SEFI Journal of Engineering Education Advancement
Vol. 3, No. 1, 2026, pp. 112-128, ISSN 3006-6301
DOI : 10.62492/sefijeea.v3i1.57

Fostering Student Motivation and Engineering Competencies: Supporting Knowledge Sharing and Critical Thinking Through Expert Roles

Ditte Baun Hermund[a], Elizabeth Rees[b], Lene Duedahl-Olesen[a,1],

[a] **National Food Institute, Technical University of Denmark, Kongens Lyngby, Denmark**
[b] **Centre for Teaching and Learning in Engineering Education, Technical University of Denmark, Kongens Lyngby, Denmark**

ABSTRACT

This study examines whether introducing structured expert roles (jigsaw) in a second-semester food analysis laboratory course was associated with changes in students' perceptions of knowledge-sharing and responsibility for understanding shared data. In the initial course design (2021–2023), student groups each analysed one macro food component, and relied on other groups' results to complete a final integrated report, making inter-group knowledge exchange necessary but uneven. In 2024–2025, the course was redesigned using a jigsaw structure in which each home group contained an "expert" for each component; experts conducted analyses in expert groups and then returned to their home groups to integrate results. Data were collected across cohorts using end-of-course questionnaires (2021: N=16; 2022: N=21; 2024: N=24; 2025: N=15) and optional reflection prompts (2025). Before the redesign, students generally viewed communication of data and methods positively but reported reluctance to share results across groups. After redesign, students reported greater confidence in contributing as experts and a greater emphasis on understanding peers' methods and results when producing the final report. Students also valued collaboration and communication, although these were not consistently identified as engineering competencies. Findings are interpreted as context-specific associations given small cohorts and reliance on self-report.

KEYWORDS

University pedagogics,
Jigsaw,
Gallery walk,
Intra-group work

PUBLICATION

Submitted:
19th December 2025

Accepted after revision:
8th March 2026

[1] Corresponding Author : Lene Duedahl-Olesen, – lduo@food.dtu.dk

This work is licensed under Attribution-NonCommercial-NoDerivatives 4.0 International. To view a copy of this license, visit http://creativecommons.org/licenses/by-nc-nd/4.0/

Introduction

Traditional teaching in engineering education has been rooted in lectures, homework and exams that encourage students to see engineering learning as an individual effort centered on producing the right answer and working independently. This stands in contrast to the collaborative, iterative and interpretive practices of professional engineering work, including team work (Mercier et al., 2023; Menekse and Chi 2019). Knowledge sharing is therefore a core feature of engineering work, where effective solutions depend on integrating diverse expertise, maintaining open communication across teams, and interpreting data collectively to guide decisions (Elliott et al., 2022; Klippert et al., 2024; Zamiri and Esmaeili 2024). Students entering engineering programmes, are as mentioned often unaccustomed to working interdependently, and taking responsibility for understanding data generated by others (Du et al., 2019; Mercier et al., 2023). As a result, they may struggle to integrate distributed analyses, explain methods and results, or assess the plausibility of shared data – activities that are central to professional engineering work (Menekse and Chi, 2019; Finelli et al., 2024; Wu 2018).

Collaborative learning constructs can therefore play an important role in helping students experience these aspects of engineering work. One established route to structuring such experiences is active learning – an approach shown to both improve learning, as well as increase retention across STEM contexts, including engineering education (Prince, 2004). Active learning refers to instructional strategies that require students to engage in tasks and reflect on what they are doing (Bonwell & Eison, 1991; Felder & Brent, 2003; Prince, 2004). In engineering education this commonly takes the form of hands-on laboratory work, group discussions, and peer teaching activities that require students to apply concepts, reflect on outcomes, and communicate their findings.

Within this broader active-learning context, specific pedagogical approaches with structured collaborative dependence are necessary to ensure that responsibility for understanding and explaining shared data is made explicit rather than assumed. Active learning strategies such as the jigsaw method and gallery walk are designed to formalize peer-to-peer exchange and strengthen accountability within collaborative work. The jigsaw method is a student-centred cooperative learning approach where students work in mutually dependent teams and are responsible for both mastering an assigned subtask and teaching it to peers (Chopra et al., 2023). In practice, students first work in "expert groups" (Table 1) on a defined subtask before teaching their peers in a "home group", where each member is responsible for sharing and integrating their specialist knowledge. This structure creates positive interdependence, as the completion of the shared task (here a report) depends on each members' contribution (Clarke, 1994; Johnson, Johnson & Smith, 1998, 2014).

Table 1. Principle of jigsaw - a "home group" (Group 1-4) is formed and then each group member is appointed a task, in this case a main food component (A-D) (e.g. fat, protein, carbohydrates and water) to perform together with others that have the same task, the "expert group"

Home groups

Group 1	A1	B1	C1	D1
Group 2	A2	B2	C2	D2
Group 3	A3	B3	C3	D3
Group 4	A4	B4	C4	D4

Expert groups

Food component A	A1	A2	A3	A4
Food component B	B1	B2	B3	B4
Food component C	C1	C2	C3	C4
Food component D	D1	D2	D3	D4

Research indicates that jigsaw-based designs can enhance student engagement and motivation by combining individual accountability with collaborative learning (Jainal & Shahrill, 2021). When applied to authentic, problem-orientated tasks - such as laboratory-based analysis of food products - this approach mirrors aspects of professional engineering work, where teams must integrate specialised expertise into a coherent whole. Consequently, communicating complex information, working interdependently, and taking responsibility for shared outcomes represents a set of highly valued engineering competencies (IEA, 2021). The jigsaw technique has also been associated with reflective learning by encouraging student engagement, collaboration, and deeper understanding (Colomer et al., 2020). A review of the jigsaw method on student educational outcomes, revealed variability in results; attributed to differences in sample size, student diversity, and disciplinary content (Drouet et al., 2023).

Furthermore, the jigsaw method changes how responsibility for data is organized in groups. In inter-group designs, students depend on results produced by other groups. This can make it unclear who is responsible for verifying and explaining results when the group using the data did not generate it. By embedding an "expert" for each analysis within the "home" group, the explanation and justification of methods in the group becomes a defined role, rather than an informal expectation. As the shared report depends on the integration of all components, the knowledge-sharing becomes a task requirement rather than an optional or uneven exchange, which may strengthen students' sense of responsibility for understanding shared data.

Complementing the jigsaw structure the gallery walk is a strategic active learning tool that fosters student engagement and motivation (Chin et al., 2015). In this activity, students explore and discuss peer work displayed around the classroom such as texts, images, and documents as illustrated in Figure 1. These materials are arranged at different stations, allowing students to move freely and engage with diverse content. Students work in small groups, rotating between stations, where they respond to comments, analyse previous groups' contributions, and build upon each other's insights. The physical movement and peer interaction central to gallery walk activities promote deeper cognitive engagement and improved retention, aligning with research showing that movement enhances memory and attention and that active, collaborative learning strategies boost student performance (Mualem et al., 2018). It also promotes deeper understanding through peer-to-peer learning and encourages students to articulate and refine their ideas in a supportive environment (Makmun et al., 2020).

Round	Presenter	Active listeners
1	Group 1 (A) Group 2 (A) Group 3 (A) Group 4 (A)	Group 2 (B, C, D) Group 3 (B, C, D) Group 4 (B, C, D) Group 1 (B, C, D)
2	Group 1 (B) Group 2 (B) Group 3 (B) Group 4 (B)	Group 3 (A, C, D) Group 4 (A, C, D) Group 1 (A, C, D) Group 2 (A, C, D)
3	Group 1 (C) Group 2 (C) Group 3 (C) Group 4 (C)	Group 4 (A, B, D) Group 1 (A, B, D) Group 2 (A, B, D) Group 3 (A, B, D)
4	Group 1 (D) Group 2 (D) Group 3 (D) Group 4 (D)	Group 2 (A, B, C) Group 3 (A, B, C) Group 4 (A, B, C) Group 1 (A, B, C)

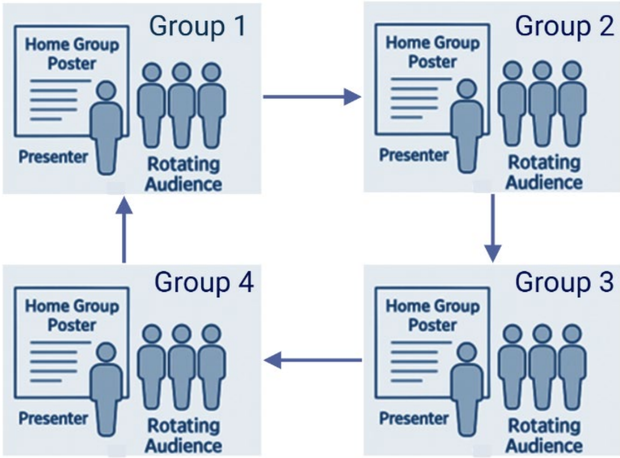

Figure 1. Principal of the Gallery walk – Posters representing 4 home groups work (Group 1-4). Four rounds, students rotating in presenting (e.g. 10 minutes), followed by peer feedback from rotating audience (e.g. 5 minutes).

Setting

The study was carried out at the Technical University of Denmark (DTU), the largest engineering education institution in Denmark (Technical University of Denmark, 2025a). DTU offers 20 Bachelor of Engineering (B.Eng.) programmes with an applied, industry-orientated and cross-disciplinary focus. The B.Eng. programmes are aligned with the international CDIO framework (Conceive-Design-Implement-Operate) (Crawley et al., 2007), and follow a predefined study plan with limited flexibility, to support integration of CDIO and learning progression. The B. Eng. programme in "Food Safety and Quality" is located at the National Food Institute (DTU FOOD). Students are trained to apply scientific and technological knowledge to solve practical engineering problems, primarily in the food and pharmaceutical industries.

As a professionally orientated, practice-based education grounded in industry trends, development projects, and relevant research fields, graduates should be qualified to take on engineering roles in both private and public sectors, obtaining key competencies (Technical University of Denmark 2025b).

In this study, engineering practice is operationalised within the context of this laboratory course as team-based analytical problem solving that requires students to exchange methodological information, interpret distributed datasets, and integrate results into a shared technical product (poster and report), while being able to justify choices and conclusions during assessment.

The course - Chemical Food Analysis 1 (23936)

Chemical Food Analysis 1 (23936) is a second-semester B.Eng. course (5 ECTS) designed to build foundational competencies in food-related analytical chemistry. Over three intensive weeks (45 hours/week), students engaged in laboratory work, data processing, and technical communication, both oral and written (poster and final report), focused on qualitative and quantitative analysis of plant-based food products. The final assessment consisted of an oral examination focused on the final report and the challenges encountered.

During the course students learn to plan and conduct experiments, select appropriate analytical methods, and critically interpret data, addressing real-world challenges such as sample preparation, extraction, method comparison, and uncertainty. Active learning formats like the jigsaw and gallery walk are integrated to support the development of core engineering skills such as critical thinking, teamwork, and professional responsibility. Figure S1 in supplementary S1 outlines the course structure and learning activities. The structure with group work, laboratory work and knowledge sharing is illustrated in Figure 2.

The learning objectives were aligned with Bloom's taxonomy (Krathwohl, 2002) and include both analytical competence and the communication and justification of methods and results, relevant for team work and knowledge sharing. These elements are central to knowledge sharing and integration in team-based engineering work. As reporting templates were not provided, the objectives also included evaluating and discussing alternative ways of presenting data.

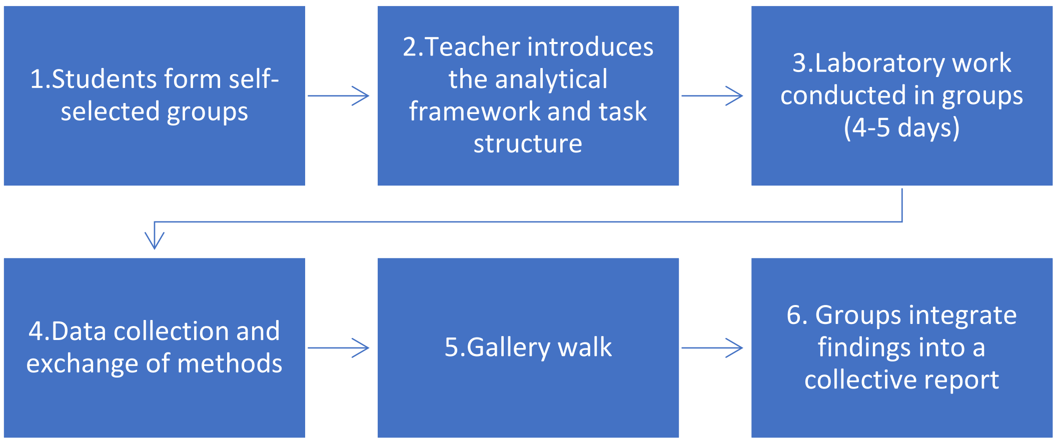

Figure 2. Group Formation and Knowledge-Sharing Process. Schematic overview of the group activities in course 23936 Chemical Food Analysis 1 for all years. Groups in 2021-2023 was based on choice of macronutrient whereas in 2024-2025 more structured steps for formation of expert groups was added between step 2 and 3 (Figure 3). Differences for step 4 was the knowledge sharing across groups in 2021-2023 and within groups in 2024-2025.

Aim and objective of the study

In 2021–2022, each self-selected home group was responsible for one analysis (e.g. protein, carbohydrates, lipids or water) and depended on other groups to obtain results with the remaining methods in needed for the final report describing the food product (Figure 2). Effective communication and data exchange across groups were therefore essential to complete the assignment.

In 2024–2025, the course was redesigned so that each self-selected home group for report writing contained its own experts based on macronutrients (Figure 3). One student from each home group joined an expert group (e.g. protein, carbohydrates, lipids, or water) to conduct a specific analysis. This included an additional instructed reorganisation step between step 2 and 3 in Figure 2, where focus was on macronutrients (Figure 3). After laboratory experimental work, experts returned to their home group to integrate all results into a poster and a shared report on the food product (Figure 3). Knowledge sharing (step 4 in Figure 2) thus shifted from intergroup (2021–2023) to intragroup (2024–2025) through the expert role structure.

This study examines whether the redesign of the course structure - from inter-group knowledge exchange (2021–2023) to expert roles within home groups (2024–2025) - was associated with changes in two outcomes central to early engineering practice namely:

1) Students' perceptions of knowledge sharing within group work and
2) Students' perceived responsibility for understanding shared data.

Therefore, this study is guided by the rationale that placing students in structured expert roles supports knowledge sharing and encourages responsibility for understanding others' results. Accordingly, the study examines whether the course redesign was associated with changes in students' perceptions of knowledge sharing and responsibility for understanding shared data. We explore this through the following research questions (RQ):

RQ1. How do students perceive the demands and value of knowledge sharing under the expert-role (jigsaw) structure, as a competence relevant to engineering practice?

RQ2. How do students perceive responsibility for understanding shared data?

Method

In this course, the gallery walk was implemented by using posters as one of two collaborative deliverables. Students were divided into smaller groups, and each member took turns presenting their home group's poster to peers from other groups, with all groups presenting simultaneously. Figure 1 illustrates how the method works in practice, for example, in round 1, all A-members present to B-, C-, and D-members for 10 minutes. After the presentation the audience provides direct feedback on both the poster and the presentation (5 minutes). Then, the roles rotate, and a new member presents in round 2.

When integrated with the jigsaw method, the Gallery walk supported knowledge sharing within "home groups". Each home group created a poster based on contributions from individual "experts" within the group. Each member then presented the group work to a small audience of students. This structure was intended to support a positive curiosity-driven climate by (i) giving students practice time in explaining and understanding results and methods in the home group, (ii) using predictable rotation formats for peer presentation and feedback, and (iii) practicing students science terms orally and interpretation of home group results before production of the final product report and assessment.

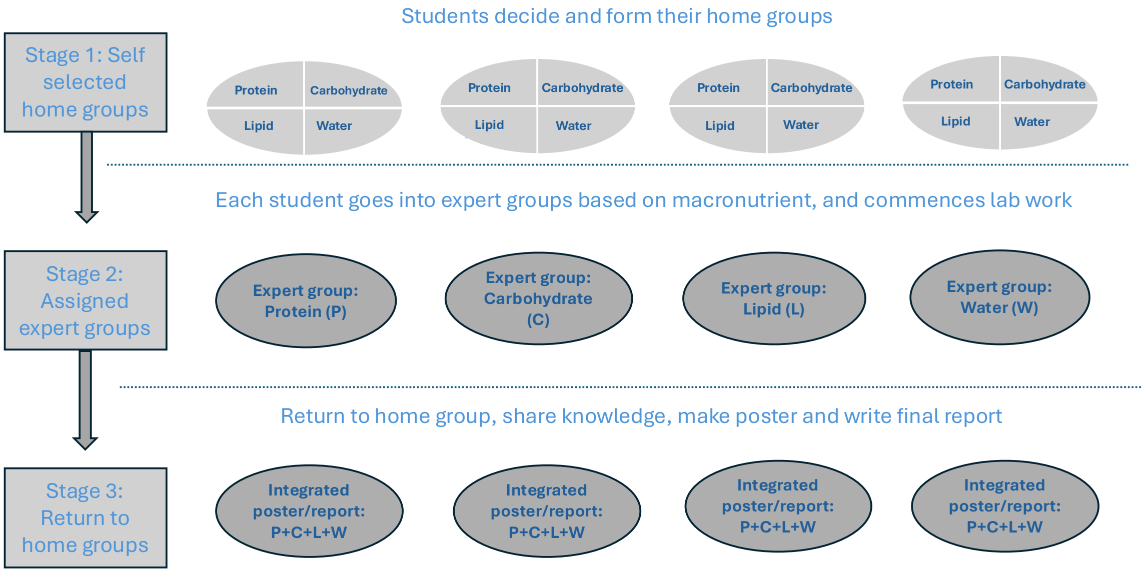

Figure 3. After implementation of the jigsaw method (2024-2025) students begin in self-selected home groups, choose their macronutrient and are then temporarily reorganized into expert roles based on macronutrient (protein, lipid, carbohydrate or water) for Laboratory experiments (4-5 days of 15 days total). Once the lab work finishes, they return to the home group to present and integrate findings into a shared poster and report.

Data was collected using questionnaires, across multiple cohorts over a four-year period (2021: N = 16; 2022: N = 21; 2024: N = 24; 2025: N = 15), introducing variation between cohorts. No inferential statistical analyses were applied due to small sample sizes (max N=24). All participants were anonymised, and none were identifiable in the questionnaires. Given the limited cohort sizes, results are reported as percentages of total responses.

To examine competence development and awareness of transferable skills, a questionnaire was administered at the end of the course in 2021 using mixed response formats (multiple choice, Likert-type items, and free text). The questionnaire included items on students' learning experiences related to course content, critical thinking, communication and knowledge sharing in group work, as items addressing general engineering competences (Supplementary S2 Table S2).

Based on the experience from 2021, the questionnaire was adjusted for subsequent cohorts (2022, 2024 and 2025), for example by replacing some free-text items with tick-box responses to improve consistency and comparability across cohorts. The full set of questions is provided in Supplementary Table S2, with response summaries in Supplementary Table S3. The purpose of the questionnaire was to evaluate students' learning outcomes and experiences in the course and aimed to get student feedback on several key areas related to the B. Eng. Competence profile (Technical University of Denmark 2025b).

Survey items addressed students':

1) Perception of the relevance of the Engineering concepts
2) Development of Engineering competences in relation to practical and theoretical skills including critical thinking and hypothesis testing
3) Strengthening of the generic (or transferable) skills

4) Confidence and preparedness of the application of own obtained competences in real-world engineering scenarios
5) Identification of individual and teamwork skills
6) Reflections and awareness of knowledge sharing and responsibility
7) Reflections on their generic skills and how they influenced the final product

For the present study, data used to compare the before (2021-2022) and -after (2024-2025) implementation of jigsaw structure focused primarily on items 3-7. Design and comparable measures are found in Table 2 with indications of survey questions included in the discussion. Questions were adjusted to near-identical wording between the years. For 2024-2025 home groups were based on first students own choice for groups, then requested to divide into expert A, B, C and D within each group (See Table 1 and Figure 3).

The final course assessment required obligatory participation in laboratory exercises and poster presentations, followed by an oral examination based on 50% "home group" report hand-in (food product description with own data) and 50% individual questions using unfamiliar data within same theoretical framework. Report presentation was based on students own choice of most important challenge or results obtained. This assessment structure emphasised both collective integration of results and individual understanding.

Analytical lens

For this paper, we use self-determination theory (SDT) as an interpretive lens to analyse the data. SDT proposes that students' motivation is supported when three basic psychological needs are satisfied within the learning environment: autonomy (a sense of volition), competence (feeling capable and effective), and relatedness (feeling socially connected and accepted) (Deci and Ryan, 1985; Ryan and Deci, 2000, 2017). When these needs are supported, students are more likely to demonstrate deeper engagement and sustained persistence in learning activities (Ryan and Deci, 2000; Niemiec and Ryan, 2009). Learning environments that promote active participation and inclusive peer interaction can be understood, within a SDT framework, as supporting competence through opportunities to contribute, relatedness through collaborative exchange, and autonomy through ownership and meaningful involvement in shared tasks (Ryan and Deci, 2000).

Results and discussion

This course was designed to make explicit to students that they played a central role in solving a real-world analytical challenge, investigating the composition of a food product and producing a technical report. To achieve this, students were required to rely on each other's analyses and to take responsibility for sharing and interpreting data. Results are presented as before (2021-2022) and after (2024-2025) introduction of jigsaw expert roles with student own reporting as comparable measures (Table 2).

Table 2: Cohort design and comparable measures. Assessment in all years was divided equally (50/50) between a written collaborative report and oral examination. Lab refers to laboratory exercise.

Year	N	Group structure	Key activities used	Survey items used	Notes on instrument changes
2021	16	Inter-group	Lab + Poster + Report	Q1, Q3, Q4, Q7, Q8, Q9, Q11, Q12	Baseline instrument with mainly free text answers.
2022	21	Inter-group	Lab + Poster + Report	Q1 (Fig 7), Q8 (Fig 3), Q9	Minor tweaks and check boxes included with several options for awareness of competences included.
2024	24	Jigsaw expert roles intra-group	Lab + Jigsaw + Gallery walk + Report	Q1 (Fig 7), Q5 (Fig 6), Q10 (Fig 4), Q11, Q16 (Fig 5), Q19	Instrument adjusted to include jigsaw.
2025	15	Jigsaw expert roles intra-group	Lab + Jigsaw + Gallery walk + Report	Q1, Q2, Q3, Q4, Q5, Q6, Q7	Instruments adjusted to fewer questions.

Before (2021-2023): Intergroup dependence and fragile knowledge exchange

In the initial course design (2021 and 2022, Table 2) knowledge sharing was structured primarily through inter-group collaboration. Each group analysed one food component and relied on other groups to obtain the remaining data required for the final report. This design was intended to encourage students to integrate results generated by others alongside their own findings and relevant theoretical knowledge. Students were asked to reflect on their experience with knowledge sharing as part of the learning process.

As illustrated in Figure 4, 25% agreed and 62.5% strongly agreed (while 12.5% were neutral) that it was a positive learning experience. However, several students noted challenges in collaboration, reporting that some groups were reluctant to share their results or explain how those results were obtained (Q9 2022 – Supplementary S3). These responses indicate that successful task completion depended heavily on openness and effective communication across groups and might reflect students' reluctance to work interdependently and rely on other groups data as previous research indicate (Menekse and Chi 2019; Mercier et al., 2023).

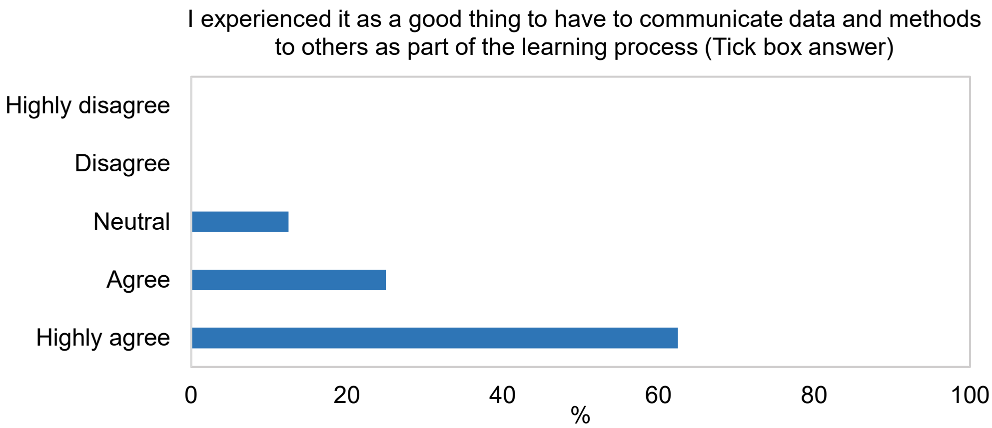

Figure 4. Result of Q8 "I experienced it as a good thing to have to communicate data and methods to others as part of the learning process (Tick box answers)" (2022).

To address these challenges, mandatory presentations and raw-data submission were introduced. Despite these structured measures, inter-group dependence remained uneven (2023 results not included).

After (2024–2025): Expert roles and structured intra-group exchange

In 2024 the course was therefore revised to emphasise intra-group knowledge sharing through the jigsaw method. This revision was expected to support more consistent peer explanation and curiosity on methods within home groups, given the shared dependence on a collective end product.

Following the redesign, students reflected on their perceived role in contributing knowledge (Figure 5). Over 70% (72.2%) agreed or strongly agreed that the course increased their confidence in contributing knowledge within a group. Interpreting this through an SDT lens, this self-reported increase in confidence is consistent with greater competence support in the redesigned course structure.

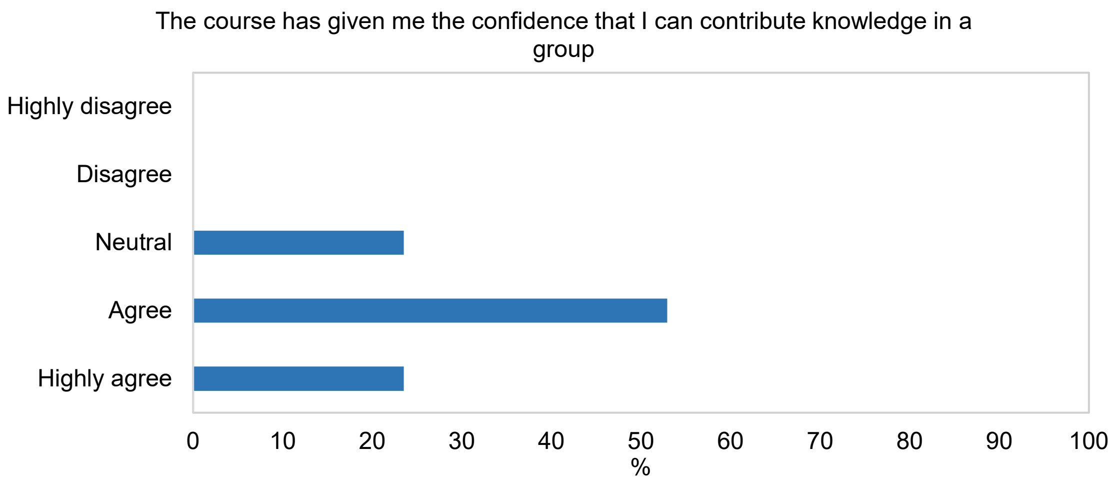

Figure 5. Result of Q10 "The course has given me the confidence that I can contribute knowledge in a group" (2024). Items were collected post-redesign and are reported descriptively.

Consistent with the intention of the gallery walk format - where students presented methods and results in small groups and engaged in structured feedback – students reported feeling able to ask questions in a positive atmosphere (Figure 6). This pattern is consistent with support of relatedness (SDT), as students appear to have experienced the group context as socially accepting and conducive to participation, Opportunities to explain reasoning and raise uncertainties may also have supported autonomy, insofar as students could engage actively and voice uncertainties within the shared task structure (Ryan and Deci, 2000; 2017).

This finding also aligns with research in Architecture and Building Engineering indicating that trust within collaborative learning environments supports interpretation of shared data and student responsibility (Sáez-Pérez et al., 2024).

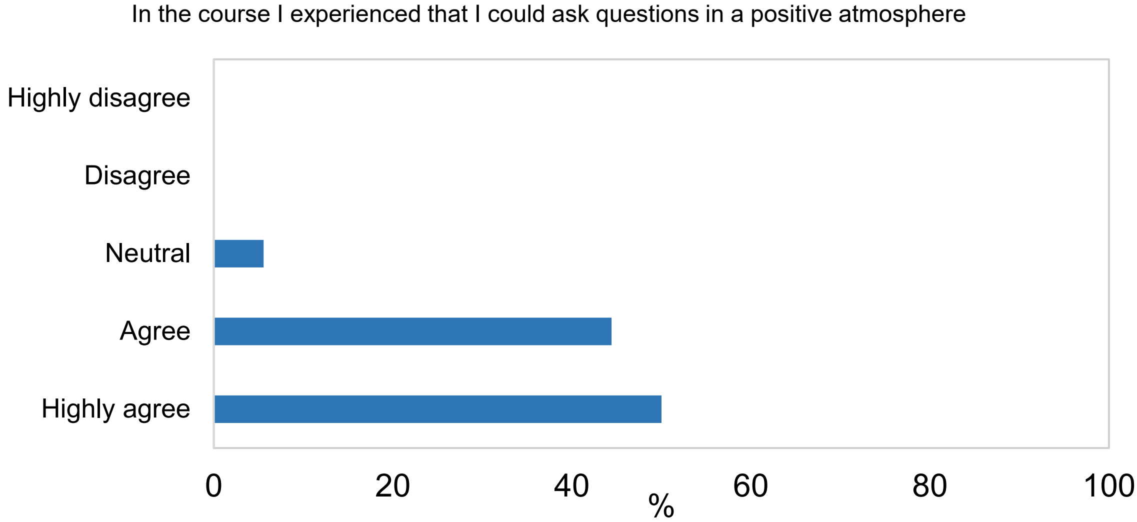

Figure 6. Result of Q16 "In the course I experienced that I could ask questions in a positive atmosphere" (2024). Items were collected post-redesign and are reported descriptively.

Additionally, 94% of students recognised knowledge sharing as a central component of the course (Q19, 2024 – Supplementary S3). Not all students expressed the same preference; one respondent indicated a desire for all group members to conduct the same analysis to enable deeper methodological discussion (Q11, 2024 – Supplementary S3). These comments suggest variation in how students experienced the expert-role structure.

This response may reflect that the dual group structure - where students chose their home group but were assigned to expert groups - was experienced differently across students. Although the design was intended to promote distributed expertise and collaboration, it required students to leave their self-selected home group temporarily and work with peers they had not chosen.

Within an SDT framework, this may have created tensions with perceived autonomy and relatedness, Students who felt a strong connection within their home group may have preferred to maintain that relational continuity. Working with assigned expert groups may have felt less socially secure or less self-determined, which may be especially acute if students have low perceived competence in their laboratory skills. If low perceived competence is the case, the collaborating with those they have a lower connection to further undermine it. Rather than signalling resistance to collaboration, this response may reflect differences in how the design supported students' sense of relatedness, competence, and autonomy (Ryan and Deci, 2000; 2017).

Outcome 1: Perceived knowledge sharing

When reflecting on skills developed during the course, 61% of students agreed that their generic competencies - such as collaboration, communication, and knowledge sharing - had been strengthened (Figure 7), indicating that these abilities were perceived as transferable beyond the immediate course context.

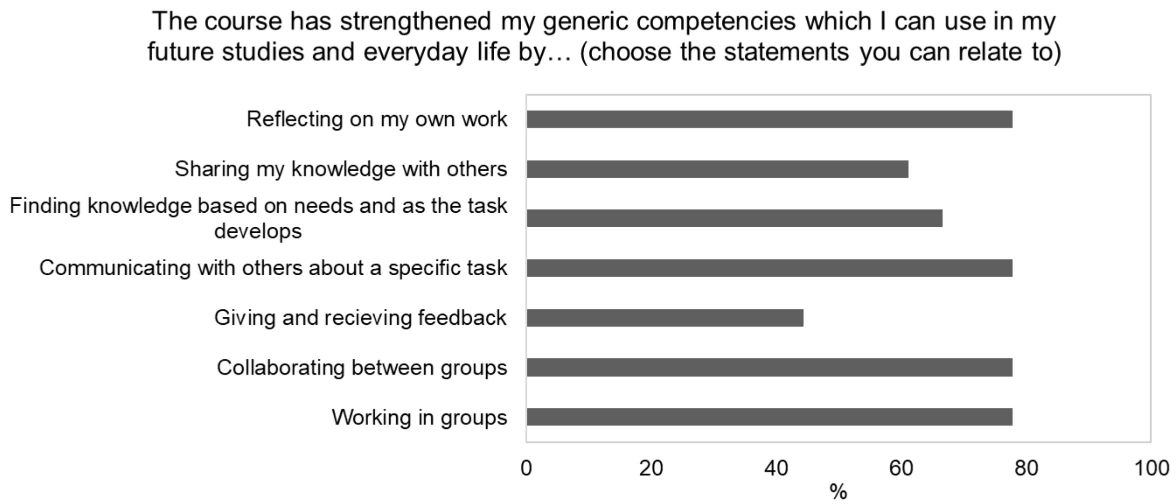

Figure 7. Result of Q5 "The course has strengthened my generic competencies which I can use in my future studies and everyday life by… (choose the statements you can relate to)" (2024). Items were collected post-redesign and are reported descriptively.

Figure 8 compares students' perceptions of engineering-relevant concepts before and after the implementation of jigsaw method. Across cohorts, acquiring new knowledge, applying existing knowledge to solve practical problems and critical thinking were consistently rated as the most important engineering competencies. Communication (presenting, communicating - both orally and in writing), and collaboration followed, with responsibility for personal learning ranking lowest.

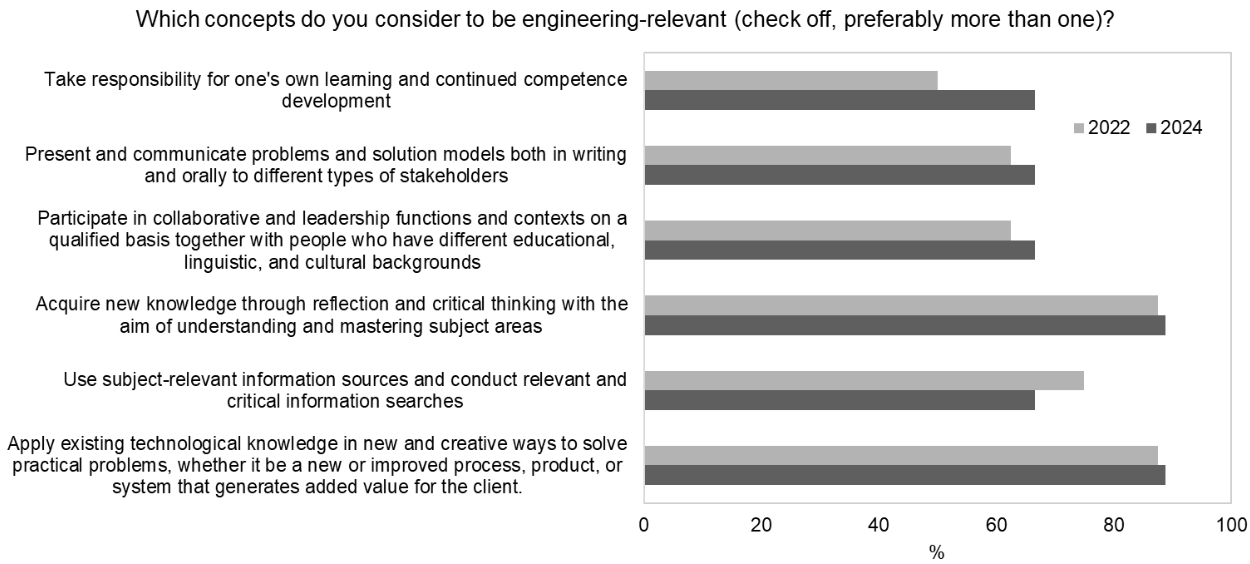

Figure 8. Result from "before" (light grey) and "after" (dark grey) on "Which concepts do you consider to be engineering-relevant (check off, preferably more than one)?" (2022 and 2024). Near-identical wording was used, see supplementary Table S2 and S3, Q1 for item text.

Outcome 2: Responsibility for understanding shared data

After the redesign (2024), data in Figure 8 show a higher proportion of students (67%) recognised responsibility for personal learning as engineering-relevant compared with earlier cohorts (50% in 2022).

When asked what they would do differently if repeating the course, all respondents answered that they would spend more time to understand the methods used by others (Q7 2025- Supplementary 2). This suggests increased awareness of shared responsibility for learning and understanding shared data.

The most noticeable structural change between the cohorts was the introduction of the jigsaw expert-role structure between 2023, and 2024, which organised students into "home" and "expert" groups and made interdependence explicit.

Through the SDT lens, the jigsaw structure may have supported greater internalisation of responsibility for shared outcomes by making each students' contribution necessary for collective completion. When students understand their role as meaningful for the group, responsibility may become more self-determined, contributions more clearly effective, and participation embedded within collaborative exchange (Ryan and Deci, 2000; 2017).

Prior research similarly indicates that when students perceive their contribution as essential to group outcomes, engagement and cooperation are more likely to increase (Aronson, 1997; Menekse and Chi, 2019; Mercier et al., 2023).

Future iterations of the course may benefit from clearer communication of the rationale for combining self-selected home groups with assigned expert groups. Making the pedagogical intention explicit may further support students' sense of autonomy and strengthen endorsement of the collaborative structure.

Conclusion

The re-design of the course to include structured expert roles was associated with more explicit knowledge sharing within home groups, and higher student-reported confidence in contributing to group work. Students also reported increased awareness of the need to understand and interpret results produced by others, including asking questions and clarifying uncertainties during collaborative activities.

Regarding RQ1, students generally viewed knowledge sharing as a positive element of the learning process. While earlier cohorts reported challenges with reluctance to share results across groups following the redesign, students more frequently recognised knowledge sharing as a central component of the course and described greater confidence in contributing as "experts".

Regarding RQ2, students' perceptions of responsibility for understanding shared data were mixed during the course, with some expressing a preference for more individual or more uniform analytical experience. However, responses after the course indicated increased recognition that time spent understanding others' methods and results is necessary for producing a coherent final product, and that this forms part of their responsibility for learning underlying concepts. Interpreted through an SDT lens, the structured interdependence embedded in the expert-role design may have supported greater internalisation of responsibility, as students' contributions became necessary for collective completion.

In practice, these findings suggest that making expert roles explicit within home groups, and pairing them with short peer-presentation checkpoints, can support structured knowledge sharing and individual accountability on collaborative laboratory-based courses. Aligning assessment with both group integration and individual understanding may further reinforce these behaviours. These implications should be interpreted considering the small cohort sizes and reliance on self-reported data.

Limitations

This study is based on small cohort sizes and relies primarily on student self-reported perceptions rather than direct performance or behavioural measures. The questionnaire was course-specific and not a previously validated instrument designed to measure discrete psychological constructs; accordingly, the results should be interpreted as indicative of students' perceptions within this context rather than as psychometric assessments. The instrument was also adjusted across cohorts to improve clarity and response consistency, which may limit strict comparability between years. In addition, the study was conducted within a single course and institutional context, and several course elements evolved alongside the introduction of the expert-role structure. The findings should therefore be understood as exploratory and context-bound.

Acknowledgements

We would like to thank Riuyinosa Igbinovia, Leise Kjelmann, Nick Kjærgaard Dahlberg, Ana-Emanuela Azoica, Karen Ingeborg Dam, Inge Holmberg, Jessie Klang Lorentzen, Thi Thu Trang Vu, Lis Berner, and Jannie Felskov Agersten for their valuable contributions in supervising the students in the laboratory. Their guidance and support were instrumental in ensuring a productive and enriching learning environment.

Declaration of Interest

No conflict of interest.

Ethical approval

Students participating in the anonymous surveys has given their consent for use of obtained data in this manuscript.

References

Aronson, E. (1997). The jigsaw classroom: building cooperation in the classroom. 2nd ed. Longman (NY), p. 180–181.

Bonwell, C.C., and J.A. Eison, (1991). Active Learning: Creating Excitement in the Classroom. In: ASHEERIC Higher Education Report No. 1, George Washington University, Washington, DC.

Chin, C.K., Khor, K.H., and Teh, T.K. (2015). Is Gallery Walk an Effective Teaching and Learning Strategy for Biology?. In: Gnanamalar Sarojini Daniel, E. (eds) Biology Education and Research in a Changing Planet. Springer, Singapore. Doi:10.1007/978-981-287-524-2_6

Chopra, D., Kwatra, G., Bhandari, B., Sidhu, J., Rai, J., and Tripathi, C.D. (2023). Jigsaw Classroom: Perceptions of Students and Teachers. *Medical Science Educator*, *33*, 853–859. Doi:10.1007/s40670-023-01805-z

Clarke, J. (1994). Pieces of the puzzle: The jigsaw method. In S. Sharan (Ed.) Handbook of cooperative learning methods. Westport CF: Greenwood press; p. 120.

Colomer, J., Serra, T., Cañabate, D., and Bubnys, R. (2020). Reflective Learning in Higher Education: Active Methodologies for Transformative Practices. *Sustainability, 12*, 3827, doi:10.3390/su12093827

Crawley, E.F., Malmqvist, J., Östlund, S., and Brodeur, D.R. (2007).(eds) S Rethinking Engineering Education.Springer Cham Heidelberg, New Yoprk Dordrecht London. Second edition. ISBN 978-0-387-38290-6

Deci, L.E., and Ryan, M.R. (1985). Intrinsic Motivation and Self-Determination in Human Behavior. New York, NY: Springer. Doi:10.1007/978-1-4899-2271-7

Drouet O.C., Lentillon-Kaestner, V., and Margas, N. (2023). Effects of the jigsaw method on student educational outcomes: systematic review and meta-analyses. Frontiers in Psychology 14:1216437. doi:10.3389/psyg.2023.1216437

Elliott, R., Beaubien, L., Coe, G., Muller, A. C., Predaina, C. M., Stiles, S., Toth, L. P., & Cline, K. (2022). Knowledge Sharing and Mentorship as a Systems Engineering Process: Stories and Methods from Industry Experts. In: Squires, A.F., Wheaton, M.J., Feli, H.J. (eds) Emerging Trends in Systems Engineering Leadership. Women in Engineering and Science. (pp. 145-167) Springer, Cham. https://doi.org/10.1007/978-3-031-08950-3_5.

Felder, R. M., and Brent, R. (2003). Learning by doing. *Chemical Engineering Education*, 37(4), 282–283.

Finelli, C.J., Bergom, I., Mesa, V. (2024). Student Teams in the Engineering Classroom and Beyond: Setting up Students for Success. CRLT Occasional Paper 29. *Center for Research on Learning and Teaching at the University of Michigan.*

IEA, International Engineering Alliance (2021) Graduate Attributes and Professional Competences version: 2021.1. IEA Constitute Agreements p. 1-23. http://www.ieagreements.org. Accessed 2nd February 2026.

Jainal, N. H., and Shahrill, M. (2021). Incorporating Jigsaw strategy to support students" learning through action research. *JonSES, 3(2)*, 252-266. https://doi.org/10.46328/ijonses.75

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college: What evidence is there that it works? *Change: The Magazine of Higher Learning*, 30(4), 26–35.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal on Excellence in College Teaching*, 25(3–4), 85–118.

Klippert, M., Stolpmann, R., and Albers, A. (2024). Improving knowledge transfers in student engineering teams through the application of the InKTI – Interdepartmental Knowledge Transfer Improvement method. *Proceedings of the Design Society: DESIGN 2024, 4*, 2875–2884. https://doi.org/10.1017/pds.2024.291.

Krathwohl, D.R. (2002) A revision of Bloom's Taxonomy: an overview. *Theory Into Practice, 41*, 212-218. doi:10.1207/s15430421tip4104_2.

Makmun, M., Yin, K.Y., and Zakariya, Z. (2020). The Gallery Walk Teaching and Learning and Its Potential Impact on Students' Interest and Performance. *International Business Education Journal, 13(1)*, 17-22. doi:10.37134/ibej.vol13.1.2.2020.

Menekse, M and Chi M.T.H. (2019) The role of collaborative interactions versus individual construction on students' learning og engineering concepts. *European Journal of Engineering Education*, 44 (5) 702-725. Doi: 10.1080/03043797.2018.1538324.

Mercier, E., Goldstein, M.H., Baligar, P., Rajarathinam, R.J. (2023) Collaborative Learning in Engineering Education. Chapter 19 in *International Handbook of Engineering Education Research* 1st ed. Johri, A (ed) Routledge pp. 402-432. DOI: 10.4324/9781003287483-23.

Mualem, R., Leisman, G. Zbedat, Y., Ganem, S., Mualem, O., Amaria, M., Kozle, A., Khayat-Moughrabi, S., Ornai, A. (2018) The Effect of Movement on Cognitive Performance. *Front. Public Health*, 6: 100 https://doi.org/10.3389/fpubh.2018.00100.

Niemiec, C. P., and Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice. *Theory and Research in Education, 7*(2), 133–144. https://doi.org/10.1177/1477878509104318

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93 (3) 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Ryan, R. M., and Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology, 25(1)*, 54–67. doi:10.1006/ceps.1999.1020

Ryan, R. M., and Deci, E. L. (2017). Self-Determination Theory. The Guildford Press.

Sáez-Pérez, M.P., Torre, C.M., Tajani, F. (2024). Effectiveness of Collaborative Learning in Engineering Degrees: Improvement of Professional Skills. In: Bienvenido-Huertas, D., de la Hoz-Torres, M.L., Aguilar Aguilera, A.J. (eds) Teaching Innovation in Architecture and Building Engineering. Springer, Cham. https://doi.org/10.1007/978-3-031-59644-5_12

Technical University of Denmark (2025a). About DTU. https://dtu.dk. Accessed 6 February 2026.

Technical University of Denmark (2025b). Competence profile for Bachelor of Engineering in Food Safety and Quality. Retrieved July 1st, 2025, from https://student.dtu.dk/studieordninger/diplomingenioer/foedevaresikkerhed-og-kvalitet/kompetenceprofil.

Wu, Y. (2018). Behavioral interdependence in project team collaboration: study of engineering students' collaborative behaviors in high levels of interdependent task settings. Dissertation – ALL 883. https://surface.syr.edu/etd/883.

Zamiri, M., & Esmaeili, A. (2024). Methods and technologies for supporting knowledge sharing within learning communities: A systematic literature review. *Administrative Sciences, 14*(1), 17. https://doi.org/10.3390/admsci14010017.

Notes on Contributors

Ditte Baun Hermund, Associate Professor at DTU Food Institute, researches bioactive compounds, nutritional composition, and functionality of marine algae-based ingredients. She teaches B.Eng. in Food Safety and Quality and M.Sc. in Food Science and Technology and is dedicated to developing high-quality education for future food engineers.

Elizabeth Rees is a Postdoctoral Researcher at the Centre for Engineering Education, where her research focuses on student persistence in engineering education, with particular attention to pedagogical approaches, motivation, and learning environments.

Lene Duedahl-Olesen, Associate Professor at DTU, is the National Food Institute pedagogical supervisor, ensuring teachers-to-be participate in teaching training and responsible for the community of teachers exchanging teaching principles and ideas. She teaches bachelor and master courses focusing on student activation and learning environment. Her research focus on food process contaminants.