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REVIEWED BY
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Ilaria Veronesi,
University of Salerno, Italy

*CORRESPONDENCE
Faycal Znidi
✉ fznidi@tamut.edu

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Evolving engineering education: online vs. in-person capstone projects compared (EEE-OIPC)

Faycal Znidi*, Md. Nizam Uddin and Mohamed Morsy

Engineering and Physics Department, Texas A&M University-Texarkana, Texarkana, TX, United States

This study examines the effectiveness of online and face-to-face (F2F) instructional methods in Capstone Senior Design (CSD) projects within Electrical Engineering (EE) and Mechanical Engineering (ME). It explores how each mode influences student success and learning outcomes, addressing the need for adaptable teaching strategies in science, technology, engineering, and mathematics (STEM) education. A comprehensive assessment was conducted, which included project evaluations, advisor feedback, and self-peer reviews. This multifaceted approach aimed to gauge the relative efficacy of online versus F2F modalities in supporting educational outcomes. The findings indicated that both online and F2F modalities achieved parity on several metrics. However, F2F settings significantly enhanced teamwork and collaboration among students. In contrast, online environments excelled in advisor evaluations, suggesting effective mentorship despite less consistent teamwork and project execution. The results emphasize the potential benefits of integrating online and traditional pedagogies to improve educational strategies and student learning experiences. The study highlights the importance of developing online instructional strategies that better mimic the collaborative advantages of F2F instruction. It also underscores the need for a holistic approach to curriculum development to prepare STEM students effectively for future challenges.

KEYWORDS

capstone senior project, online learning, F2F, teamwork, engineering education, project-based learning, group projects, communication

1 Introduction

Project the comparison of student performance and team dynamics between online and F2F learning has been a subject of extensive research, particularly in the wake of the COVID-19 pandemic. Engineering programs, like many others, were compelled to swiftly transition from traditional in-person teaching to online formats. This transition prompted a critical examination of how students adapt to and perform in these different modes of education, as well as how teamwork dynamics evolve. Researchers have delved into these aspects to gain insights into the effectiveness and challenges of online engineering education, offering valuable findings for educators and institutions navigating this new educational landscape. The studies explore various aspects of education, including teaching strategies, student experiences, and project outcomes in both online and in-person contexts. Some studies emphasize the importance of communication, leadership, and team dynamics in project success, while others focus on assessment tools and adapting industry-level project management practices to academic settings. These studies provide valuable insights into education but may have limitations based on their specific contexts.

The studies examine teaching strategies, student experiences, and project outcomes in different educational contexts, both online and in-person. While some studies emphasize the importance of effective communication, leadership, and team dynamics in project success, others focus on assessment tools for evaluating design outcomes and the adaptation of industry-level project management practices to academic settings (Bower et al., 2015; Neyem et al., 2018; Ghasem and Ghannam, 2021; Farraj et al., 2023). These studies offer valuable insights into the challenges and opportunities in education, although some may have limitations based on their specific contexts (Said et al., 2015; Coman et al., 2020; Asgari et al., 2021; Mielikäinen and Viippola, 2023). The series of articles explores various aspects of online and traditional teaching methods across different courses and disciplines. In Gill and Mullarkey (2015), the article addresses the shift of a MIS capstone course to an online format, focusing on preserving interactive elements like case discussions and projects. It assesses the design, delivery, and outcomes of both in-person and online versions, finding that the online format effectively meets learning objectives, albeit with mixed student reactions. Interestingly, the online method resulted in higher-quality project presentations. The study demonstrates the viability of online interactive courses but notes challenges in replicating certain in-person elements online. Friday et al. (2006) compares student performance in traditional and online management courses over eight semesters, revealing no substantial difference but gender-based performance variations. While it offers insights into the effectiveness of online learning, its focus is narrow. In Sum and Light (2010) a political science capstone course at the University of North Dakota is discussed, utilizing innovative assessments but limited to its specific field. In Oyewola et al. (2022), it was found that there is no difference in academic outcomes between online and F2F engineering capstone courses, highlighting the potential of blended instruction. However, its focus on engineering limits broader applicability. Lastly, Viswanathan (2017) examines the implementation of capstone projects in an engineering program, offering practical guidance but primarily focusing on project methodologies. Each study offers insights into online education's effectiveness but with limitations in scope and focus.

This collection of academic studies investigates various aspects of education, particularly focusing on engineering and IT-related subjects. The studies examine teaching strategies, student experiences, and project outcomes in different educational contexts, both online and in-person. While some studies emphasize the importance of effective communication, leadership, and team dynamics in project success, others focus on assessment tools for evaluating design outcomes and the adaptation of industry-level project management practices to academic settings. These studies offer valuable insights into the challenges and opportunities in education, although some may have limitations based on their specific contexts. In Goñi et al. (2020), the focus is on comparing teamwork dynamics in engineering education through online and traditional F2F methods. Utilizing the AIRE Questionnaire, the research evaluates student experiences in project-based learning, particularly during the shift to online learning due to COVID-19. It discovered minimal differences in objectives, challenges, and strategies between online and F2F learning, with some specific elements less frequent in the online format. Another study, Paul and Jefferson (2019) examines the efficacy of online versus traditional teaching over an eight-year period. Analyzing 548 students, this study concludes that there is no significant difference in performance between online and in-person formats. The advantage of this research lies in its long-term analysis of teaching methods. Nevertheless, it's crucial to acknowledge that both of these studies are context-specific and were notably influenced by the unique circumstances of the COVID-19 pandemic, which forced an abrupt shift to online learning for many educational institutions.

In a comprehensive exploration of educational strategies within engineering and I.T., four distinct studies provide valuable insights into various teaching and learning approaches. Study, Rostom et al. (2021) conducts a meticulous comparative analysis of teaching a senior engineering course, examining challenges in both online and in-person formats, with a specific focus on project design and student outcomes. While it utilizes a shared rubric and draws from instructors' insights, it primarily reflects instructors' perspectives. In Wu et al. (2021), the article delves into the impact of project-based learning in introductory engineering courses, assessing student motivation and skill development in F2F and hybrid formats. The study finds no significant motivation changes but notes improved engineering skills and a positive correlation with performance. However, reliance on self-reported data may introduce subjectivity. Study, Ahmad and Alammary (2022) surveys faculty about software capstone projects in Saudi universities, providing regional insights but limiting the scope to faculty perspectives. Study, Martonosi and Williams (2016) focuses on integrating statistical capstone projects into undergraduate curricula, enhancing practical skills but requiring substantial faculty involvement and resource allocation. The combined disadvantages of these studies include a notable bias toward instructors' perspectives over those of students, which could potentially limit the breadth of insights in teaching engineering courses. Additionally, the reliance on self-reported data in evaluating the impact of project-based learning may not fully capture the intricacies of skill development. Furthermore, the predominant focus on faculty views in the study of software capstone project management might inadvertently neglect the valuable insights and experiences of students. Finally, the implementation of statistical capstone projects, while beneficial, demands a substantial commitment of faculty effort and resources, which could pose a potential challenge in terms of practical execution. Each article offers unique insights but also highlights specific limitations, such as reliance on subjective measures or a narrow focus.

The studies presented in Zhang and Wang (2011), Jain and Sobek (2004), and Morris (2021) offer valuable insights into various aspects of capstone projects in engineering and I.T. In Zhang and Wang (2011), the study explores the factors contributing to the success of IT. capstone projects, with a focus on communication, leadership, and team dynamics. It identifies challenges such as team size limitations, tight project schedules, and extensive documentation requirements. However, the study heavily relies on student self-reflection, which may introduce subjectivity into the findings. In Jain and Sobek (2004), it introduces assessment tools, the Client Satisfaction Questionnaire (CSQ) and Design Quality Rubric (DQR), designed for evaluating the quality of design outcomes in engineering capstone projects. It places emphasis on evaluating the final results of projects rather than the processes used to achieve them. However, the study heavily depends on these assessment instruments, potentially missing some dimensions of project success. Lastly, in Morris (2021), the study discusses the adaptation of industry-level project management practices to a collegiate competition-based capstone project. It highlights the importance of effective team management and project planning in achieving success in such complex projects. However, the specific context of the competition and the focus on a single team's experience may limit the generalizability of the findings to broader project environments.

The research comparing online and F2F learning in engineering education provides valuable insights into education, emphasizing communication, leadership, and assessment tools. While offering valuable findings, they may have context-specific limitations. Similarly, research on engineering CSD projects has highlighted factors like communication, assessment tools, and project management practices. Overall, these studies contribute to our understanding of education but should be considered within their respective contexts. However, these studies also have limitations, such as subjectivity and a narrow focus on specific contexts. Therefore, a detailed approach is needed to evaluate and contrast the performance of online students with F2F students, utilizing strategic metrics for a thorough assessment of learning outcomes and effectiveness.

The proposed study adopts a comprehensive approach to assess and compare the performance of online synchronous students at Texas A&M-RELLIS (satellite campus) with their F2F counterparts at the main campus of Texas A&M University in Texarkana (TAMUT), specifically for their final engineering CSD. To ensure a thorough evaluation, a set of strategic metrics is employed, encompassing aspects such as overall project success, feedback from advisors, peer reviews among students, and self-assessment by students themselves. Furthermore, this study applies specific criteria to assess both individual and group performance within educational environments, including attendance and engagement, responsibility, timeliness in completing assignments, work quality, collaboration and support within learning groups, and communication skills. This multifaceted approach aims to provide a comprehensive understanding of learning outcomes and effectiveness across different instructional modes. The study hypothesizes that in engineering CSD projects, F2F instruction will demonstrate superior effectiveness in fostering teamwork and collaboration skills compared to online synchronous learning, despite both methods providing comparable outcomes in other areas.

2 Texas A&M-RELLIS campus model

The Texas A&M-RELLIS campus, located in Bryan, Texas, is a dynamic and expansive center for collaboration among academia, private enterprises, and government entities. Covering over 2,000 acres, this campus serves as a vibrant hub for innovative research, academic pursuits, and comprehensive testing facilities. Its vast and diverse facilities include dedicated areas for autonomous vehicle testing, drone research, and large-scale assessments of materials and technologies. One of the primary focal points of the Texas A&M-RELLIS campus is workforce development. Recognizing the evolving demands of today's competitive landscape, the campus offers a range of programs and initiatives designed to equip students and industry professionals with the skills and knowledge needed to excel in their respective fields. These initiatives encompass internships, co-op programs, and customized training programs tailored to meet the specific requirements of industry partners. The research initiatives at the Texas A&M-RELLIS campus span a wide spectrum of critical areas. These encompass autonomous systems, energy solutions, cybersecurity, and advanced manufacturing techniques. To drive these research endeavors, the campus collaborates with leading experts from academic institutions, industry specialists, and government agencies. This multidisciplinary approach ensures that research conducted at the campus addresses real-world challenges and contributes to technological advancements.

One standout feature of the Texas A&M-RELLIS campus is the Academic Alliance. This strategic partnership links Texas A&M System universities with community colleges, streamlining the academic journey for students. It simplifies the process of transitioning from community colleges to universities, allowing students to pursue bachelor's degrees in high-demand fields such as computer science, engineering, business, biology, and information systems. Faculty members from participating universities and community colleges deliver these degree programs, ensuring a high-quality educational experience. In addition to academic programs, the Academic Alliance provides vital support services to help students achieve their academic and professional goals. These services encompass academic advising, tutoring, and career counseling. By offering a seamless pathway to higher education and comprehensive support, the Academic Alliance enhances educational access and attainment for students across Texas. In summary, the Texas A&M-RELLIS campus stands as a beacon of collaboration, innovation, and education. Its expansive facilities, commitment to workforce development, diverse research initiatives, and the transformative Academic Alliance all contribute to its role as a driving force for academic and economic advancement in the region.

TAMUT is a distinguished public university known for its comprehensive undergraduate and graduate programs. As a partner of the Texas A&M-RELLIS campus, TAMUT extends its educational reach, offering specialized programs in biology and E.E. This partnership grants TAMUT students access to the Texas A&M-RELLIS campus's advanced facilities and resources, enhancing their educational experience. Students benefit from unique opportunities to collaborate with industry leaders and engage in hands-on learning experiences, further preparing them for successful careers in their respective fields. This collaboration underscores TAMUT's commitment to providing a dynamic and practical learning environment.

3 Engineering program at Texas A&M-RELLIS campus

3.1 Program overview

Blinn College has formed a strong partnership with the Texas A&M-RELLIS Campus, offering associate degree programs. Students can enroll in courses taught by faculty from both institutions and transfer credits to participating universities in the Academic Alliance at Texas A&M-RELLIS. This facilitates a smooth transition for Blinn College students to pursue advanced degrees. The Texas A&M-RELLIS Campus, in collaboration with TAMUT, offers a Bachelor of Science in E.E. program. It prepares students for careers in various fields, covering digital systems, communications, control systems, and power systems. The program emphasizes hands-on experience through laboratory exercises and design projects, enhancing practical knowledge and skills. Modern lab facilities are available for students' use, fostering a comprehensive learning experience.

3.2 Course delivery

The Texas A&M-RELLIS EE program primarily serves transfer students entering at the junior and senior levels. Typically, students transfer into the program as juniors, and if they lack prerequisites from their first 2 years, they can complete those courses at Blinn College. As depicted in Figure 1, the program curriculum encompasses 21 core courses and three elective engineering courses, with an emphasis on experiential learning opportunities. The pinnacle of the program is the Senior Design courses, which provide a year-long hands-on project experience. This program follows a hybrid course delivery model, offering courses either F2F or via Two Way Interactive Video (TTVN). Notably, the CSD courses are delivered online for Texas A&M-RELLIS students and F2F for TAMUT campus students.

4 Capstone senior design project structure

The CSD Project at TAMUT is a collaborative effort involving students from various disciplines, such as E.E., and M.E. These students form multidisciplinary teams and work on projects sourced from local industries, often backed by manufacturing firms or sponsored by TAMUT. This unique approach emphasizes the value of real-world, project-based learning combined with industry engagement within CSD courses. Undergraduate teams engage in practical problem-solving, developing software, hardware, interfaces, and testing systems, all while adhering to project deadlines. This experience hones their teamwork, communication, and project management skills, providing a bridge to the challenges of larger-scale industry projects. The CSD project is a valuable platform for students to tackle authentic problems over two semesters, either by creating new products or contributing to existing industry endeavors. This approach benefits not only students but also faculty

RELLIS
THE TEXAS A&M UNIVERSITY SYSTEM

Electrical Engineering (Bachelor of Science) from Texas A&M University-Texarkana
Graduation Plan - Recommended Course Sequence (2024-25)
4-Year (Full-Time)

Blinn College District Engineering (A.S.)					Texas A&M University-Texarkana Electrical Engineering (B.S.)				
Freshman		**Fall**			**Junior**		**Fall**		
	EDUC 1100	Learning Frameworks	1			010-GEN E	PUBLIC SPEAKING*	3	
	ENGR 1201	Intro to Engineering	2			EE 307	Probability & Random Process	3	
	MATH 241	Calculus I	4			EE 319	Electric Circuits II	3	
	CHEM 140	Gen Chem for Engr Ma	4			EE 321	Digital Logic	3	
	ENGL 1301	Composition I	3			EE 322	Digital Logic Lab	1	
	PHIL 2306	Introduction to Ethics	3			EE/ENGR	Enginering Elective (Upper)	3	
		TOTAL	**17**				**TOTAL**	**16**	
		Spring					**Spring**		
	MATH 241	Calculus II	4			EE 325	Signals & System I	3	
	PHYS 2425	University Physics I	4			EE 326	Signals & System Lab	1	
	ENGL 1302	Composition II	3			EE 335	Electronics I	3	
	060-GEN E	US HISTORY*	3			EE 336	Electronics Lab	1	
	050-GEN E	CREATIVE ARTS*	3			EE 345	Intro to Electromagnetics	3	
						EE/ENGR	Enginering Elective (Upper)	3	
		TOTAL	**17**				**TOTAL**	**14**	
Sophomore		**Fall**			**Senior**		**Fall**		
	MATH 231	Linear Algebra	3			EE 305	Fundamentals of Power System	3	
	MATH 241	Calculus III	4			EE 306	Electric Power & Machinery La	1	
	PHYS 2426	University Physics II	4			EE 429	Basic Comm. Theory	3	
	ECON 2301	Princ of Macroeconom	3			EE 490	EE Senior Design I	3	
	070-GEN E	GOVERNMENT*	3			EE/ENGR	Enginering Elective (Upper)	3	
		TOTAL	**17**				**TOTAL**	**13**	
		Spring					**Spring**		
	ENGR 2304	Prog for Engineers	3			EE 432	Control Systems	3	
	ENGR 2405	Electrical Circuits	4			EE 445	Embedded Systems	3	
	060-GEN E	US HISTORY*	3			EE 446	Embedded Systems Lab	1	
	MATH 232	Differential Equations	3			EE 474	Power Systems Analysis & Co	3	
	070-GEN E	GOVERNMENT*	3			EE 491	EE Senior Design II	3	
						ENGR 312	Engineering and Business Ethics	3	
		TOTAL	**16**				**TOTAL**	**16**	

FIGURE 1
RELLIS electrical engineering program plan.

and industry partners, fostering a culture of collaboration and innovation.

A combination of industry partners and faculty members typically sponsors the CSD projects at TAMUT. These projects involve a comprehensive design process that includes initiation, scope definition, planning, various design stages, testing, performance analysis, simulation, and final presentations. The participation of industry sponsors allows students to gain practical experience and collaborate with engineers and customers. These projects have proven highly beneficial for the E.E., and M.E. programs at TAMUT. The course structure emphasizes forming multidisciplinary teams matched with projects aligned with their interests, all under the guidance of academic and industry mentors.

In this study, the CSD projects comprise six teams, with each team consisting of 3–4 student groups and each group comprising 3–4 students. Three of these teams collaborate face-to-face, while the remaining three work online. The journey begins in the fall term with students proposing their project ideas, which are reviewed and approved by their academic mentors. Regular meetings with the course instructor, either in person or online, are crucial for progress updates. At the end of the second term, students are expected to submit comprehensive reports and participate in public presentations, including poster displays. Industry mentors play a pivotal role in evaluating presentations and providing valuable feedback, enriching the overall learning experience.

The evaluation process is comprehensive, encompassing both individual effort and teamwork. Individual contributions are assessed through reviews by industry and faculty mentors, as well as peer reviews. Teamwork evaluation consists of multiple components, including the proposal report and presentation, oral updates in class, the electronic team notebook, midterm reports and presentations, and the final written reports and design and poster presentations. In particular, industry mentors play a crucial role in assessing the final design of poster presentations. They evaluate various aspects, including the student teams' verbal presentation skills, such as organization, delivery, and professionalism. Additionally, they assess written presentation skills, focusing on content and poster quality. This feedback not only enhances student performance on their projects but also equips them with valuable skills for their future engineering careers. The balanced evaluation approach ensures that students are not only technically proficient but also effective in communication and teamwork, which are essential attributes in the engineering field.

This research conducts a comprehensive evaluation of online synchronous students at Texas A&M-RELLIS and F2F students at TAMUT, employing strategic metrics for assessing learning outcomes. Key metrics include: *the overall project success, advisor feedback, peer reviews among students, and Self-Assessment by students*. Moreover, particular criteria evaluate both individual and group performance, covering: *attendance and participation, accountability, punctuality in completing assignments, the caliber of work produced, collaboration and assistance within learning groups, and proficiency in communication.*

5 Materials and methods

This research employs a detailed approach to evaluate and contrast the performance of online synchronous students at Texas A&M-RELLIS with F2F students at the main campus of TAMUT, utilizing strategic metrics for a thorough assessment of each group's learning outcomes and effectiveness. The key metrics include:

1. *Overall Project Success:* This measures the success of students in achieving their learning objectives by evaluating the quality of their work and outcomes.
2. *Advisor Feedback*: Insights from instructors overseeing the students are crucial, providing perspectives on the students' problem-solving approaches, adherence to course guidelines, and overall learning methodologies.
3. *Peer Reviews Among Students*: Involving students in evaluating each other, focusing on dynamics within learning groups, individual contributions, and overall cohesion among peers.
4. *Self-Assessment by Students*: Each student's self-evaluation is considered, focusing on personal growth, challenges encountered, and individual contributions to their learning success.

The study also employs specific criteria for assessing individual and group performance in educational settings. These criteria are:

- *Attendance and Engagement*: Emphasizing the importance of regular attendance and active participation, whether in online or F2F settings.
- *Responsibility*: Expectation for students to contribute effectively to collaborative learning tasks and discussions.
- *Timeliness in Assignments*: Stressing the importance of meeting deadlines for coursework and projects.
- *Quality of Work*: Ensuring high standards in the completion of assignments and participation in class activities.
- *Cooperation and Support in Learning Groups*: Encouraging an environment that is cooperative and supportive among students.
- *Communication Skills*: Highlighting the importance of effective communication, both in online and F2F interactions.

The study utilizes a numerical scoring system, ranging from 1 to 4, with 4 being the highest, to facilitate a clear, quantifiable comparison between the two student groups. Additionally, the standard deviation of these scores is calculated to gage the variability in the data. This methodical approach helps in understanding the consistency of results across different learning environments and metrics, thereby providing a nuanced understanding of the performance variations between online synchronous students at Texas A&M-RELLIS and F2F students at TAMUT's main campus. This methodology aims to comprehensively assess each learning modality's effectiveness, identifying their strengths and areas for enhancement.

6 Results and discussion

6.1 Overall CSD project success

Analyzing the data presented in Figure 2 for the overall performance of online synchronous students at the Texas A&M-RELLIS campus versus those attending F2F CSD classes in TAMUT reveals some nuanced differences. Students attending synchronous online classes at Texas A&M-RELLIS scored an average

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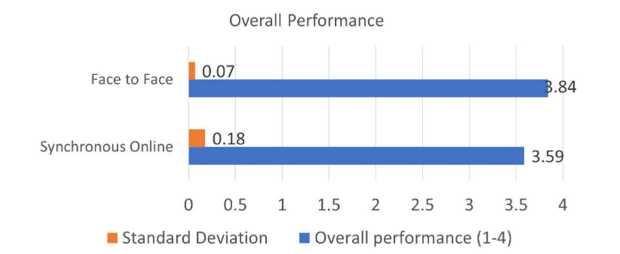

FIGURE 2
Overall performance of students enrolled in CSD project.

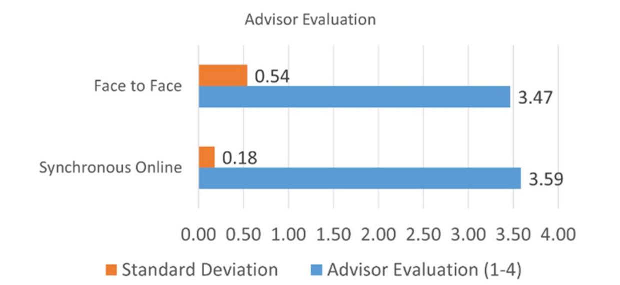

FIGURE 3
Advisors' evaluations of students enrolled in CSD project.

of 3.586 out of 4 points. This performance metric encompasses various aspects of the student's academic work, including midterms, final presentations, poster designs, and final reports. While this score indicates a commendably high level of achievement, it is slightly lower than the average score for F2F students at TAMUT, who scored an average of 3.841.

The higher average score for F2F students might suggest that the in-person educational environment provides certain advantages. This could include more direct interaction with instructors, immediate feedback, and potentially more dynamic group discussions and collaborations, all of which can contribute positively to students' understanding and mastery of the material.

In terms of variability in performance, as indicated by the standard deviation, there is a notable difference between the two groups. The online synchronous students at Texas A&M-RELLIS show a standard deviation of approximately 0.179, which implies a broader range of performance levels among these students. This could reflect varying degrees of adaptability to online learning environments, differences in resource access, or individual preferences for learning styles.

Conversely, the F2F students at TAMUT have a standard deviation of approximately 0.069, demonstrating a tighter cluster of scores around the mean. This suggests a more uniform performance level, which may be attributed to the structured setting of traditional classroom learning, where students experience a more controlled and consistent learning environment.

6.2 Advisor feedback

The data for CSD students' advisor evaluations shows that synchronous online students at Texas A&M-RELLIS have a higher average evaluation score of 3.59 compared to the F2F students at TAMUT's main campus, with an average score of 3.47, as shown in Figure 3. Given that each team is assigned a faculty advisor based on the type of project, this outcome indicates that online students are rated more favorably in their CSD projects. The online setting seems to foster an effective advisory process, where faculty advisors can closely monitor and consistently evaluate students' performance.

The standard deviation for the online students' evaluation scores is 0.18, demonstrating uniformity in the advisors' assessments across the online cohort. This contrasts with the F2F students' evaluations, with a standard deviation of 0.54, indicating a substantial disparity in the advisors' ratings. This disparity suggests that the evaluation process for F2F students encompasses a broader range of perceptions about student performance and possibly a more diverse set of factors influencing these assessments.

The consistency in the advisor evaluations of online students points to an effective and uniform advisory system at Texas A&M-RELLIS. This suggests that the faculty advisors are using a consistent set of criteria to evaluate all students, leading to similar scores across the board. The higher variability observed in the evaluations of F2F students at TAMUT indicates that more variable factors, including project type, team dynamics, or individual student interactions with advisors, influence the assessment process.

These findings suggest that while the quality of faculty advisement is recognized as high in both settings, the online advisory process at Texas A&M-RELLIS results in more predictable and consistent evaluations. For F2F students at TAMUT, the greater range in evaluation scores calls for an analysis of the advisement process to ensure that all students are being assessed with the same level of rigor and fairness. Standardizing the evaluation criteria and advisement approach for F2F projects could help achieve consistency in advisor evaluations comparable to that of the online students.

6.3 Self and peer evaluation

The Peer and Self Evaluation Form for Team Projects, as shown in Figure 4, is a crucial tool utilized in CSD courses to gage the performance and contribution of each student within a team. It is structured to capture both self-assessment and peer feedback across multiple key performance areas. Each student is required to provide a project title for context and then rate themselves and each of their team members against a set of criteria on a scale from 1 (strongly disagree) to 4 (strongly agree). The criteria encompass attendance and punctuality at team meetings, responsibility in completing assigned tasks, timeliness of task completion, the quality of work prepared, teamwork and supportiveness, and the ability to listen effectively to others.

This comprehensive approach allows for a well-rounded assessment, ensuring students are recognized for their efforts and ability to function within the team. At the form's conclusion, numerical totals for each column offer a quantifiable measure of each student's perceived contribution. Such peer evaluations are invaluable in educational settings, as they provide instructors with insights into the internal workings of student teams and individual participation, which might otherwise remain opaque. By integrating these evaluations into the final grade, the educational system ensures that

Peer Evaluation Form for Team Projects				
Project Title :				Team no.
Write the name of each of your team members (including you) in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.				
	Student #1 (Self-evaluation)	Student #2	Student #3	Student #4
Attends team meetings regularly and arrives on time.				
Take responsibility in team efforts to complete the assigned tasks				
Completes team assignments on time.				
Prepares work in a quality manner.				
Demonstrates a cooperative and supportive attitude.				
Demonstrates effective listening skills to other team members.				
TOTALS				

FIGURE 4
Self- and peer-evaluation form on a 1–4 scale.

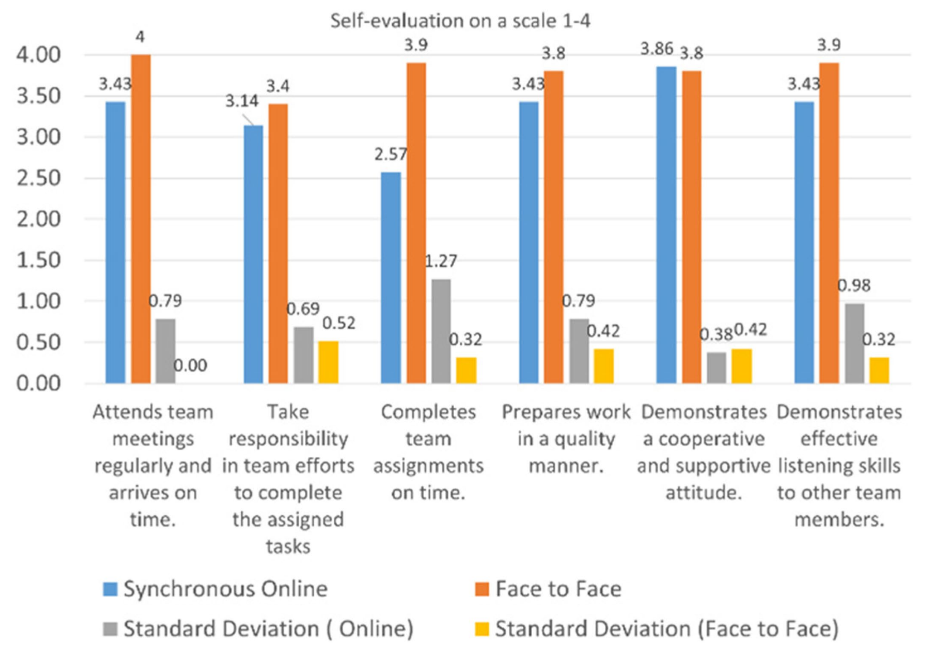

FIGURE 5
Self-evaluation results.

the collective outcomes of team projects fairly reflect individual inputs, thereby reinforcing the importance of every team member's active involvement and cooperative spirit.

In reviewing the self-evaluation results for the CSD students in Figure 5, it's evident that those attending the main TAMUT campus outperform their online counterparts at the Texas A&M-RELLIS campus in several key areas. F2F students consistently report full marks for punctuality and attendance at team meetings, demonstrating a uniform commitment to engagement. They also surpass online students in taking responsibility for team tasks and completing assignments on time, with the latter group displaying significant variability in their self-assessment, indicating a concern for the consistency of their performance.

Moreover, while the quality of work prepared by both groups is relatively comparable, the F2F group still maintains a slight edge, with less variation in their self-ratings. Online students present a more unified front in their cooperative and supportive attitudes, rating themselves higher than F2F students, which suggests a strong team dynamic despite the challenges of remote collaboration. Lastly, both groups assert effective listening skills, yet F2F students give themselves marginally higher ratings with more agreement among members, pointing to a possibly more harmonious team interaction.

The data unequivocally shows that F2F interactions at the TAMUT campus foster a more consistent and favorable self-evaluation in team-based settings, suggesting that the physical classroom environment contributes positively to student performance and perception. This implies a need to address and bridge the gaps in the online synchronous format to elevate student engagement and effectiveness to the level of their F2F peers.

The peer review results presented in Figure 6 indicate a clear trend in the perception CSD students' performance at both Texas A&M-RELLIS campus (online synchronous) and the main TAMU-T campus, across various evaluation criteria. Students attending sessions F2F at TAMUT consistently received the highest ratings, achieving a perfect score of 4.00 in three categories: "Attends team meetings regularly and arrives on time," "Demonstrates a cooperative and supportive attitude," and "Demonstrates effective listening skills to other team members." They also scored highly in "Completes team assignments on time" and "Prepares work in a quality manner," both with a 3.92 rating. These results suggest that the F2F environment at TAMUT is conducive to fostering punctuality, collaboration, and communication among team members.

On the other hand, online synchronous students at R Texas A&M-RELLIS campus scored marginally lower, with the highest ratings being 4.00 in "Attends team meetings regularly and arrives on time" and "Demonstrates a cooperative and supportive attitude," indicating that despite the challenges of online learning, these students are still maintaining high standards of participation and teamwork. However, their scores for "Completes team assignments on time" and "Prepares work in a quality manner" were slightly lower, at 3.67 and 3.33, respectively. This could reflect the inherent challenges of online coordination and execution of tasks.

The standard deviation (a measure of variability) for online students is notably higher in "Takes responsibility in team efforts to complete the assigned tasks," suggesting there is a wider range of behavior in this category among online students compared to their F2F counterparts, who have a standard deviation of zero in all categories, indicating absolute agreement among the reviewers.

Overall, the F2F interactions at the TAMUT campus appear to enhance team dynamics and individual accountability, as evidenced by the consistently high and uniform scores. In contrast, while the Texas A&M-RELLIS online synchronous students perform admirably, the variations in their scores indicate a need for strategies to improve consistency in teamwork and task completion.

7 Discussion

The comprehensive analysis of the CSD students' performance at both the Texas A&M-RELLIS campus (online synchronous) and the

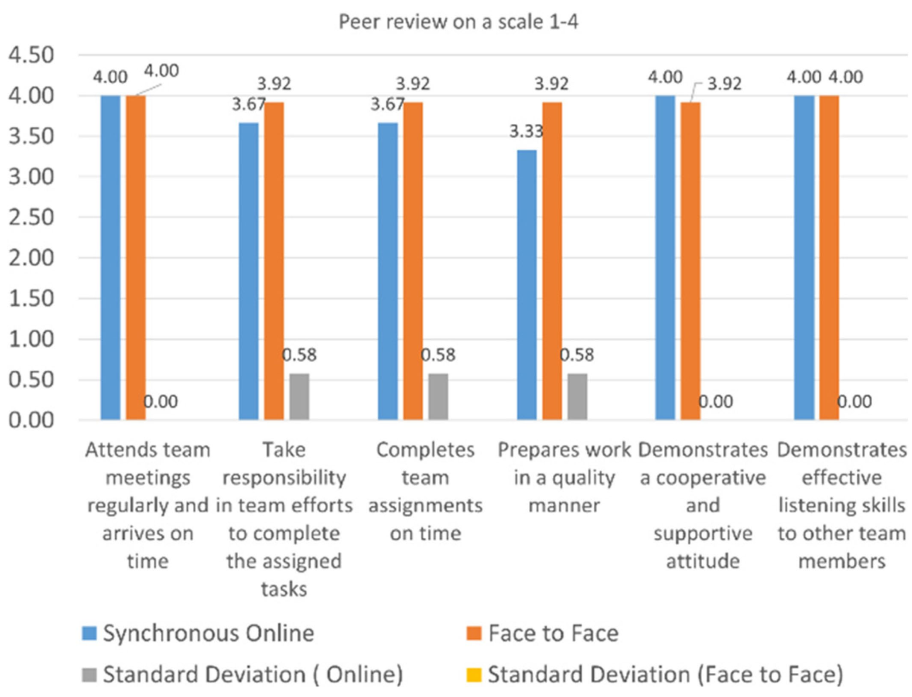

FIGURE 6
Per review results.

main TAMUT campus (F2F) reveals that the learning environment significantly influences student outcomes. Starting with the overall CSD project success, the data showcases that F2F students at TAMUT have an edge with a higher average performance score of 3.841 compared to their online peers at Texas A&M-RELLIS, with 3.586. The lower variability in scores among TAMUT students suggests a more uniform understanding and application of the course material, likely facilitated by direct, real-time interactions that are inherent to the traditional classroom setting. This is further corroborated by the tighter standard deviation of 0.069 for TAMUT students, indicating more consistent performance levels, likely due to the structured nature of in-person learning environments.

In contrast, advisor feedback paints a different picture. The Texas A&M-RELLIS online students received a higher average evaluation score from advisors, standing at 3.59, versus 3.47 for TAMUT students. This suggests that the online advisory process may be more effective, with advisors possibly having better oversight and consistent engagement with students. The lower standard deviation for online evaluations also implies a more uniform assessment standard. However, the high variability in TAMUT advisor feedback, indicated by a standard deviation of 0.54, points toward a need for a more standardized evaluation process to ensure equity and consistency in assessments.

Delving into self and peer evaluations, there's a discernible pattern where F2F students at TAMUT perceive their own performance more favorably and consistently, particularly in areas such as punctuality, responsibility, and work quality. The perfect scores in several categories reflect a conducive environment for collaboration and communication. This is in contrast to online students who, despite rating themselves highly in terms of cooperation and support, show greater variability in task completion and responsibility.

The peer review data echoes these findings, with F2F students at TAMUT receiving uniformly high ratings across all criteria. The lack of variability (standard deviation of zero) in their scores reflects a consensus among peers regarding each member's contribution, which is indicative of a well-synchronized team dynamic. Online students at the Texas A&M-RELLIS, however, exhibit a wider range of scores, especially in taking responsibility and completing tasks, pointing toward potential disparities in online team coordination and individual commitment.

The synthesis of these results indicates that while both F2F and online students are capable of high performance, the traditional F2F setting at TAMUT fosters more consistent and predictable outcomes. The controlled environment, the immediacy of interaction, and the ability to engage in real-time discussions appear to streamline the learning process and enhance team cooperation. Online students at the Texas A&M-RELLIS do show commendable performance levels, particularly in advisor evaluations, suggesting that the online advisory process is robust. However, the greater variability in their peer and self-evaluations suggests that there are aspects of the online learning model that could be optimized to support more uniform performance.

The data underscores the need for tailored strategies in online settings to improve consistency in teamwork and task completion. This could involve enhancing virtual communication platforms, providing additional support for project management in a remote context, and refining online evaluation methodologies to ensure that they capture student performance accurately and fairly. Both learning environments have their merits, but the aim should be to leverage the strengths of each to support student success in all aspects of their CSD experience.

8 Conclusion

The main goal of the research was to critically assess the effectiveness of online synchronous versus F2F learning environments in CSD courses through a multifaceted evaluation comprising overall project success, advisor feedback, and self and peer assessments. The study aimed to illuminate the distinctions between the two learning modalities and provide insights for optimizing educational strategies.

In conclusion, the study reveals that F2F students at TAMUT excel in uniformity and higher averages in performance evaluations, suggesting that in-person interactions may better support consistent high achievement in academic collaborations. Meanwhile, online students at Texas A&M-RELLIS, despite facing the challenges of remote coordination, demonstrate strong performance, particularly in advisor evaluations, indicating an effective online advisory process. However, the variability in their self and peer assessments suggests a need for improved consistency in online teamwork and project execution.

The data indicates that while online learning can offer a high-quality educational experience, F2F learning environments at TAMUT foster a more consistent level of student engagement and performance. Moving forward, this study underscores the importance of adopting tailored strategies in online education to match the effectiveness of traditional classroom settings and suggests a reevaluation of the advisory process to ensure equitable and consistent standards for all students. The findings advocate for leveraging the unique strengths of each learning modality to enhance the overall educational experience and success of CSD students.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

FZ: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NU: Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing. MM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Ahmad, E., and Alammary, A. (2022). Towards unified management of software capstone projects in Saudi universities: a survey-based study. *Arab Gulf J. Sci. Res.* 40, 118–138. doi: 10.1108/AGJSR-04-2022-0037

Asgari, S., Trajkovic, J., Rahmani, M., Zhang, W., Lo, R. C., and Sciortino, A. (2021). An observational study of engineering online education during the COVID-19 pandemic. *PLoS One* 16:e0250041. doi: 10.1371/journal.pone.0250041

Bower, M., Dalgarno, B., Kennedy, G. E., Lee, M. J. W., and Kenney, J. (2015). Design and implementation factors in blended synchronous learning environments: outcomes from a cross-case analysis. *Comput. Educ.* 86, 1–17. doi: 10.1016/j.compedu.2015.03.006

Coman, C., Țîru, L. G., Meseșan-Schmitz, L., Stanciu, C., and Bularca, M. C. (2020). Online teaching and learning in higher education during the coronavirus pandemic: 'Students' perspective. *Sustain. For.* 12:10367. doi: 10.3390/su122410367

Farraj, A., Znidi, F., and Morsy, M. (2023). On delivering the electrical engineering program at the RELLIS campus. In Proceedings of the 2023 IEEE Frontiers in Education Conference (FIE). College Station, TX, USA: IEEE 18, 1–6.

Friday, E., Friday-Stroud, S. S., Green, A. L., and Hill, A. Y. (2006). A multi-semester comparison of student performance between multiple traditional and online sections of two management courses. *J. Behav. Appl. Manag.* 8, 66–81. doi: 10.21818/001c.16698

Ghasem, N., and Ghannam, M. (2021). Challenges, benefits & amp; drawbacks of chemical engineering on-line teaching during Covid-19 pandemic. *Educ. Chem. Eng.* 36, 107–114. doi: 10.1016/j.ece.2021.04.002

Gill, G., and Mullarkey, M. (2015). Taking a case method capstone course online: A comparative case study. *J. Inform. Technol. Educ. Res.* 14, 189–218. doi: 10.28945/2171

Goñi, J., Cortázar, C., Alvares, D., Donoso, U., and Miranda, C. (2020). Is teamwork different online versus face-to-face? A case in engineering education. *Sustainability* 12:10444. doi: 10.3390/su122410444

Jain, V., and Sobek, D. (2004). Two instruments for assessing design outcomes of capstone projects. In Proceedings of the 2004 Annual Conference Proceedings. Salt Lake City, UT, USA: ASEE Conferences pp. 9.1327.1–9. 1327.13.

Martonosi, S. E., and Williams, T. D. (2016). A survey of statistical capstone projects. *J. Stat. Educ.* 24, 127–135. doi: 10.1080/10691898.2016.1257927

Mielikäinen, M., and Viippola, E. (2023). ICT engineering 'Students' perceptions on project-based online learning in Community of Inquiry (CoI). *SAGE Open* 13, 1–22. doi: 10.1177/21582440231180602

Morris, B. D. (2021). *Application of Project Management strategies and tools for an efficient and successful competition-based engineering senior capstone design project*. Morgantown, WV, USA: West Virginia University Libraries.

Neyem, A., Diaz-Mosquera, J., and Benedetto, J. I. (2018). A cloud-based Mobile system to improve Project Management skills in software engineering capstone courses. *Mob. Inf. Syst.* 2018, 1–16. doi: 10.1155/2018/6371793

Oyewola, O. M., Osunbunmi, I., Ajide, O. O., and Oyewola, Y. (2022). "The influence of in-person and online modes of instruction on academic performance in engineering capstone design courses: A comparative study based on non-parametric statistics" in *World transactions on engineering and technology education*, 20.

Paul, J., and Jefferson, F. (2019). A comparative analysis of student performance in an online vs. F2FEnvironmental science course from 2009 to 2016. *Front. Comput. Sci.* 1:7. doi: 10.3389/fcomp.2019.00007

Rostom, R., Ferdous, S., and Shahhosseini, A. (2021). A comparative analysis of challenges encountered in achieving student outcomes when teaching a senior engineering technical Core course online and face-to-face. In Proceedings of the 2021 ASEE Virtual Annual Conference Content Access Proceedings; ASEE Conferences. Virtual Conference.

Said, H., Kirgis, L., Verkamp, B., and Johnson, L. J. (2015). Online vs. F2FDelivery of information technology courses: 'Students' Assessment. *J. Inform. Technol. Educ. Res.* 14, 297–312. doi: 10.28945/2274

Sum, P. E., and Light, S. A. (2010). Assessing student learning outcomes and documenting success through a capstone course. *PS Polit. Sci. Polit.* 43, 523–531. doi: 10.1017/S1049096510000764

Viswanathan, S. (2017). Implementation of effective capstone projects in undergraduate manufacturing design engineering program. *Am. J. Eng. Educ.* 8, 45–60. doi: 10.19030/ajee.v8i1.9967

Wu, L. L., Fischer, C., Rodriguez, F., Washington, G. N., and Warschauer, M. (2021). Project-based engineering learning in college: associations with self-efficacy, effort regulation, interest, skills, and performance. S.N. *Soc. Sci.* 1:287. doi: 10.1007/s43545-021-00286-4

Zhang, C., and Wang, J. A. (2011). "Effects of communication, leadership, and team performance on successful I.T. Capstone projects" in *Proceedings of the proceedings of the 2011 conference on information technology education* (New York, NY: ACM), 281–286.