructor. Another

Table 1. Summary of resources required for different team formation approaches

Team Formation Approach	Estimated Time Required	List of Projects	Considerations
Randomly assigned teams and projects	Minimal time	Not required	
Self-formed teams (no guidance)	None	Partial list required before the term starts	Manual matching of remaining teams and projects
Conditional self-formed teams	None to minimal time	Partial list required before the term starts	Manual matching of remaining teams and projects
Student skills-based assignments of team & project	Some time	Complete list required before the term starts	
Student preference assignments of team & project	Significant time commitment	Complete list required before the term starts	
Client/sponsor preference-based assignments of team & project	Significant time commitment	Complete list required before the term starts	
Computer-aided team formation (e.g. CATME Team Maker)	Minimal time	Not required	Project matching to teams is done after teams are formed

significant aspect to consider is that not all methods match teams to projects. In such cases, project assignments may need to be done after the team assignments are finalized. If projects are being assigned along with the team formation, then it is necessary to have a complete list of projects along with a description before such team assignments can begin. This is often a challenge for capstone coordinators to have all projects defined prior to the beginning of the term.

Multidisciplinary or cross-disciplinary teams have more complex structure both in terms of the skill sets required for roles on the project and the competency of team members; hence multidisciplinary teams cannot be randomly assigned or self-formed with no guidance. At the minimum, multidisciplinary teams must be guided based on the skills and competencies required for the project, if self-formation is used at all. Also, for any multidisciplinary course a complete list of projects with pre-defined disciplinary areas and some instructor mediation is desired for successful team formation. Any of the instructor-formed methods of team formation work very well with multidisciplinary projects.

5. Teaching and industry perspectives on learning outcomes

Most capstone programs involve a variety of stakeholders including the students, project sponsors (which are often external partners), and the University. However, it is important to recognize that the primary objective of the capstone sequence is for the educational experience of the students. While the team formation process is often used to serve as a "means to an end" in creating the project teams, the process itself can also be used as a valuable educational experience. The following sections will discuss the relevance of the team formation process from both a pedagogical perspective and from an industry perspective, which is where the majority of students will begin their careers.

5.1 Pedagogical perspective

If we choose to leverage the team formation process for educational purposes, it is important to first be clear about the expected learning outcomes for the process. While many potential outcomes are possible, the learning outcomes may be articulated such that, as a result of the team formation process, students will have improved their skills to satisfy the following learning outcomes:

> Learning outcome 1: Evaluate different project opportunities systemically, in order to:
>
> (a) Analyze the technical skills required for each project, and
> (b) Classify which projects may be a good fit for their skills, career goals, and personalities.
>
> Learning outcome 2: Create new employment opportunities for themselves via networking and project proposals.

Although it is unlikely that students will master these skills during one cycle of team formation, students should ideally recognize the value of evaluating different opportunities and the value of networking to help shape their careers. With these objectives in mind, a variety of approaches are available for coordinating team formation, including those outlined in Fig. 1. Table 2 provides a quick

Table 2. Summary of potential team formation approaches, their connection to the possible learning objectives and association with active learning, and promoting student ownership

		Learning Outcome			
Team Formation Approach		**LO1 -Evaluate opportunities**	**LO2 - Networking**	**Promote Ownership**	**Active Learning**
Randomly Assigned	No prior input or knowledge considered	-	-	-	-
Self-formed teams (no guidance)	Students recruit their own teammates and projects	X	X	X	X
Conditional self-formed teams	Only one high performer on a team	-	X	?	X
	Assign leaders who recruits team members	-	X	?	X
	After mingling with other students	-	X	X	X
Student skills	GPAs	-	-	-	-
	Competency project results	-	-	-	-
	Schedule & Availability	-	-	-	-
Student preferences	Probe student interests & career goals	X	X	X	X
	Probe student compatibility with other students	-	-	X	X
Client/sponsor preferences	Identify project needs	-	-	-	-
	Preferred students (based on relationships)	-	X	X	X
	Consider past experience	-	-	-	-

summary of the different approaches and how they may align with these objectives.

For learning outcome 1, students will be empowered to conduct their own evaluation of the project options only if capstone coordinators or instructors actually probe their interests, preferences, and career goals, or let them form their own teams autonomously. By enabling students to self-lead their own analysis, the process lends opportunity for capstone instructors to coach students in different strategies for making their evaluations. Meanwhile the other formats in Table 1 (random, conditionally self-formed, or instructor-led skills or GPA-based methods) do not appear to offer specific opportunities for all students to do their own evaluation of the options and provide input. A study by Richards and Thompson demonstrated higher rates of satisfaction from the team and overall project impact when student preferences are incorporated into the project assignment and team formation process [29].

As students are preparing to embark on industry or academic careers after graduation, recognizing the influence they have on their own career trajectories (via networking and making proposals) is an important revelation for students (i.e., learning outcome 2 above). Several of the methods identified here offer the chance for students to network and create opportunities for themselves, either through working to self-form teams or networking with potential clients to measure their own interests or make a positive impression. Conversely, the other formats only allow students to either passively evaluate options (providing input to a skills inventory or competency project) or reluctantly accept their assignments from faculty (via random or instructor-led assignment based on skills or GPA). In any case, the process of connecting students to projects and sponsors during the team formation process often sparks connections which influence decisions made during the team formation process, including those decisions which are ultimately made by the instructors.

It is generally accepted that student learning can be greatly enhanced through active learning [30]. The same principles will also apply for the learning outcomes of the team formation process, and incorporation of active learning is clearly evident in these formats: 1) self-forming teams, 2) probing student preferences, and 3) soliciting sponsor input (assuming students are involved with sponsor interaction). In fact, one could argue that these formats also include elements of flipped classroom principles, requiring students to prepare at home proactively before coming to ''class'' ready for active engagement.

5.2 Industry perspective

The majority of students in a typical capstone design sequence will go on to pursue careers in industry. Therefore, capstone design is intended to be the culminating experience in the student's education and preparation for an industry environment. As a result, it is an important opportunity for students to develop additional "soft" skills beyond the engineering skills taught in traditional classrooms. Central to the soft skills needed to succeed in industry (team citizenship, communication, etc.) is an overall sense of "ownership" of their project and its ultimate success. This type of ownership, which is evidenced by passion and commitment to the project, has also been shown to be an indicator of capstone project success [26]. Similarly, Aller et al. found that interest and motivation were the best indicators of successful student performance as they implemented a "mingling" format for student engagement and input into the team formation process [25]. Therefore, we want to implore students to take initiative and demonstrate their own influence upon the outcome of the project. This philosophy can certainly extend to the team formation process.

It is frequently argued that employees in industry do not have choices about their projects and teammates, supporting the notion of purely instructor-led assignment [1, 10] of teams using either their perception of student's skills, classroom performance, or GPAs. Purely instructor-led team assignments that bypass student background, skills, and interests may contribute to other learning outcomes such as how to be productive on teams without initial buy-in or passion. However, the idea that industry employees are forced to reluctantly accept their assignments without any influence is not necessarily true, and is counter to the ideology of "ownership". In reality, engineering employees *do* have options in making choices about where they work and typically have numerous avenues available to influence their assignments and career paths. As a result, it is not unreasonable to incorporate student preferences into the team formation process. In fact, such engagement ensures that students working on preferred projects are more likely to demonstrate "ownership" of their projects, working hard to make it successful and modeling the type of behavior which will make them successful in their future careers.

6. Conclusions

We review a variety of approaches used for team formation in capstone design programs. The approaches range from purely faculty-chosen methods (either random or systematic) to student self-formed student teams. Many programs also use a combination of these approaches to maximize the integrity of the process. Generally, with random or solely instructor-led approaches, the students are left to only passively participate or reluctantly accept their assignments with very little preferential input. On the other hand, many approaches allow students to have some ownership in the process and their project assignment. A sense of ownership has been shown to correlate to project success and likely translates well to the industry environment. Student involvement also enables the team formation processes to be a learning experience. Most notably, students can practice skills including networking, writing proposals, and general evaluation of the project options. Such skills are also likely to translate well to their industry careers.

Fortunately, the team formation process chosen for implementation does not need to be exclusively one single method from the approaches listed here. Many hybrid processes are possible, incorporating the positive elements from several different approaches. For example, several capstone programs are utilizing a Project Fair format to introduce students to their project options. In this format, students "mingle" with each other, network with potential sponsors, and bid for their project preferences. Faculty then use the student input as the primary reference for team assignments while also retaining flexibility to synthesize heterogeneous teams through their knowledge of the students' GPAs, skills, and personalities. Thus, a balance of student ownership and faculty oversight of the team formation can be maintained.

Finally, it is important to recognize that team formation is only the first step in the capstone design experience. As a result, it is only the beginning of the coaching and mentoring process for students as they transition from academic learners to the industry practitioners and leaders of the future.

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