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An Experiential Learning Opportunity in Norway: Computation for Bioengineering and Mechanical Engineering Students

The global learning initiative at Northeastern University is focused on fostering intercultural communication skills. The Dialogue of Civilization (DOC) program serves as a mechanism to achieve such a goal by offering faculty-led international experiences. In this paper, we have presented a detailed account of a DOC program that took place in Norway. The primary objective of the program was to teach mechanical engineering and bio-engineering students computational skills while stimulating critical thinking about the cultural and social aspects of technology and engineering in Norway. The program focused on two courses: a technical course and a special topics course. The technical course introduced students to finite element analysis, with practical applications and site visits in Norway to enhance experiential learning. In the special topics course, the interplay between modern technologies, like green energy, state policies, and the rights and traditions of the indigenous Sámi people was explored. The course highlighted both the progressive social policies in Norway and the historical discrimination against the Sámi. Student feedback was positive and experiential learning components such as guest lectures and site visits were particularly appreciated. Additional surveys showed that students' self-confidence was higher following the DOC program. In addition, female-identifying students had higher confidence in their future success after completion of this program as compared to their male-identifying counterparts. Our paper is expected to serve as a resource for educators seeking to integrate technical education with intercultural experiences and discussions on social and cultural impacts in engineering. [DOI: 10.1115/1.4064791]

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1 Introduction

Global learning is a central focus at Northeastern University, where students are strongly encouraged to participate in activities that foster the enhancement of intercultural communication skills. In a global learning context, students benefit both from international and transnational aspects of their disciplines and from intercultural and local nuances in the host country. The Dialogue of Civilization (DOC) program serves as an important opportunity to achieve the intercultural learning goals of Northeastern University. As a faculty-led initiative, the DOC program consists of students spending 30 days or more of a summer semester with a faculty leader in locations outside of their main campus. This short-term program provides students with valuable international experience. During the program, students are required to complete two courses, which are carefully designed to address problems and potential solutions specific to the host country, with the assistance of local stakeholders.

Traveling to Paraguay and Argentina for learning Guarani or spending time in Samarkand and Bukhara to examine the history of the silk road in central Asia seems to be no-brainer idea for DOC programs. However, learning computational skills for mechanical engineering and bio-engineering students may not seem to be a skill requiring a global framework. After all, everybody can sit at their computer and write scripts. Although initially unconventional, the objective of the program was to teach computational skills to engineering students and simultaneously encourage them to engage in critical thinking and discussions concerning the cultural and social dimensions of engineering and technology. Furthermore, a more in-depth analysis of the ethical considerations inherent in the application of engineering was deemed a subject that could greatly enhance students' learning experience.

Despite the initial perception that computational skills may not require a global framework, our previous research has shown that active learning positively influences students' course-specific knowledge and self-efficacy [1,2]. The DOC program in Norway discussed in this paper aimed to facilitate training in essential technical skills while providing engineering students with opportunities to explore and ponder the cultural and social aspects of engineering and technology in Norway.

By blending technical education with exposure to Norway's culture and history, especially regarding the indigenous Sámi people and their land rights, the program aimed to broaden students' perspectives and equip them with interdisciplinary problem-solving capabilities. In this paper, we have provided a detailed account of the program's curriculum, experiences, and student feedback, underscoring the success of the program in achieving its objectives.

2 Program Description

We selected Norway due to its pioneering contributions to the development and application of computational methods in engineering. Notably, the Norwegian Computing Center, established in 1952, stands as one of the world's pre-eminent institutions in computational research and the birthplace of many innovations in the field [3]. Our immersive program centered on two courses: Mechanical Engineering Computation and Design (ME 4508, 4 credit hour) and a special topics class particularly designed for this DOC program (ME4699, 4 credit hour).

The core focus of ME 4508 was to introduce students to the theory of finite element (FE) analysis, with particular emphasis on the behavior of elastic materials. Additionally, the course covered essential aspects of heat transfer through conduction and convection. Students developed scripts in MATLAB (The MathWorks, Inc., Natick, MA) and used available commercial FE software (Ansys Workbench, Ansys, Inc., Canonsburg, PA). At Northeastern University, ME 4508 is a required course for the Bachelor of Science in mechanical engineering, and an elective course for the Bachelor of Science in bio-engineering. With Norway as our backdrop, we strategically selected applications that aligned with guest lectures and site visits. For instance, students were privileged to receive lectures from biomechanics experts at the prestigious Norwegian University of Science and Technology, which consequently culminated in a biomechanics project involving organic meshes obtained from computed tomography. This interdisciplinary approach extended beyond the classroom, as students had the extraordinary opportunity to witness firsthand the outcomes of the design and analysis they had been studying during their site visits (Fig. 1). For example, after introducing fundamental principles of solving balance equations with the assumption of linear elasticity through FE analysis, the students received a guest lecture by a computational modeling expert specializing in heart valves. During the session, the guest lecturer delved into more intricate subjects, including the application of FE analysis in the presence of large strains. Drawing practical connections, they then showcased how such theories find utility in analyzing heart valves of individuals affected by degenerative diseases [4]. In addition, the lecturer showed how future surgical outcomes for these patients could be enhanced by integrating simulations of this nature.

Another instance of effectively harnessing the expertise of local professionals and organizing insightful site visits pertained to the field of renewable energy technologies. Following instructions on employing computational methods in windmill design—spanning structural analysis and weather data interpretation—students were given the opportunity to visit a nearby wind farm. This excursion proved rewarding for many participants, as they witnessed the wind farm in dynamic operation. Guided by the explanations generously provided by the local operational manager, they gained a profound appreciation for the sheer scale and intricacy of these engineering marvels. In addition, they embarked on an exhilarating mountain hike that led them through the very terrain where the wind farm had been meticulously erected. Subsequently, numerous students expressed how this experience illuminated the critical role of engineering tools and computational techniques, especially when they observed the giant wind turbine blades operating against the backdrop of the natural landscape. This firsthand encounter underscored the tangible impact of their engineering studies in the realm of sustainable energy.

The course entitled "ME 4699 Special Topics in Mechanical Engineering: Exploring Engineering, History, Environment, and Culture in Norway" served as a powerful vehicle for immersing students in a different culture, one filled with a captivating history spanning the modern era and the time-honored traditions of the indigenous Sámi people. The central theme of ME 4699 revolved around the intricate interplay between cutting-edge technologies, particularly in the realm of green energy, and the rights and traditions of the Sámi. Norway, a nation blessed with abundant crude oil resources, is also known for its pro-active and vibrant pursuit of alternative energy sources, including hydropower, wind power, and wave power. In addition to its environmentally conscious stance, Norway has earned its place as a beacon of progressive values in Europe, exemplified by its pioneering legislations supporting women's rights, minority rights, and LGBTQIA+ rights [5–7]. However, it is essential to juxtapose such a progressive image with the historical injustices inflicted upon the Sámi people who, for decades, were subjected to discrimination and the unjust dispossession of their ancestral lands as a consequence of the Norwegianization policies [8]. The Norwegianization policies, a dark chapter in the history of Norway, constitute a sobering reminder of the complexities surrounding indigenous rights and cultural preservation. These policies, enacted during the 19th and 20th centuries, were characterized by a concerted effort to assimilate the Sámi people into what was defined at the time as "the mainstream Norwegian" society. Assimilation was pursued through a range of measures, including the suppression of the Sámi language and traditional practices, and the forced displacement of the Sámi from their ancestral lands. These policies had profound and lasting consequences on the Sámi community, contributing to the erosion of their cultural identity and socio-economic disparities that persist to this day. The Norwegianization policies highlight the enduring struggles faced by indigenous populations globally when confronted

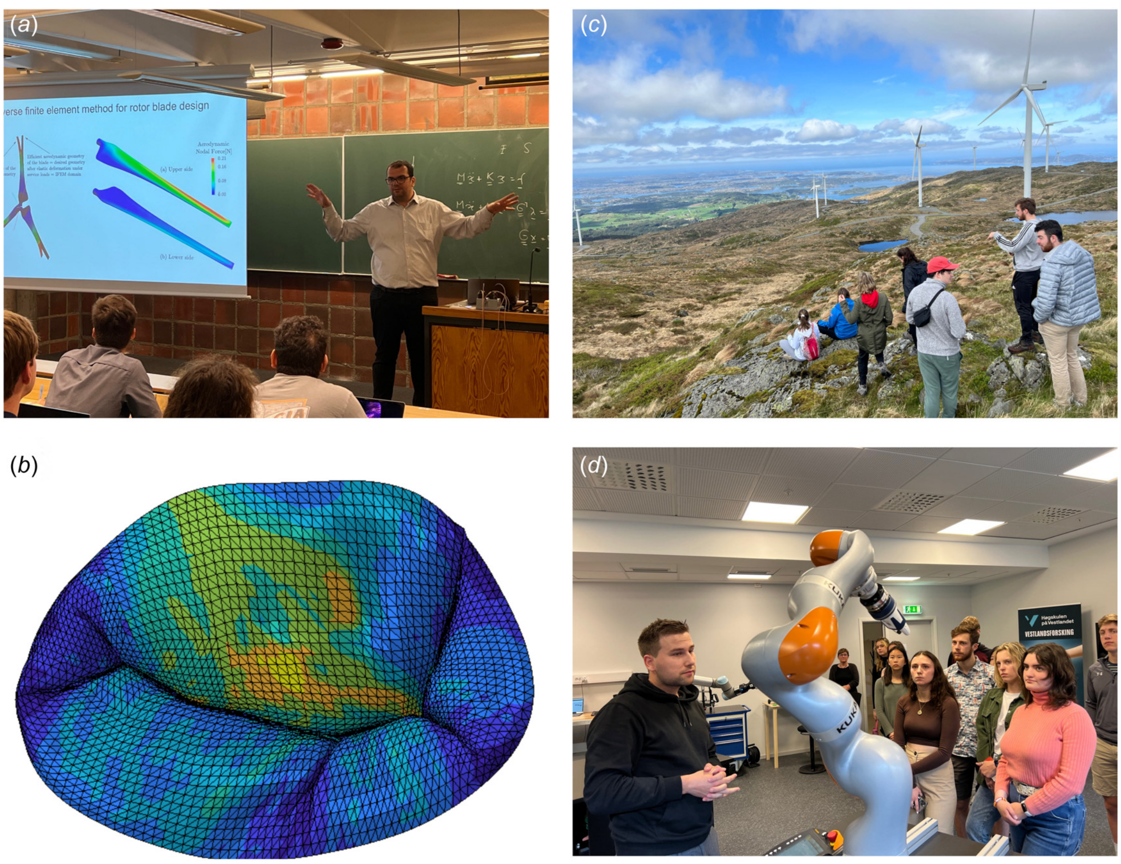

Fig. 1 Guest lecturers presented applications of computational techniques in (*a*) mechanical and (*b*) biomedical engineering often accompanied by (*c*) and (*d*) visiting the sites where the technologies are used

with state-driven assimilation efforts. Incorporating the indigenous history of the region into the DOC alongside the technical content of ME4508 enabled students to form a direct connection between the technologies they were exposed to through site visits and the impacts, both positive and negative, on local communities. Such an approach encouraged students to think about engineering decisions they encountered in ME4508 from a human-centered perspective.

Such a multifaceted course started with local guest lectures providing an introduction to Norway's governance policies, such as education and healthcare, while also introducing the important concept of a "welfare state." Subsequently, students were introduced to the nuances of contemporary Sámi life and their place within Norway's present-day governance landscape. The course then pivoted toward an in-depth examination of the Sámi people's historical travails, shining a stark light on the profound injustices that have persisted across generations (Fig. 2). Finally, the guest lecturers discussed the contemporary issue of "green colonialism," with striking instances like the intrusion of the wind energy sector and the extraction of rare elements, crucial for rechargeable electric batteries, into the historic homelands of the Sámi people.

This intricate and multifaceted curriculum posed profound open-ended questions, a departure from the typical exact solutions sought in technical problem solving, provoking thought and enriching students' perspectives. Students had the opportunity to delve into complex professional issues facing the modern practice of engineering by engaging with each other and local experts. The course exposed students to the dynamic and multicultural role that engineers must play in the future. As a culmination of their journey through this course, students undertook a final project that explored, in depth, the multifaceted dynamics of green colonialism, sustainability, and indigenous rights. With insights from guest lecturers, this project was meticulously crafted to provoke contemplation on the intricate interplay between technology, history, culture, and ethics. The students were divided into groups of four and given the following topic for an oral presentation and a written essay:

> *Renewable energy resources (including wind) are often considered as the solution to curb global warming. However, they may have other environmental and social disadvantages. In Norway, for example, they can lead to deposition of micro-plastic beads in protected mountain lakes and/or to stressing and starving reindeer. Another example is the offshore windmills that generate vibrations, changing the marine lifestyle and affecting the fishing industry. While these problems may affect many people, some like Sámi people, who traditionally live outside of urban centers and/or are involved in farming reindeer, may suffer more than others. How can we protect the earth's inhabitants (including ourselves) from climate change without marginalizing already disadvantaged groups such as Sámi people?*

The students' oral presentations and written documents for this project were replete with thoughtful ideas, exemplifying their critical thinking about this important topic. For instance, one group discussed the challenges and considerations related to renewable energy, specifically focusing on Norway's reliance on hydropower and wind power and their impact on the environment and the Sami indigenous people. While hydropower was recognized as an efficient approach, the discussion extended to its alterations of landscapes, disruptions to ecosystems, and effects on Sami communities, including the interruption of reindeer herding routes and fishing ecosystems. The students emphasized the necessity of a diversified approach to renewable energy, incorporating solar, biomass, and carbon capture to minimize the environmental and cultural impacts of wind energy. They highlighted the importance of collaborating with indigenous communities in decision-making processes, establishing legal policies, and fostering international cooperation to achieve a balance between green energy and indigenous rights. The students meticulously presented the complexities of this interdisciplinary challenge, underscoring the need for compensatory measures and a commitment to sustainable solutions while considering the long-term effects on local ecosystems and communities. The instructor and a guest referee, possessing extensive knowledge of current issues in Norway, were both impressed by the depth and breadth of the students' reports.

As the concluding event of their program, following their transformative international experience in Norway, the students were presented with a captivating opportunity: a guest lecture delivered by one of the Northeastern University philosophy professors. Beginning with a bit of stage setting concerning the purview of ethics and applied ethics, the speaker explained the basics of ethical decision-making—when we are considering whether an action is morally right or wrong, which factors or considerations are morally relevant and how ought we to weigh them against one another? Concerning our students' own direct experiences, he discussed the ethical dimensions of issues, including climate change and local versus state-level interests. For example, he discussed the importance of respect for the cultural practices of the Sámi people in the process of expanding clean energy alternatives. Through the lecture and subsequent discussions, students learned to expand their engineering thought process beyond their technical expertise to navigate the intricate social and cultural issues presented. Such an approach to the engineering thought process is profoundly modern, and effectively complemented the modern techniques in structural engineering taught in ME4508.

3 Students' Feedback

The anonymous feedback received from the students was positive and encouraging. Many students specifically commended the experiential learning aspect of the course. For instance, they expressed fascination with the lecture provided about the heart valve structure and the utilization of FE modeling in in vivo image-based simulations, offered by one of the guest experts. Such a practical

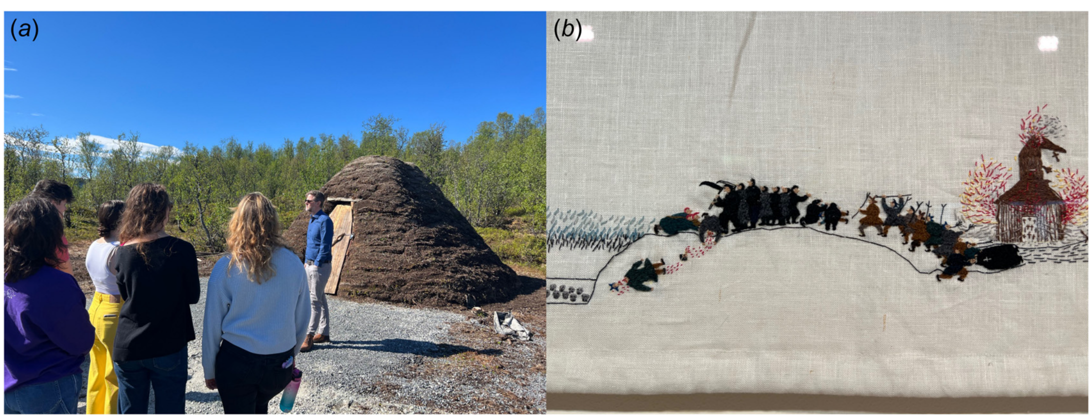

Fig. 2 (*a*) Lectures at Arctic University of Norway, (*b*) history of the struggles of Sámi people in handmade artwork (Britta Marakatt-Labba, "Historja," 2007)

example was considered highly pertinent and inspiring, particularly in the context of one of the course projects centered on the intricacies of image-based simulation in biomechanics. The students stated that such an exposure helped them value the multifaceted process of model segmentation, mesh generation, mesh convergence, and other nuances involved in the simulation.

The students also stated that the ethics discussions with the philosophy professor were extremely insightful. Philosophy's integration with engineering highlighted the program's interdisciplinary benefits, inspiring ethical considerations beyond conventional approaches. The comprehensive lectures in Boston and Norway evoked reflection on climate change, cultural sensitivities, and the moral dimensions of environmental decision-making, fostering a deeper understanding of complex global challenges and ethical pathways forward.

Some of the students' comments are provided here:

- *I want you to know that this trip has had an incredibly positive effect on my life (and for a lot of other people), and I'm so happy that I had this opportunity. This was such a unique experience that I will be talking about for the rest of my life. Thank you so, so, so much for everything. I really can't thank you enough for planning and executing this trip.*
- *Wrapping up this trip, I am very happy with everything we were able to see and do over the past month in Norway. This is the most engaging trip I have ever been on and I will definitely be applying for another dialogue of civilization in the future.*
- *This program has truly been a source of great personal growth as well as great enjoyment for me, and I am so very grateful for having been given the opportunity to participate in it.*

4 Self-Efficacy and Career Aspiration Assessment

To investigate the impact of immersive experiential learning on students' educational experience, as opposed to those who completed the technical course ME 4508 in Boston, we conducted an assessment that included a few questions focusing on students' "self-efficacy" and future aspirations. Introduced by Albert Bandura in 1977, the concept of self-efficacy pertains to an individual's belief in their ability "to organize and execute courses of action required to produce given attainments" [9]. Perceived self-efficacy has emerged as a potent predictor of student motivation, persistence, and academic development [10,11], as well as a crucial factor contributing to educational advancement [9]. Self-efficacy also reflects a student's ability to make informed career choices while pursuing meaningful employment opportunities [12]. Previous works indicate a close connection between self-efficacy and stress and anxiety, which can directly and indirectly affect a student's performance, overall well-being, and personal adjustment [13–15]. Therefore, comprehending self-efficacy within academic contexts is of great significance in enhancing students' learning experiences and providing them with valuable resources and perspectives to support informed career decision-making.

Our group, as well as other researchers, have also examined the role of gender in computing-related self-efficacy [2,16]. When it comes to computer programming, many factors could contribute to a lack of confidence in students of different backgrounds. For example, it has been shown that gender-biased societal expectations expressed by parents and the resultant gender-based disparities in students' self-confidence may contribute to lower participation rates of female-identifying students in computer-related fields [13,16–20]. At the conclusion of the program, we hypothesized that experiential learning techniques in the global setup of the DOC program positively impacted students' academic and career-oriented confidence as compared to those students who took a similar course on campus. Additionally, we analyzed gender-based differences in both groups.

This investigation was conducted with the official exemption of the Institutional Research Board at Northeastern University. To gauge the impact of experiential learning in the DOC, anonymous surveys were administered to students in two groups: (1) students who took the course ME 4508 in Norway as part of the DOC program (N = 14), (2) students who took the same course in Boston ($N = 29$). These surveys were collected after completion of the course and were optional, having no bearing on course grades. The survey consisted of 11 questions to be rated on a likert scale from 1 ("Not at all true of me") to 7 ("Very true of me"), as presented in Table 1. Questions 1, 4, and 6–11 were used to evaluate career-related elements and gather students' viewpoints regarding the importance of including computer programming training in their academic curriculum. Questions 2, 3, and 5, which were borrowed from a previously validated tool [21], gauged the academic aspects of students' self-efficacy. Parametric statistical analyses were conducted after verifying data normality using the Kolmogorov-Smirnov test. A multiple comparison two-way analysis of variance (ANOVA), followed by a Fisher's least significant difference (LSD) test, was employed to statistically compare scores across genders and location (DOC versus Boston). The significance level was set at $\alpha = 0.05$.

A total of $N = 43$ survey responses were collected from students who completed the course across both locations. Student respondents self-reported their gender identity as male ($N = 30$), female ($N = 11$), nonbinary ($N = 1$), and "prefer not to say" ($N = 1$), as shown in Figs. 3(*a*) and 3(*b*). Survey responses collected from students in the DOC group ($N = 14$) consisted of 10 male-

Table 1 Survey used to assess students' academic and career self-efficacy and expectation of success adopted from Rezvanifar and Amini [2]

	Question	Not at all true of me			Somewhat true of me			Very true of me
(1)	I believe that computational skills are an essential element in engineering training.	1	2	3	4	5	6	7
(2)	I'm confident I learned the concepts taught in this course.	1	2	3	4	5	6	7
(3)	I'm confident I understood the most complex material presented by the instructor in this course.	1	2	3	4	5	6	7
(4)	I'm more confident that I will be a successful engineer in the future after taking this course.	1	2	3	4	5	6	7
(5)	I'm confident I can be successful in a future career that involves computation either in Mechanical Engineering, Bio-engineering, or other engineering fields.	1	2	3	4	5	6	7
(6)	I would like to have a future career in engineering, either one that involves computation or not.	1	2	3	4	5	6	7
(7)	I would like to have a future career in engineering that involves computation for sure.	1	2	3	4	5	6	7
(8)	I expect to be successful in a career that uses computation for renewable energy application (windmill design, CFD modeling, etc.).	1	2	3	4	5	6	7
(9)	I expect to be successful in a career that uses computation for bio-engineering applications (imaging systems, surgery robots, artificial organs, pacemakers, etc.).	1	2	3	4	5	6	7
(10)	I would like to have a career in policy making and government (e.g., FDA medical device safety, Department of Energy, Think Tank Organizations, etc.).	1	2	3	4	5	6	7
(11)	I expect to be successful in a career in policy making and government (e.g., FDA medical device safety, Department of Energy, Think Tank Organizations, etc.).	1	2	3	4	5	6	7

identifying students and 4 female-identifying students. For survey respondents in the Boston-based group ($N = 29$), 20 students identified as male, 7 students identified as female, 1 student identified as nonbinary, and 1 student selected "prefer not to say."

Overall, students highly ranked questions pertaining to the importance of computational skills in engineering training and their interests in having an engineering career in the future (Fig. 3). As such, no significant differences were observed across genders or course location (DOC versus Boston) for Questions 1, 2, and 5–7 as described in Table 1. However, among female students, those who participated in the DOC program reported significantly higher self-confidence ratings in their ability to understand the most complex course material (Fig. 3(*e*)). Similarly, female DOC participants reported higher self-confidence in becoming a successful engineer as a result of taking this course compared to Boston-based female students (Fig. 3(*f*)). These initial results indicate that the DOC course enabled higher course-related self-efficacy among female students.

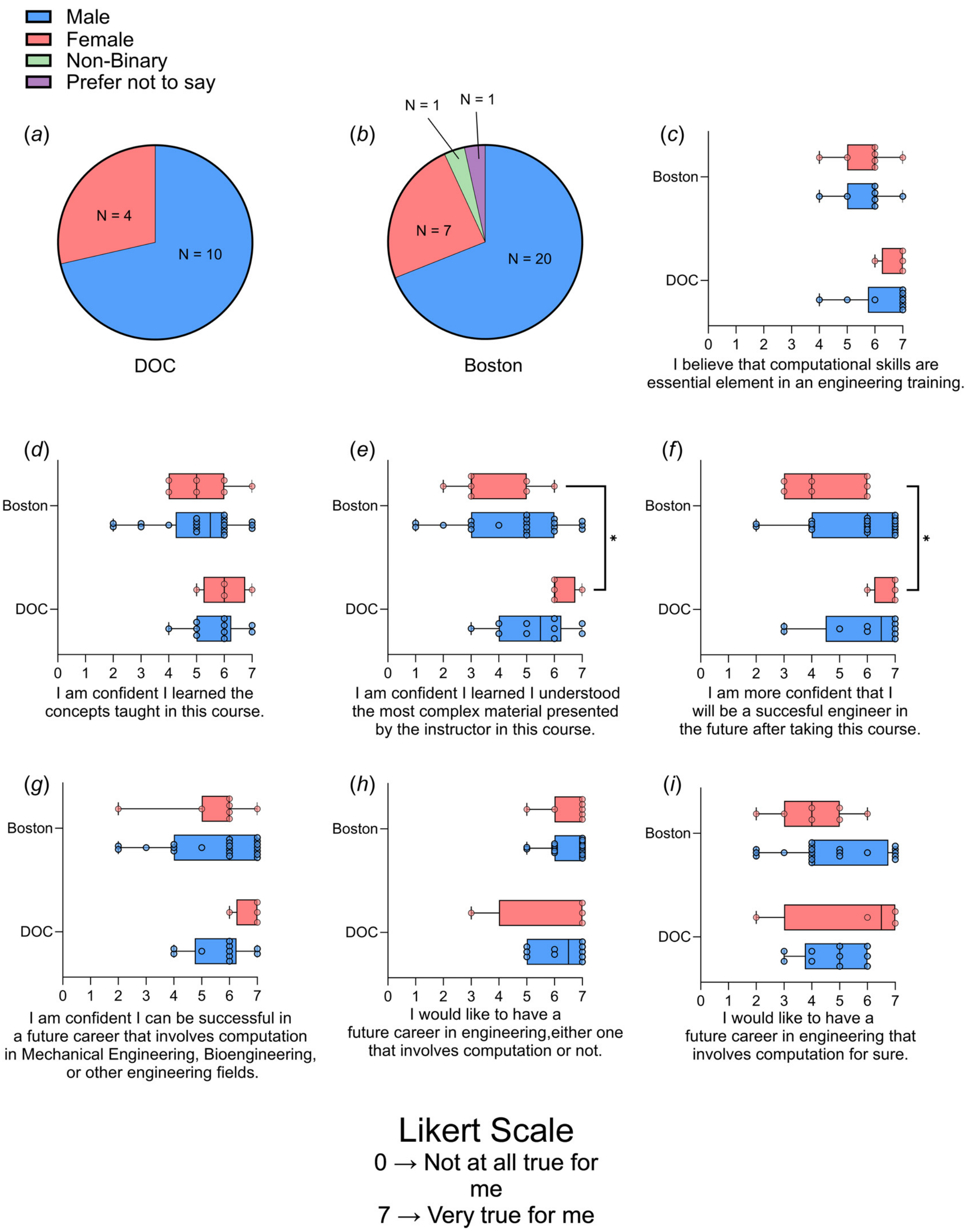

Fig. 3 Comparative examination of gender distribution and students' anonymous responses to Table 1 survey questions in DOC and Boston classes. (*a*) and (*b*) Pie chart illustrating the gender distribution of students in the DOC ($N = 14$) and in Boston ($N = 29$). (*c*)–(*i*) Box and whisker plots for different likert statements. These graphs provide insights into students perceptions of the course and their career aspirations using a likert scale from 0–7, where 0 represents "not at all true for me" and 7 represents "very true for me." Statistical significance was assessed by a multiple comparison 2-way ANOVA followed by a Fisher's least significant difference (LSD) test—with a 0.05 confidence level. Above, * represents $P < 0.05$.

Figure 4 displays the students' responses to Questions 8–11 described in Table 1, which focus on career aspirations. Within the Boston-based group, male students reported significantly higher confidence than female students on their ability to succeed in a career that uses computation for bio-engineering applications (Fig. 4(*b*)). In contrast, female students in the DOC group reported significantly higher self-confidence on Questions 9–11 than male students within the same program. Additionally, female students in the DOC group reported significantly greater career-oriented confidence for Questions 9 and 11, which pertain to careers in computational bio-engineering and in policy making and government. While there was no significant difference in female students' career interests, those in the DOC group reported significantly higher scores in their ability to be successful in policy making and government careers (Figs. 4(*c*) and 4(*d*)). Such results prompt further investigation into the potential benefits of DOC programs on academic and career-oriented confidence, especially among female-identifying engineering students.

While the underlying factors contributing to the higher self-confidence levels among female-identifying students in the DOC program require further investigation, a plausible explanation could be attributed to their exposure to a more diverse range of professional guest speakers within the DOC framework. It is conceivable that students develop increased confidence in their future prospects when they witness individuals with similar identities achieving success in engineering or other career fields that have historically been underrepresented by those sharing their identity [22–24].

The overarching objective of the surveys conducted was to obtain a preliminary evaluation of students' self-efficacy and their overall experience. However, it is important to acknowledge that these surveys were conceived as an addendum rather than being meticulously designed prior to the program's initiation. Consequently, it is crucial to approach the outcomes of this evaluation with caution, recognizing that our study is subject to several limitations. While the ad hoc questions were designed to assess students' self-efficacy and expectations within the context of course objectives and future careers, incorporating established theoretical models such as expectancy-value theory [25,26] and social cognitive career theory [27] in the design of ad hoc surveys in future studies could provide a more precise and systematic evaluation of students' self-efficacy. To refine and enhance the research program, incorporating additional qualitative assessments, such as focus group interviews with students, is crucial. Focus group interviews provide a unique and

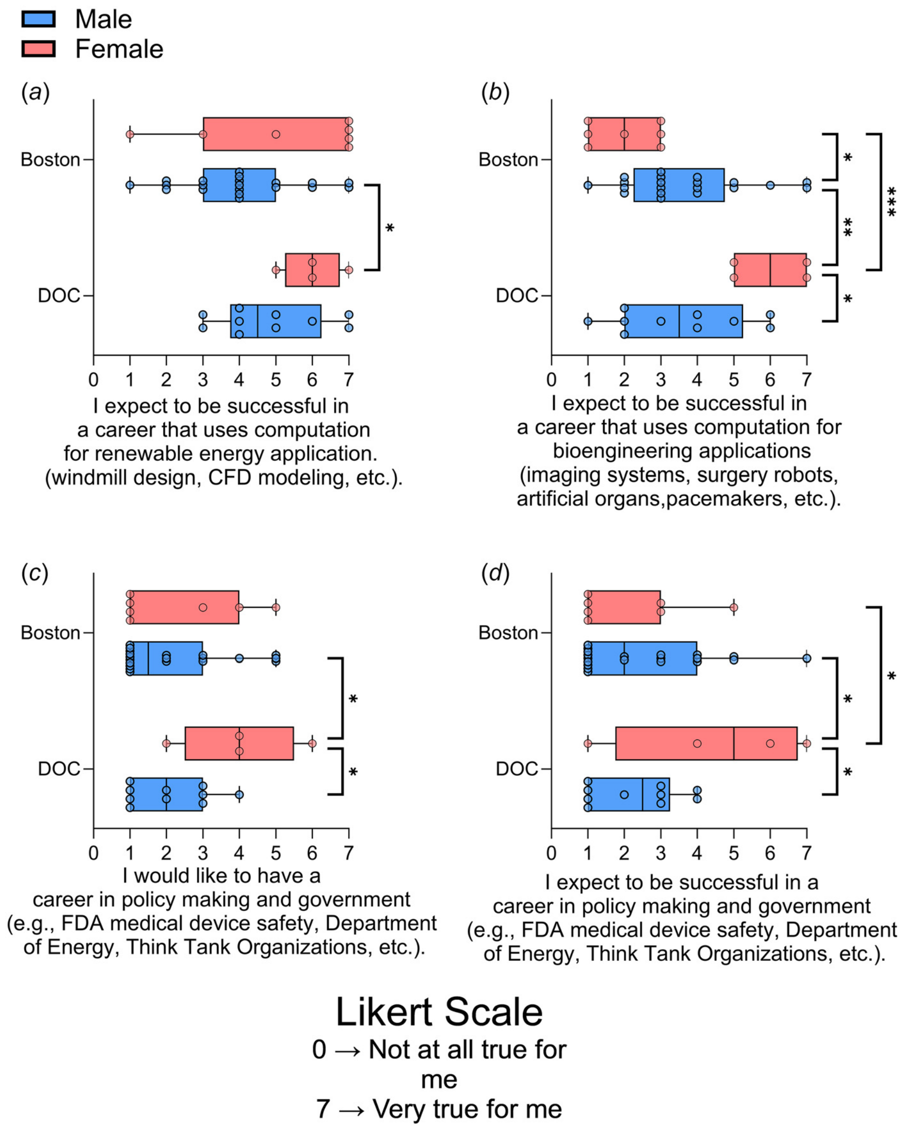

Fig. 4 Students' anonymous survey responses rated on a 7-point likert scale. Statistical significance was assessed by a multiple comparison 2-way ANOVA – Fisher's least significant difference (LSD) test – with a 0.05 confidence level. *$P<0.05$, **$P<0.01$, ***$P<0.001$.

valuable method for gaining a comprehensive understanding of participants' experiences, capturing diverse perspectives within a collaborative setting. The dynamic nature of focus groups encourages open dialogue, allowing researchers to examine the nuances of students' experiences and explore shared themes. This approach goes beyond individual interviews, fostering group dynamics that uncover insights not easily revealed through other methods.

Another notable limitation lies in the anonymous nature of the surveys, chosen to encourage honest responses but restricting more robust statistical analyses and the exploration of broader facets of students' learning experiences, such as exam performance and downstream academic enhancements. Despite the inclusion of gender fluidity options in the demographic question, only one student selected "nonbinary," and one student chose not to provide any gender-related information. Consequently, statistical analyses were not conducted for these specific groups. Furthermore, it is worth noting that the sample size for female students was smaller in both the DOC and Boston groups, potentially influencing the interpretation of the statistical analysis. The smaller sample size for the female and nonbinary gender-based groups, however, reflects broader disparities in gender representation within bio-engineering and mechanical engineering courses and careers.

5 Conclusions

During our recent DOC program, held in Norway in 2022 and 2023, we aimed to teach mechanical engineering and bio-engineering students computational skills while encouraging critical discussions on the cultural and social aspects of engineering and technology in Norway. Student feedback was overwhelmingly positive, highlighting the value of experiential learning within a global framework. Assessments and surveys indicated increased confidence among program participants, especially female-identifying students. We found the integration of technical education with intercultural experiences and discussions on the societal and cultural impacts within engineering and technology fields an enriching experience for the students who participated in this program.

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Data Availability Statement

The datasets generated and supporting the findings of this article are obtainable from the corresponding author upon reasonable request.

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