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Contents

Special Issue

Selected Papers from the 2018 Capstone Design Conference

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Susannah Howe, Bridget Smyser, Robert Hart and R. Keith Stanfil 1883–1887 Guest Editorial: The 2018 Capstone Design Conference

The 2018 Capstone Design Conference held in Rochester, NY expanded and improved upon previous conferences (2007 and 2010 in Boulder CO, 2012 in Champaign IL, 2014 and 2016 in Columbus OH) and further developed the community of educators, students, and industry members engaged in discussing, analyzing, and improving capstone design education and pedagogy. Sessions at the 2018 Capstone Design Conference enabled vibrant sharing of ideas and experiences across the capstone community via interactive panel sessions, conference-wide poster session, hands-on workshops, and many informal social activities. A special effort was made this year to improve networking and idea sharing among capstone design students, and to allow instructors to gain insight from this key group of stakeholders. This editorial discusses conference preparation, the range of conference sessions, and feedback from attendees. The technical papers that follow in this issue represent extended versions of selected papers, panels, and workshops from the conference. Topics include noteworthy capstone course innovations, pedagogical tools, effective practices for managing and assessing capstone students, and research on developing both design and professional skills in capstone students.

Keywords: capstone design courses; design pedagogy; capstone conferences; capstone community

Brian J. Novoselich and David B. Knight 1888–1906 Relating Shared Leadership to Capstone Team Effectiveness

Waning student engagement over the course of year-long capstone design projects may decrease team effectiveness and create challenges for capstone faculty advisors and student team leaders. Because leadership is an influence process, reframing how leadership is conceptualized for students may provide a tool that can bolster student effort and overall team effectiveness. Recent literature suggests that sharing leadership may be more effective than vertical leadership for complex design work, but little is known regarding shared leadership within the undergraduate engineering context. This study examined the relationship between shared leadership and team effectiveness for undergraduate mechanical engineering capstone design teams using an adaptation of the Full Range of Leadership model. Results indicated that the overall strength and a limited sharing of select team leadership behaviors relate to a team's effectiveness through group process and individual satisfaction, but not task performance. This study provides capstone faculty with insights into effective leadership behaviors that may be encouraged within the capstone design experience.

Keywords: engineering leadership; capstone design; team effectiveness; teamwork

Emily Dringenberg, Annie Abell and Giselle Guanes 1907–1917 Decision Making in Engineering Capstone Design: Participants' Reactions to a Workshop about Diverse Types of Reasoning

Engineers are expected to make decisions in the context of design, which is ill-structured. Capstone courses serve as an opportunity for engineering students to engage in design and practice making decisions that do not have a single correct answer. Empirical research has demonstrated that when making such decisions, people use informal reasoning, of which there are multiple types: rationalistic, intuitive, and empathic. Despite this reality, engineering education often portrays decision making in the context of engineering design as objective. For example, capstone design instruction typically focuses on providing students with tools to facilitate rational reasoning alone. In this paper, we introduce a framework for informal reasoning that can be used to think critically about how we teach decision making in the context of engineering capstone design. In addition, we use this paper to briefly describe the ways in which capstone design conference attendees engaged with this framework when it was presented in a workshop during the 2018 Capstone Design Conference. To conclude, we present preliminary recommendations for capstone design educators to integrate more opportunities for diverse and realistic forms of reasoning in their teaching practices.

Keywords: design; decision making; capstone; reasoning

Andrew Gouldstone and Bridget M. Smyser 1918–1925 Comparing Patterns of Quantitative Literacy in Mechanical and Industrial Engineering Capstone Teams

One of the desired outcomes of capstone design is the ability to use mathematical arguments such as calculations, modeling, and statistical data analysis to inform design decisions. The VALUE rubric for quantitative literacy (QL) was used to assess the work of 66 capstone teams from a program that contains both mechanical engineering and industrial engineering groups. The goal was to determine if there were particular team, discipline, or project characteristics that led to high quantitative literacy in the final project. Correlation analysis indicates that high levels of quantitative literacy are associated with more successful projects. In particular, the ability to discuss and present calculations seems to be an indicator of success. The patterns of correlations are different for mechanical and industrial engineering teams. Industrial engineering teams who performed highly in the communication aspect of quantitative literacy tend to have higher overall quantitative literacy scores, while this relationship was not as strong for the mechanical engineering groups.

Keywords: quantitative literacy; mechanical engineering; industrial engineering; VALUE rubric

Rick Parker, Shraddha Sangelkar, Matthew Swenson and Julie Dyke Ford 1926–1936 Launching for Success: A Review of Team Formation for Capstone Design

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

Brian Novoselich, Daria Kotys-Schwartz, Kimberly Demoret, Marco Nunez and Patricia Brackin 1937–1952 Considering Capstone Team Member Roles with a Shared Leadership Framework

Managing student roles and responsibilities in team-based courses often presents challenges for both faculty and students. At the 2018 Capstone Design Conference, a panel discussion specifically addressed the impact of roles and responsibilities on teams in capstone design. This paper summarizes the main discussion points of that panel session and relates these topics to a model of shared leadership and distributed influence in the innovation process. The shared leadership model addressed in this study combines an Input-Process-Output (IPO) model from research on teams with existing leadership behavior literature to link team characteristics and leadership practices to team responses and team effectiveness. The students and faculty that comprised the panel represented diverse areas: engineering practice, military teams, academia, and undergraduate design. Detailed notes from the panel session were analyzed by panel members to identify themes and current practices that emerged from the discussion. These themes and practices were mapped to the existing shared leadership model to situate the phenomena in the larger IPO model and positions the phenomena in current organizational leadership literature. The result of this study is a capstone design-specific adaptation of the existing shared leadership model. This model provides capstone faculty and students a more comprehensive framework in which to consider how team roles and responsibilities may affect team response and effectiveness. Conclusions from this study stress the criticality of capstone design faculty in team formation to foster shared leadership. The framework suggests that shared leadership within the team may elicit positive team response through accountability and responsibility and will lead to greater team effectiveness. Specific recommendations for capstone design courses are offered and recommendations for future research are addressed.

Keywords: shared leadership; teamwork; team roles

John K. Estell, Susannah Howe, B. Kris Jaeger-Helton, Shraddha Sangelkar, Kristoph-Dietrich Kinzli and Dustin Rand 1953–1968 Client Interaction Tools: Supporting Student Professionalism on Client-Based Capstone Design Projects

Effective communication between project teams and client sponsors is an essential skill for engineering students and practitioners alike. This paper outlines the three phases of the development, implementation, and assessment of two Client Interaction Rubrics and a subsequent Client Interaction Checklist to guide and support student-client interaction at the outset and throughout the duration of capstone projects. The developed resources were tested in multiple capstone design and project-based courses over three years at a total of six academic institutions. Both formal and informal assessments were conducted regarding the use of these three tools. Students were surveyed following their use of the tools and data were collected on several aspects of instrument use, content, and design with a mix of Likert and open-ended questions. These methods yielded predominantly positive feedback referencing the value of the tools in effectively preparing for, conducting, wrapping up, and following up after client meetings. Constructive feedback was used to inform and revise subsequent versions of the interaction tools for functionality and usability. All of the materials developed through this research are freely available via download, easily editable, and adaptable for use in whole or in part for capstone and similar project-oriented courses. Through the use of such tools, student engineers are better prepared and positioned for success in their interactions with clients. Likewise, effective professional interactions with project clients can build and strengthen relationships between the clients and the associated academic programs, leading to future opportunities and partnerships.

Keywords: client meeting; rubric; checklist; capstone project

Rocio Alba-Flores and Fernando Rios 1969–1982 Incorporating Peer Review Techniques to Enhance Students' Communication Skills and Team Performance in Engineering Capstone Projects

This paper will describe the educational experiences gained by the authors by adding peer review activities to the Capstone Design courses in the Electrical Engineering (EE) program at Georgia Southern University. In particular, the authors have incorporated three peer-focused activities in each of the two EE program capstone design courses (Senior Project I and II), where a peer review assessment is used as a communication enhancement tool. The peer review activities and their corresponding assessment tools have been designed with the main objective to help student to enhance their written and oral communication skills, as well as their leadership and teamwork skills. The activities in which peer review has been added are writing assignments, oral presentations, and team member performance evaluations. Also, to help in the peer review process the instructors introduced the help of a Student Writing Fellow (SWF); this is a student with outstanding written and oral communication skills who was trained to perform the peer review process. The role of the SWF was to provide support to the instructors, to ensure that students gain some benefits from the peer review process without increasing the workload on the faculty teaching the course, and to provide an individual with whom students feel more comfortable interacting. This paper describes the process and the rubrics used to perform the peer review assessment in the different activities. Results from surveys showed an increase in student awareness about the importance of seeking feedback from others when working on important written documents. Results of the peer evaluation of oral presentations provided the most benefits because by the end of the semester, students showed improvement in their presentation skills: they were more confident, came better prepared, interacted more with the audience, and kept track of the time. This improvement was reflected in the rubric scores trends during the two semesters. Results on the assessment of team members' effectiveness helped the instructors to identify in a timely manner conflicting issues in some of the teams. The overall experience of the instructors adding the peer review was very positive and of benefit to the students.

Keywords: capstone design; assessment; peer review; teamwork

Catherine D. D. Bowman, Linda T. Elkins-Tanton, Dean Bacalzo, Paul Howell, Eric J. Montgomery, Alfred Sanft, Dillon Briggs, Yitao Chen, Daniel McCarville, Ryan Meuth and Ming Zhao 1983–1992 Coordinating Opportunistic Interdisciplinary Projects Across Single-Discipline Capstone Courses

There is increasing interest in developing interdisciplinary capstone courses in which students from different majors enroll to work together on complex, real-world projects. Creation of new interdisciplinary capstone courses may not be feasible for some departments or institutions, however, due to administrative or funding complexities. As an alternative, the inclusion of

interdisciplinary *projects* engaging students enrolled in separate single-discipline capstone courses may offer the opportunity to undertake interesting projects, or engage with certain sponsors, that would not be possible without the contributions of students from diverse disciplines. Having such projects undertaken by interdisciplinary teams of students who remain in their single-discipline capstone courses does not reduce, and may amplify, the challenges found in full-fledged interdisciplinary capstone courses (e.g., misaligned schedules, differing requirements, and unfamiliar working cultures). This paper provides findings from the pilot year of a series of opportunistic interdisciplinary capstone projects associated with NASA's Psyche Asteroid Mission involving students from computer science, computer systems engineering, engineering management, industrial design, and graphic design. The findings highlight the importance of close communication and flexibility between faculty and identify a novel and potentially-replicable approach of including project management capstone students on interdisciplinary teams. The paper also describes changes that were implemented for the national expansion of the program with the 2018–2019 academic year and provides early lessons learned associated with those changes, outlining a plan for iterative improvement.

Keywords: interdisciplinary; STEM; disciplinary culture; teamwork; program evaluation

Julie Ford, Marie Paretti, Daria Kotys-Schwartz, Susannah Howe, Christopher Gewirtz, Jessica Deters, Tahsin Mahmud Chowdhury, Robin Ott, Nicholas Emory Alvarez, Daniel Knight and Cristian Hernandez, Laura Mae Rosenbauer, Anne Kary and Francesca Giardine 1993–2013 Transitioning from Capstone Design Courses to Workplaces: A Study of New Engineers' First Three Months

This study investigates engineering students' transitions from academic to professional environments by examining the role capstone design courses play in preparing graduates for the workplace. To better understand how capstone design experiences contribute to graduates' professional preparation, we recruited participants from four different institutions as they completed multiple-semester project-based capstone design courses. We then followed them through their first three months of work using weekly quantitative surveys about participants' work activities and perceived preparedness, and weekly reflective journal responses about significant challenges experienced. To analyze the data, we used *a priori* and emergent codes to identify challenges, strategies, and areas of transfer from capstone to work, in combination with frequency analysis to identify patterns across the data set. The results indicate that participants' most significant challenges centered on self-directed learning and interpersonal communication, and that capstone courses played a key role in supporting professional preparation in these areas.

Keywords: learning transfer; professional preparation; capstone design; school-to-work transition