Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47310

Capstone Course Team Formation: Enhancing Interdisciplinary Collaboration and ABET Outcome Achievement by Integrating the CREAC Legal Reasoning Framework

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Abstract

This paper presents a novel adaptation of a legal framework to the creation of teams in a capstone class, as well as findings and results of the effectiveness of the method on the team creation process. The approach, based on an adaptation of the CREAC (Conclusion, Rule, Explanation, Analysis, Conclusion) legal reasoning framework, has yielded positive results in a year-long capstone course required by the Computer Graphics Technology department ("department") at Purdue University. The paper discusses how CREAC maps onto technology and engineering practice and why this structured framework assists students make intentional decisions in the formation of their senior capstone teams.

Introduction and background

The Computer Graphics Technology department at Purdue University requires students to take a two-course senior capstone to satisfy the Student Objectives (SO) required by the Accreditation Board for Engineering and Technology (ABET) under the Engineering Technology Accreditation Commission (ETAC).

During the first semester, students evaluate Requests for Proposals, respond to proposals by pitching solutions to the projects that align with their interests, negotiate terms for the execution of their project, and write the necessary contracts and charters to enter into a binding agreement with the client.

To succeed, the students must demonstrate they have "an ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature" [ETAC SO #3] by critically evaluating the requests for proposals submitted by potential clients, researching and formulating plausible technical solutions, and then writing persuasive and credible proposals to satisfy the presented problem. In addition, students must also demonstrate "an ability to design systems, components, or processes meeting specified needs for broadly defined engineering problems appropriate to the discipline" [ETAC SO #2] by articulating in their proposals technical solutions that are reasonably designed and supported by the data and rationale used by the student in their proposals. [1]

During the second semester, the students execute the project, evaluate their solution, and deliver the project to the client. To succeed the students must demonstrate, "an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly defined engineering problems appropriate to the discipline" [ETAC SO #1] by implementing the technical solution that they proposed to the client. In general, this entails, researching the literature for solutions to the issues faced by the students and then critically applying and adapting those techniques to implement a bespoke solution for the client. Solutions explored by the students, regardless of degree of novelty are required to be supported

by the promise of success based on the literature and existing body of work. Extremely novel solutions are acceptable when students include a rational basis for assessing the progress and likelihood of success of the proposed course of action. Along the way the students demonstrate "an ability to conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes" [ETAC SO #4] by conducting formative and summative evaluations of their solutions relative to the measure of success and threshold for success associated with their key performance indicators and unit level evaluation of their functional specifications. Throughout, the process the students take on various roles within their larger teams and sub-teams as they demonstrate "an ability to function effectively as a member as well as a leader on technical teams." [ETAC SO #5]. The class aims for students to work in teams of 15 students.

Justification for adapting a legal framework to engineering team formation

The author thought that adapting CREAC to the team formation process was a good idea because engineering decisions require structured problem-solving. CREAC's structured decision-making process mirrors the Systems Engineering Design Process because, in both, solutions are informed via the analysis of relevant rules and past cases (successful solutions). Second, the CREAC process helps students navigate the team formation process by asking them to systematically analyze potential projects, evaluate working with potential teammates based on needs, and justify their selections with data. Finally, CREAC forces students to explicitly articulate why a specific team composition and project selection support their career trajectories rather than relying on convenience or habit. The following table illustrates how each stage of CREAC aligns with the capstone process:

CREAC Stage	**Capstone Application**
Conclusion	Define the ideal project outcome and personal career objectives.
Rule	Research industry standards and team structures in relevant professional fields.
Explanation	Analyze case studies of successful and unsuccessful project teams.
Application	Compare potential projects and teammates to past successful industry structures.
Conclusion	Form a team and select a project based on a structured analysis.

Pre-intervension: state of the capstone experience in 2019

Prior to the introduction of the CREAC framework, students self-selected into teams based on their self-established criteria. This approach often resulted in students self-selecting into teams based on their familiarity with the other students in the team and also did not seem to result in student explicitly selecting teams to align with their career goals.

The class required students to submit a "Team Formation" document, in which the students articulated how they: (a) formed their team, (b) identified the roles and skills required in their team, (c) a rationale for how they selected their teammates, and (c) how they envisioned their role within the team would contribute to their individual career goals.

Pre-intervension results

An analysis of the Team Formation documents submitted by the student revealed:

1. The students did not critically select projects to meet their career goals. In almost no instance did a student explicitly state that they had selected a role within a team because it had been demonstrated that doing so was likely to further their career aspirations.
2. Students often selected their team members first and then selected a project from those that had been passively submitted to the class. Approximately 10% of the student, however, did actively pursue projects outside of those that had been brough into the class by the instructor.
3. Students who majored in animation, visual effects, or video game development, tended to select projects in which their major was either ancillary to the project or declared that no local clients had a need for an animation, visual effects, or video game project and then tried to pursue projects in which departmental faculty served in the role of a client.

Literature review

Prior to modifying the capstone courses, the author performed a literature review to identify the methods other ABET programs used to organize their senior capstone classes and the implications of adapting those methods.

The literature review suggested that when students self-select into teams, they tend to select team members that with whom they already have a relationship. This is effective at making the students feel comfortable in a large class, such as the CGT capstone, which had 200 students from six different majors. The method can also lead the students to feel productive quickly because some of the work that goes towards negotiating new social relationships has been previously done in the students' previous encounters. Detriments to this method, however, are that the homogeneity of skills and background of the students can be a limiting factor in the solutions the students envision [2]

In addition, the team may not account for the necessary skills required to solve their client's problem. [3].

Further review of the literature revealed that some capstone classes have used an instructor-led method to create teams based on the instructor's perception of how team should be organized to achieve success. The criteria used by instructors using these methods varied, with some instructors basing their assignments solely on the needs of the project and other instructors also striving to balance the experience and expertise possessed by the students across the teams. This approach, generally, seemed successful at avoiding homogeneity and at identifying the skills necessary to complete the project. A detriment to this method was that students might not be satisfied if they were placed into a team that did not match their interest or skills [4]. In

addition, some student disengagement was documented when the students lacked interest in the project [5].

Another approach used by capstone classes entailed randomly assigning students to teams. This method seemed to increase the student's exposure to a wide variety of perspectives and students with different backgrounds. A detriment to this approach was that students had to spend a significant amount of time building rapport with each other, which decreased their time and attention on the non-team related aspects of the project, and the number of misunderstanding and conflicts was reported to be high [6].

Analysis of 2019 CGT capstone team formation through lens of the literature review

The 2019 iteration of the CGT capstone class relied primarily on self-selection and suffered from the detriments that were identified and alluded to in the literature review. In most cases, the teams tended to primarily form around members from a single CGT major with the occasional single member from another major offered by the department.

For example, it was common to see a group with five UX majors and two web development majors, or a group with eight game development majors with two animation majors. With a class of 200 students, composed of students from six majors (animation and visual effects, game development and design, UX, web programming and design, and data visualization), whom had primarily worked in isolation throughout their college career and had worked on many smaller projects solely with students from their own major, it was little surprise that the students would self-select in a manner that felt natural and familiar to them.

Often, once a project was on the way, the students would often voice that they had failed to consider all the roles and skills that were needed in the team for the project to be successful. They tried to cure this issue by either adjusting their schedule and effort to account for the additional time to get up to speed, or by attempting to renegotiate their contract with their clients. Neither of these was ideal.

In addition, many students, particularly in highly specialized areas without a predominant number of local potential clients, such as animation or game development, often indicated that their ultimate career goals were not advanced by participating in the capstone class. To them, the capstone class was a hurdle to graduation rather than an opportunity for engaging in an activity to further their careers.

Applying CREAC to critically analyze and inform team formation

Starting in 2020, the instructor decided to teach the students to use the CREAC legal framework to systematically analyze the issue of forming a team and determine if participation in the group was like to advance the student's career aspirations.

CREAC, which stands for Conclusion, Rule, Explanation, Application, and Conclusion, is a legal framework used by law students to structure and analyze problems. To employ the framework, the students first establish a conclusion. Then, they research and state the rules that govern the determination of how their issue should be analyzed. In the "explanation" step, the students look

a specific instance where the rules have been applied to similar scenarios to the one they are analyzing. The goal at this step is to determine the contours of when the rules they have stated apply and when those rules do not apply. Next, the students analyze their specific issue by analogizing to the successful scenario they examined during the explanation section and also distinguish from those scenarios they determined were not a successful application of the rules.

Method: adapting CREAC to the CGT capstone team formation process

During the first two week of the class, the students (1) identified their career goals, (2) examined any projects that had been submitted to the class by outside sponsors, (3) identified potential clients they approach (if the projects that had been submitted to the class did not provide them with the opportunity to develop the skills they required to further their career goals, and (4) applied the CREAC process to identify possible projects and other students who could work with the student at hand to complete a project. During these two weeks, the compositions of the teams was in flux as students reformed teams based on the results of their CREAC analysis.

For example, one common occurrence was students self-identifying to work on teams that required a limited amount of workhours from students with a particular skillset. For example, a team might need students with iOS Mobile App development skills, but the scope of the project could only reasonably supply enough work for two students, but the team had identified four students with the same iOS Mobile App development skills. Here, the team would need to rescope the project to supply sufficient amounts of work or to reform the team with less students to match the requirements of the project.

The students adapted the generalized CREAC method to analyze how groups should be formed for their client project and if they should participate in the team.

First, the students identified and defined the goals of their project, after consulting with stakeholders. Then, students identified rules to accomplish the project goals by researching the structure, expertise, team size, and other relevant factors of industry groups tackling the same problem. Next, the students identified a reasonable number of specific projects executed by companies and analyzed how the rules they discovered through their research in the previous step allowed the companies to either succeed or fail at meeting the goals of the project. Finally, the students analogized to how the factors faced by their project were like those faced by the companies they researched in the previous step and then critically articulated how and why they were likely to succeed based on the results achieved by projects they had researched. As part of this analysis, the students also articulated how their situation was distinguishable from situations that they had identified as failures.

This process enabled the students to identify (a) the goals of the project, (b) the characteristics required for success at accomplishing the task, (c) the results of specific companies applying those principles, and (d) a plan for organizing a team with the required skills, size, and organization to foreseeably succeed.

After establishing a roadmap of the needs of the team, the students turned their attention to using the CREAC process to determine how their individual participation in the project would enable the student to build the necessary educational base and skills to advance their careers.

First, each student inventoried her current skills and identified the skills necessary to fulfill her target job. Next, the student researched the necessary characteristics that are reasonably required to be employable. Then, the students selected a reasonable number of specific people who had both succeeded and failed at landing their targeted job and articulated the impact of the choices made by the person they were examining. Finally, the student analogized the factors of her plan that aligned with those actions of people who had succeeded in landing the target job and also distinguished their plan from those who had failed.

Necessary sample: team formation reference document in appendix A
The instructor's initial attempt at implementing the method relied on explaining the concept and showing small examples of the method applied to solving technical tasks. This did not work, and students initially had many questions.

To alleviate this issue, the instructor created a reference document that showed how the method could be used by a fictitious group to analyze a project and form a team (see Appendix A). A critical aspect of the reference document was showing how all statements of facts, regardless of how small or incremental required data or expert opinions in order to factor into the analysis. In addition, the reference document was critical in showing how it is important to extract generalize rules for the issue the students were contemplating but that it was also equally important to find situations where those rules had failed, where they had succeeded, and to fully understand how the student's situation was similar or different to those situations they had studied.

Post-intevension results and analysis
An examination of the 2024 Team Formation documents revealed that:

1. Students structured their groups in a similar fashion to commercial companies that performed the type of work the students were interested in pursuing.
2. The students explicitly articulated how their group's organization matched commercial efforts that had worked for others and how their observations of what had failed for others guided them to put less weight on failed attempts by others.
3. The skills and roles within the teams they formed mirrored those of industry groups.
4. The student's choice of the projects to pursue and teams to join mirrored their skills and interests.
5. The interdisciplinary nature of the teams increased because teams formed based on the needs of the project rather than based on the familiarity of the students with each other (who came from the same major)

Overall, the CREAC method provided the students with a tool to identify the issues of forming an effective team to solve the problems by their client and also to inform their decision of how to further their career aspirations. Prior to implementation of CREAC, the students had the desire to take on a useful project and form an effective team, but because they had never been exposed to a systematic tool that enabled them to critically make this determination, the students ended up taking a passive approach to their capstone experience, in terms of what teams to join. Further, because of the large class environment of the capstone class, the student's natural inclination of

aggregating around familiar faces took precedence to taking active approach to the team formation process.

This approach has enabled the students to create teams that meet the objectives of their project and then staff those teams in a manner that advances their career aspirations. The CREAC based approach has led to measurable improvements in team cohesion, project outcomes, and student performance. Team formation effectiveness has assessed high and findings demonstrate the method has been effective at preparing graduates for professional roles that require interdisciplinary teamwork applied problem solving skills. An increased in the interdisciplinary composition of the teams followed from the impact of CREAC focusing the students on the needs of the project.

Conclusion

In the end, this retrospective case study lacks the rigor and methodology necessary to attribute the improvements in team formation to the application of the CREAC methodology. However, based on the improvements the author has seen in students following this method, it makes sense for the author and other faculty who are interested in improving the team selection process in ABET capstone classes to explore this technique further.

Based on the instructor's observations and the information reported by the students in their Team Formation documents, it seems like there is a likelihood that by applying CREAC the students identified and defined the goals of their project, after consulting with stakeholders. Then, students identified rules to accomplish the project goals by researching the structure, expertise, team size, and other relevant factors of industry groups tackling the same problem. Next, the students identified a reasonable number of specific projects executed by companies and analyzed how the rules they discovered through their research in the previous step allowed the companies to either succeed or fail at meeting the goals of the project. Finally, the students analogized to how the factors faced by their project were like those faced by the companies they researched in the previous step and then critically articulated how and why they were likely to succeed based on the results achieved by projects they had researched. As part of this analysis, the students also articulated how their situation was distinguishable from situations that they had identified as failures. In the end, collectively, these incremental steps in the team formation process appear to have improved how teams are formed in the capstone course.

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Appendix A: team formation reference document

Maelstrom Interactive is a student-run mobile application and game development company whose goal is the creation of entertainment games and highly-interactive educational experiences for web, mobile, and desktop. With expertise in real-time graphics, animation, and software development, *Maelstrom Interactive* can handle the development of interactive games, apps, and experiences for museums and marketing companies.

Team goals, organization, and size

The interdisciplinary expertise that each *Maelstrom Interactive* member brings to the team, along with the organization and size of the team, enables *Maelstrom Interactive* to succeed in creating entertainment games and highly-interactive educational experiences for web, mobile, and desktop.

Successful creative agencies that operate in the marketing and museum sectors are staffed by artists, application developers, and web-developers.[1] [2] [3] Teams usually range from five to ten people.[4]

The artists in these teams tend to either be 2D generalists who tackle illustration, user interface asset creation, etc. or 3D generalists who tackle all aspects of 3D asset creation, including

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modeling, texturing, and animation.[5] [6] [7] Expertise in Photoshop, Illustrator, and Maya is common.[8] [9] However, a non-trivial number of companies use Cinema 4D or Blender.[10] Character animation skills, mostly, appear to be minimally existent amongst workers in this sector. [11] [12]

The application developers usually use tools such as Unreal or Unity.[13] [14] [15] Swift and Java are also used, but to a lesser extent.[16] The teams that use Swift or Java appear to employ more developers with a formal background in computer science and focus on projects that require capabilities outside of a traditional game engine.[17] Workers who primarily work in Unreal or Unity usually have backgrounds in informatics, game development, user experience design, or computer graphics technology.[18] [19]

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Web developers within these teams usually work in team of two to three people, with each person having the skills of a full-stack web developer.[20] [21] Rarely do web developers on these teams separate into back-end web developers and front-end web developers.[22] JavaScript, Vue.js, Angular, Bootstrap, MySQL, PHP, and web-server configuration and deployment are common skills required. [23] Unique to groups that focus on developing interactive applications for museums, is the need to connect to physical components with web technologies and physical devices such as sensors.[24]

In 2009, a team of five workers developed *Angry Birds*.[25] [26] The team consisted of one lead designer, one programmer, one artist, one composer, and three producers.[27] The game took eight months to develop and had a budget of 25,000 euros. [28] The development of *Angry Birds* is significant because it illustrates that a small team composed of a single technical person in the three major game development areas is enough to create a highly successful interactive game. By 2011, the game was making approximately $1 million per month from the free Android version.[29]

In 2011, a team of five CGT students developed the iOS game *Pak Attack*.[30] The team consisted of one programmer, one game designer, two artists, and a user experience designer who also programmed some of the web back-end components.[31]

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In 2024, G&A digitally recreated *St. Nicholas Greek Orthodox Church and National Shrine* as a way to enable those located outside of New York City to experience space.[32] A small team of web developers, 3D artists, and user experience designers, working under the direction of Scott Wickstrom, created a web and mobile experience that G&A's Senior Integrated Producer, Stephanie Land, says was so "wholly integrated with physical space that using it simply feels like part of actually being there." [33]

Like the team of five Rovio workers who successfully created *Angry Birds* in eight months working in a team composed of programmers, artist, and game designers, *Maelstrom Interactive* has students who have assumed the roles of programmers, artist, and game designers. Because *Maelstrom Interactive* has assumed a similar organizational structure to Rovio, it is likely that from a structural perspective the team will be well poised to work on 2D interactive game similar to Rovio. In addition, because the Rovio team had approximately the same amount of experience and education when they started to develop *Angry Birds*, as the senior students in *Maelstrom Interactive*, Maelstrom Interactive likely will not be negatively impacted by a relative lack of experience compared to Rovio's team.

However, *Maelstrom Interactive*, cannot produce the volume of content that Rovio produced because Rovio's workers worked in a commercial setting (number of hours, support staff, budget) and *Maelstrom Interactive* is working within the constraints of an academic class. *Maelstrom Interactive*, thus, faces similar challenges to those faced by the CGT team that developed and published *Pak Attack*.

Like the *Pack Attack* team, who combined their unique CGT expertise to tackle a unique game project that could not be successfully implemented without the unique skills of each of the constituent members, the *Maelstrom Interactive* team will focus on projects that require the collaborative expertise of the individual members and allow the individual team members to create unique portfolio pieces that would not be possible working solely in their majors.

Like the G&A team that integrated contemporary 3D technologies, such as photogrammetry, into a real-time game environment, which it then integrated with a web site and mobile app experience to create an emotional and compelling emotional experience, the *Maelstrom Interactive* team will have team members with a track record of producing engaging 3D real-time experiences. Thus, like G&A *Maelstrom Interactive* can create content that immerses the end user with 3D graphics and can be delivered both to the desktop via the web, mobile devices, and headsets.

Member goals and relationship to team

Because of the expertise of its members, the organization of the team, and its size, *Maelstrom*

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[32] Archinect. (2023, September 12). G&A helps the worldwide faithful experience the rebirth of St. Nicholas Church digitally for the first time. *Archinect*. https://archinect.com/news/article/150445901/g-a-helps-the-worldwide-faithful-experience-the-rebirth-of-st-nicholas-church-digitally-for-the-first-time

[33] Archinect. (2023, September 12). G&A helps the worldwide faithful experience the rebirth of St. Nicholas Church digitally for the first time. *Archinect*. https://archinect.com/news/article/150445901/g-a-helps-the-worldwide-faithful-experience-the-rebirth-of-st-nicholas-church-digitally-for-the-first-time

Interactive is well positioned to succeed in creating entertainment games and highly interactive educational experiences for web, mobile, and desktop.

Maelstrom Interactive will provide its members with the opportunity to develop expertise in the areas that each member finds necessary to enhance the pursuit of their career goals but is outside of the scope of their major specific classes.

John Smith
John Smith has the goal of becoming a technical artist working on technical projects for either Game Development or Hollywood animation studios.

Employability as a technical artist in the Game Development or Hollywood industries requires a Computer Science degree with examples that demonstrate mastery of programing principles (algorithms, data-structures, graphics APIs) and examples work that demonstrate the application of those principles to entertainment projects.[34]

A BS degree in computer graphics technology coupled with technical demonstrations and code samples that demonstrate the ability to solve practical problems in the entertainment pipeline is sufficient in some instances.[35] A Computer Science degree is not the only pathway to becoming a technical director; practical skills and a portfolio of relevant work can also lead to opportunities in the industry. [36]

The career trajectories of CGT alumni John Doe and Jane Doe are illustrative of the possibility of becoming a technical director in major studios without a computer science degree. [37] [38]

John and Jane both graduated with a BS in Computer Graphics Technology, programmed technical demos that exhibited their ability to use scripting and programming for solving entertainment-based technical problems, and both achieved tremendous success. John has worked at Lucas Arts, Industrial Light and Magic (ILM), Blizzard, Meta, and Apple. Jane has worked at Lucas Arts, Electronic Arts (EA), Rockstar Games, and Intel.

To target the same type of jobs that John and Jane have succeeded in landing, John will create technical samples that demonstrate his skills in applying computer graphics programming to entertainment.

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[34] Keogh, B. and Hardwick, T. (2023). Creative, technical, entrepreneurial: formative tensions in game development higher education. Games and Culture, 19(6), 804-826. https://doi.org/10.1177/15554120231176874
[35] Bowers, D. and Sabin, M. (2023). Demonstrating the use of a professional skills framework to support the assessment of dispositions in it education. Education and Information Technologies, 29(6), 7595-7632. https://doi.org/10.1007/s10639-023-11933-z
[36] Kurok, V., Voyitelyeva, H., Lytvyn, O., Khoruzhenko, T., & Borysenko, N. (2020). Training intending technologies teachers for forming middle school students artistic and technical skills. Revista Romaneasca Pentru Educatie Multidimensionala, 12(1Sup1), 147-162. https://doi.org/10.18662/rrem/12.1sup1/228
[37] Doe, John. (2024, September 17). LinkedIn profile. LinkedIn. Retrieved September 17, 2024
[38] Doe, Jane. (2024, September 17). LinkedIn profile. LinkedIn. Retrieved September 17, 2024

Specifically, John acknowledges that a significant number of technical artist and technical directing jobs require knowledge of Python as applied to the manipulation of digital assets using tools that employ Universal Scene Description (USD)

The opportunity to participate in *Maelstrom Interactive* is immensely valuable to John's success because without the opportunity to work on the interdisciplinary projects that *Maelstrom Interactive* is targeting, John likely would not have the opportunity to create the necessary technical portfolio artifacts to demonstrate his knowledge of using Python to manipulate digital assets using USD tools, which is critical to his ability to be employable as a technical director. In exchange for John's participation, *Maelstrom Interactive* will prioritize pursuing projects that satisfy John's needs.

John will actively utilize the opportunity to work interdisciplinarily on *Maelstrom Interactive* Projects likely to further his goal of become of an Entertainment Technical Artist.