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On-site inspection as a tool for developing auditing skills in engineering: integrating continuous education contents into higher education programs

Rebeca María García-García, Cristal Alejandra García-Caballero, Raúl Villarreal-Lara* and Vicente Antonio Mirón-Mérida*

School of Engineering and Sciences, Tecnologico de Monterrey, Monterrey, Mexico

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EDITED BY
Guillermo M. Chans,
Department of Science, Monterrey Institute of Technology and Higher Education (ITESM), Mexico

REVIEWED BY
Oscar Jerez,
University of Chile, Chile
Andrea Benešová,
University of West Bohemia, Czechia

*CORRESPONDENCE
Raúl Villarreal-Lara
✉ raulvl@tec.mx
Vicente Antonio Mirón-Mérida
✉ vicente.miron.m@tec.mx

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Employability has been a priority for higher education institutions, and some skills, such as auditing skills, are necessary for students to enter into work life. In this regard, auditing skills can be applied in the food industry in different areas such as production, food safety, quality assurance, and environmental responsibility. Developing these skills could take years of practice and the completion of several courses, certifications, and diplomas, increasing the existing gap regarding auditing skills. In this work, 25 students from a Design of Process and Food Safety Management Systems class implemented a Food Safety and Food Quality checklist based on the Mexican regulation NOM-251-SSA1-2009 Hygiene Practices for Food, Beverage, and Supplement Processing, to analyze a real-life challenge in a beverage company that participated as a Training Partner. Two soft skills were evaluated: decision-making and problem-solving. The problem-solving effectiveness of these instruments was assessed by collecting the feedback of an experienced auditor and a representative from the audited company. The average result obtained for students after auditing the beverage company was 67.04, which was close to the assigned grade from the senior auditor (72.94), which indicates a good estimation from the instruments generated by the students. This exercise demonstrated the effectiveness of the students in performing accordingly and delivering the expected outcomes in front of a real industrial challenge. The combination of continuous education with a work-based challenge functioned as a laboratory for the students, where they can obtain technical skills in combination with fundamental, personal, and cooperative skills, which are necessary for facing industry challenges in an environment of globalization.

KEYWORDS

auditing skills, continuous education, higher education, engineering, employability

1 Introduction

Employability is related to the ability to demonstrate a good performance in the workplace based on specific expected skills and abilities (Thapa, 2024). This term has been a priority for higher education institutions that strive to continuously design, implement, evaluate, and improve their students' curricula to match the industry's current expectations and requirements. Simultaneously, industrial employers are constantly setting a competitive scenario, flanked by the need for leaders who can cope with the challenges arising from the continuous development of technology. In some cases, higher education institutions set specific standards to measure the acquisition of employability skills; however, as the students start moving into the workplace, the transference of those skills is somehow more complex to record (Jackson, 2014).

Unemployment represents an important challenge, especially in developing countries, as one of the main attributed reasons is the existing gap between the pragmatic knowledge provided by higher education institutes and the workplace requirements. Additionally, employers occasionally trust that universities are responsible for providing the desired skills to their graduates (Tushar and Sooraksa, 2023). Nevertheless, different opinions among educators have taken place when determining if universities are either places for developing capabilities, in which the students acquire disciplinary knowledge, while competencies are acquired at the workplace through practice, mentoring, and continuous education, or if higher education institutions should be reinforced with applied knowledge to build work-ready graduates with a complete set of skills (Jackson, 2014). In developing countries, employability skills are more directly related to productivity, job opportunities, and economic and industrial advancements (Mukul et al., 2024). For this reason, universities in emerging economies are modifying and improving their educational programs to prepare their students in accordance with the market demands (Arredondo-Trapero et al., 2024).

One of the main required employability skills in engineering is applying theory to solve real industrial problems (Morgan and O'Gorman, 2011). This can be accomplished by integrating problem-based learning that not only increases the effectiveness of education through practice but also promotes the obtention of employability skills such as communication, teamwork, and leadership, among others (Othman et al., 2017). Another important aspect is the development of technical competencies, which is linked to an increased analytical capacity and desirable aptitudes that graduates can apply to real industrial problems (Morgan and O'Gorman, 2011). Likewise, work-based learning is focused on learning for, at, and through work, which could result in networking, employment opportunities, and, most importantly, the development of work-related technical, generic, and personal skills (Thapa, 2024).

Furthermore, some employability skills necessary for graduates include the ability to analyze different processes to diagnose problems, which eventually must be derived into decision-making for improvement. Analysis, reasoning, intuition, and experience can be highly valued by managers, who also expect a degree of troubleshooting and decision-making abilities in their new employees (Solís et al., 2024). An opportunity to acquire and practice the aforementioned skills occurs during auditing, which can be applied in areas such as production, health and safety, food safety, quality assurance, and environmental responsibility. However, depending on the universities' capability, curricula, and infrastructure, those auditing skills are usually not enforced unless the student can apply them as part of an internship, a thesis project, or after securing a job in this area. Yet, a significant element to ensure employability is the inclusion of professional qualifications throughout higher education studies (Herath and Ekanayake, 2024), which are commonly achieved as part of continuous education content.

In this regard, considering the factors arising from the industry 5.0 changes, engineers should receive transdisciplinary and continuous education to ensure that both knowledge and skills are achieved by the students, mainly by adapting the curriculum to the high-speed changes and disruptions of the globalized society (Gürdür Broo et al., 2022). In the auditing context, compared to recent graduates, many experienced auditors spend years of practice as well as participate in diplomas and certifications, which could increase the already existing gap between recent graduates and senior auditors regarding those skills. Therefore, the integration of different continuous education contents at a higher education level might enhance the employability opportunities of engineering students, in which an evaluation of the effectiveness of this strategy should be considered. In this work, the students implemented a Food Safety and Food Quality checklist to analyze and resolve a real-life industry case through an auditing exercise. The problem-solving effectiveness of these instruments was assessed by collecting the feedback of an experienced auditor, as well as a representative from the audited company, to determine if the application of continuous education content through work and problem-based learning is effective for providing work-related skills to the students. This work hypothesized that when engineering students progressively solve real-life industrial challenges in collaboration with an industrial training partner, they can develop important employability skills through the achievement of an approbatory competency level.

2 Materials and methods

2.1 Group selection and work-based challenge

The selected group was part of the Design of Process Management and Safety Systems class (Course code: TA2006B.301), which was taught in Spanish between August and December of 2023, for 5 weeks, as part of the fifth semester of the Food Engineering Program at Tecnologico de Monterrey, Campus Monterrey (Monterrey, Mexico). The course is divided into five modules as displayed in Supplementary Table S1, from the supplementary information. The syllabus of this course can be accessed online,[1] where the main learning objectives upon completion are that the student manages food conservation and transformation processes, using operation management tools, as well as manages food safety systems according to the transformation and conservation process considering national and international guidelines. In addition, the students were simultaneously taking the course TA2020 Administration of Processes and Safety Systems[2] which is a complementary course, as its main objectives are the same to those from the TA2006B course, due to its relevance for auditing. The TA2006 course was attended by 25 students (68% female, 32% male), who were allocated to 6 teams for the auditing exercise as indicated in Table 1. Of the 25 students (ages

1 https://samp.itesm.mx/Materias/VistaPreliminarMateria?clave=TA2006B&lang=EN

2 https://samp.itesm.mx/Materias/VistaPreliminarMateria?clave=TA2020&lang=EN

TABLE 1 Team distribution, food safety checklist instrument's specifications, and audit results.

Team number	Team conformation		Audit instrument description			
	Male	Female	Number of inspected sections	Total applicable instrument points	Complied points	Scaled audit grade (0–100)
1	0	4	2	98	65	66.33
2	2	2	12	101	65	64.36
3	2	3	15	55	38	69.09
4	2	2	14	42	33.5	79.76
5	2	2	2	62	32.5	52.42
6	0	4	20	96	67.5	70.31
Auditor	0	1	28	109	79.5	72.94

20–22), 88% were originally from Mexico, while 12% were from Honduras. All the students already fulfilled their exploratory and engineering introductory phases (semesters 1–3) and already had one semester with courses from the Food Engineering area as stated in the curriculum.[3] This class was chosen due to the scope of the assessed competencies and the opportunity to apply a real work-based challenge in partnership with an industrial company. The evaluated competencies and the main challenge are outlined in Table 2. As noted, the competencies included decision-making and problem-solving, which are employability skills highly required for auditing. The selected food industrial company was a beverage company that participated as a Training Partner, specific information regarding the company is not shown due to confidentiality however, this company allowed access to their quality assurance and food safety records, along with the application of the food safety audit instrument during an inspection visit by the students to their facilities.

2.2 Application of continuous education courses

Before generating the audit instrument, the students received two continuous education courses provided by Secretaría de Salud from the Nuevo León state, which is regarded as the Mexican Ministry of Health. This organization offers an Online Training System[4], from which the two selected courses consisted of Hazard Analysis and Critical Control Points (HACCP; https://saludnl.gob.mx/regulacion-sanitaria/cursos/course/sistema-de-analisis-de-peligros-y-de-puntos-criticos-de-control-haccp/) and Good Manufacturing Practices (GMP's; https://saludnl.gob.mx/regulacion-sanitaria/cursos/course/bph/). The fulfillment of both courses was proven by an exam with a minimum approbatory grade of 80/100 and the obtention of a certificate. The HACCP certification was relevant for this course as the students got to know the seven principles of HACCP. At the end of the certification, they are expected to know about the HACCP system, the prerequisite program, and some preliminary steps. This integration is related to the audit exercise, as the students analyze all the process hazards, identify any preventive measures, determine the critical control points (CCP) and their critical limits, establish a monitoring system for the CCP, establish all the applicable corrective measures for CCP identified as under control, and establish a checklist procedure to validate and assess the HACCP system. On the other hand, the GMP's course is related to the analysis of all the risks and foodborne illness vectors, which is also applicable for the process taking place at the training partner's facility.

2.3 Activities related to the course modules

Based on the different course modules and as indicated in Supplementary Table S1, the students completed a total of 22 activities as follows: five from Module 1, four from Module 2, five from Module 3, four from Module 4, and four from Module 5. All the activities were finished throughout the course and as the contents were progressively covered. The teacher from each module (Supplementary Table S1) oversaw requesting, marking, and providing feedback regarding his/her corresponding module activities. In the case of Modules 1–3, the activities were applied to the audited process and integrated into the executive report for the training partner. In Module 1, Activity 1 was focused on the establishment of all the equipment utilized for the selected process, by indicating in a table their installed and utilized capacities as well as their operation conditions. Activity 2 consisted in indicating the required time for each process step and the type of step (operation, inspection, transport, delay, storage) along with specific observations from the auditing activity. Activity 3 consisted in designing the process layout with all the equipment location and mass flow, while Activity 4 was the utilization of a software for creating the same layout. Activity 5 was the production plan, in which the students determined parameters such as the total requirement, available balance, net requirement, reception of planned materials and placement of planned orders, based on the weekly demand. For Module 2, the students revised and proposed the applicable legislation to the audited process (Activity 6), verified the preventive controls that the training partner had in place (Activity 7) including operative procedures, SOPs, product traceability and tracking, transport, personnel training, product information, and allergen control. In Activity 8 the students had to determine the CCP from the process, this was completed with Activity 9, which helped indicate the plant diagnosis regarding the

3 https://samp.itesm.mx/Programas/VistaPrograma?clave=IAL19&modoVista=Default&idioma=ES&cols=0

4 https://saludnl.gob.mx/regulacion-sanitaria/cursos/

TABLE 2 Competencies and work-based challenge evaluated during the application of the design of process and food safety management systems class (TA2006B.301) during August–December 2024.

Competency code	Competence	Expected outcome in the student	Work-based challenge
SIBQ0401	Application of Standards and Norms	The student applies standards and norms in the exercise of his/her profession as references to follow during problem-solving in bioengineering and chemical processes.	The students prepared a checklist instrument and visited, and audited the status of the Training Partner in terms of food safety, based on the national legislation NOM-251-SSA1-2009 (SSA, 2009).
STA0204	Management of Food Processes	The student manages food preservation and transformation processes by using operations management tools.	
STA0302	Management of food safety systems	The student manages food safety systems in accordance with transformation and preservation processes by following applicable national and international guidelines.	
SEG0302	Collaboration	The student builds agreements and interactions through a collaboration that considers his/her differences and skills as well as others.	
SEG0303	Effectiveness in negotiation	The student generates results and commitments in his/her group through collaborative work, decision-making, and value generation.	

existing prerequisites and Good Manufacturing Practices. The activities from Module 3 were implemented to identify the company's status regarding quality assurance (Activities 10–14). The activities from Module 4 were focused on allowing the students to assess their performance and the performance of their team members in all the collaborative activities, by answering a weekly individual co-assessment and auto-assessment format. Additionally, the activities from Module 5 were individual written reflections that allowed the students to think about their roles as food engineers, in this type of collaborative auditing tasks.

2.4 Elaboration of the auditing checklist instrument

Based on the Mexican regulation NOM-251-SSA1-2009 Hygiene Practices for Food, Beverage, and Supplement Processing, the continuous education courses indicated in section 2.3, and the process particularities from the Training Partner, the students prepared a checklist with all the applicable HACCP/Food Safety and Hygiene aspects. Each team formulated its own instrument, and all the audited elements were classified in sections or listed as a whole document. The six checklist instruments are indicated in the Supplementary Information section (Supplementary Tables S2–S7). Each instrument received an initial screening and feedback from the teacher in charge of module 2 (Supplementary Table S1). |The audited sections are indicated in Supplementary Table S8, while the number of sections and the total obtainable points are indicated in Table 1.

2.5 Implementation of the auditing checklists

The students visited the Training Partner facilities located in Monterrey, Nuevo León, Mexico. A detailed description of the areas cannot be disclosed due to confidentiality, yet the auditing exercise consisted in arriving at the company, where employees from the quality assurance areas received the students and explained the access protocol. The visiting group passed through the sanitizing station, and was then divided into two groups, supervised by one teacher and one employee. Teams 1–3 started the inspection at the storage room while Teams 4–6 started at the processing area. Each team printed their formats and filled the sections as they were inspecting the areas. All the team members had the opportunity to ask or request any evidence for completing the checklist format. In some cases, the students had access to records and documents from the company, as well as the utilization of timers and measuring tape to obtain specific data. After 40 min in the initial area, the teams switched areas and continued the inspection. The students inspected the areas and processes by marking the expected compliances as indicated in the checklist instruments. Once the inspection and checklist were completed, the overall audit grade was calculated according to Equation 1.

$$Audit\ Grade = \frac{Complied\ Points}{Total\ Applicable\ Points} * 100 \qquad (1)$$

2.6 Assessment of the competencies' achievement level and course grade

The assessment of the course was divided into quantitative and qualitative assessment, as indicated in Supplementary Table S9. The quantitative assessment was formed by a summative grade formed by the 22 activities, the final evidence and a final exam. In the final exam the students received a flow chart for a specific process in which they had to identify the hazards, CCP, critical limits, preventive and corrective actions, type of operation and solve a collaborative situation within the process. On the other hand, the qualitative assessment consisted in assigning the achievement degree for each competency based on the final evidence. In the final evidence, based on the auditing exercise, the students had to individually explain the findings and propose improvement actions, along with a negotiation and collaboration strategy to implement the proposed measures, and the applicable legislation.

2.7 Performance validation of the instruments with a senior auditor

An experienced senior auditor simultaneously visited and audited the company by revising 28 sections, as indicated in Supplementary Table S1. The checklist result was received, and the audit grade was calculated according to Equation 1. A graphical comparison was made between the auditor's grade and the students' results.

The percentage of approximation between the student's instrument and the auditor's grades was calculated according to Equation 2.

$$Grade's\ Approximation = \frac{Instrument's\ grade}{Auditor's\ grade} * 100 \quad (2)$$

In addition, an opinion from the experienced auditor, regarding her expertise as a food safety and quality assurance auditor was obtained by asking the question: How did you achieve your level of expertise in auditing?

2.8 Obtention of the companies' feedback

An online survey was provided to the owner of the Training Partner company to obtain the company's perception and feedback on the effectiveness and pertinence of the implemented audit exercise. The survey was sent and answered in Spanish through RedJade and consisted of 10 questions, where only the name (Q1) was covered due to confidentiality. The received answers are presented in Supplementary Figure S1, while the translated questions and answers are shown in Table 3. All the methodological phases for auditing the selected industrial company and for assessing the students' collective and individual performance are outlined in Figure 1.

2.9 Statistical analysis

All the statistical analysis was performed in Minitab 21.4 Statistical Software.

3 Results and discussion

The audit grades calculated by the students are indicated in Table 1. Regardless of the number of sections, all the instruments aligned with the corresponding legislation and revised the same scope of checklist points. The average audit grade given by the students was 67.04 ± 8.92, with a range of 27.34, and minimum and maximum values of 52.42 and 79.76, respectively. The average group grade was close to the assigned grade from the senior auditor (72.94), which indicates a good estimation from the instruments generated by the students. In engineering, audits are essential elements within the companies, as they prevent risk and reduce losses, which positively impacts overall competitiveness (Wang and Li, 2011); hence the pertinence of the instruments is a good indicator of the capability of the students to identify, propose, and solve real industrial problems.

As noted in Figure 2, only for Team 4 the company surpassed the senior auditor grade. In contrast, the audit results from Teams 1, 2, 3, and 6 were lower than the auditor's result, yet within the same range of compliance. In the case of Team 5, the final grade was lower (52.42) than that of the other teams due to the stricter approach from the students in this team. Nevertheless, all the teams had the opportunity to receive feedback from the senior auditor and a space to present the results to the Training Partner, in which the company's feedback was given, and the students could homologate the expected audit approach for further interventions. This type of academic exercise is appropriate for developing employability skills. The competency levels achieved by the students are indicated Table 4, where most of students were evaluated with an outstanding level of accomplishment for competencies SEG0302: Collaboration (96%), STA0302: Management of food safety systems (80) and SIB401: Application of Standards and Norms (84%). For the competency SEG0303 Effectiveness in negotiation, 60 and 32% of the students achieved an outstanding and solid level, respectively. Both SEG302 and SEG303 are linked to collaboration among team members, decision-making for problem-solving, and value generation in their results. Assets such as communication, problem-solving, leadership, and decision-making have been indicated as engineering skills highly required in developed countries (USA, UK, Australia, Japan, EU), where an agreement between higher education institutions and employers has been proposed as necessary for determining a common perception and development of these graduate skills (Zaharim et al., 2010). Although in competency STA204 only a 44% reached an outstanding level, all the students from the course achieved approbatory competency levels, which denoted the achievement of the learning objectives, as they were able to apply the recommendations and procedures from national and international legislation into a transformation process, through the utilization of operation management tools.

TABLE 3 Approximation between the student's and the auditor's audit grade and final grades obtained by the students.

Team number	Approximation with the auditor's grade (%)	Audit activity grade	Final course grade
1	90.93	98	96.75 ± 2.63
2	88.23	91	90.25 ± 3.59
3	94.72	96	96 ± 0.50
4	109.35	100	97 ± 2.16
5	71.87	99	95.75 ± 1.26
6	96.40	97	94.25 ± 1.89

A key element when developing employability skills is the generation of fully aware and self-conscious students who can identify their skill set and the opportunities to work on for improvement. In this framework, an important action of higher education institutions for reducing the academia-industry gap is allowing and promoting awareness and self-analysis in the students to empower them by creating the ideal space and structures to acquire the desired skills (Kaushal, 2011). In this regard, during the whole class length, all the team members performed three self-assessments and co-assessments based on the work-based challenge. This represented an opportunity for the students to mature self-awareness regarding their performance and improve their skill achievement.

Work-based challenges are a good opportunity for practicing soft and technical skills (empathy, communication, knowledge,

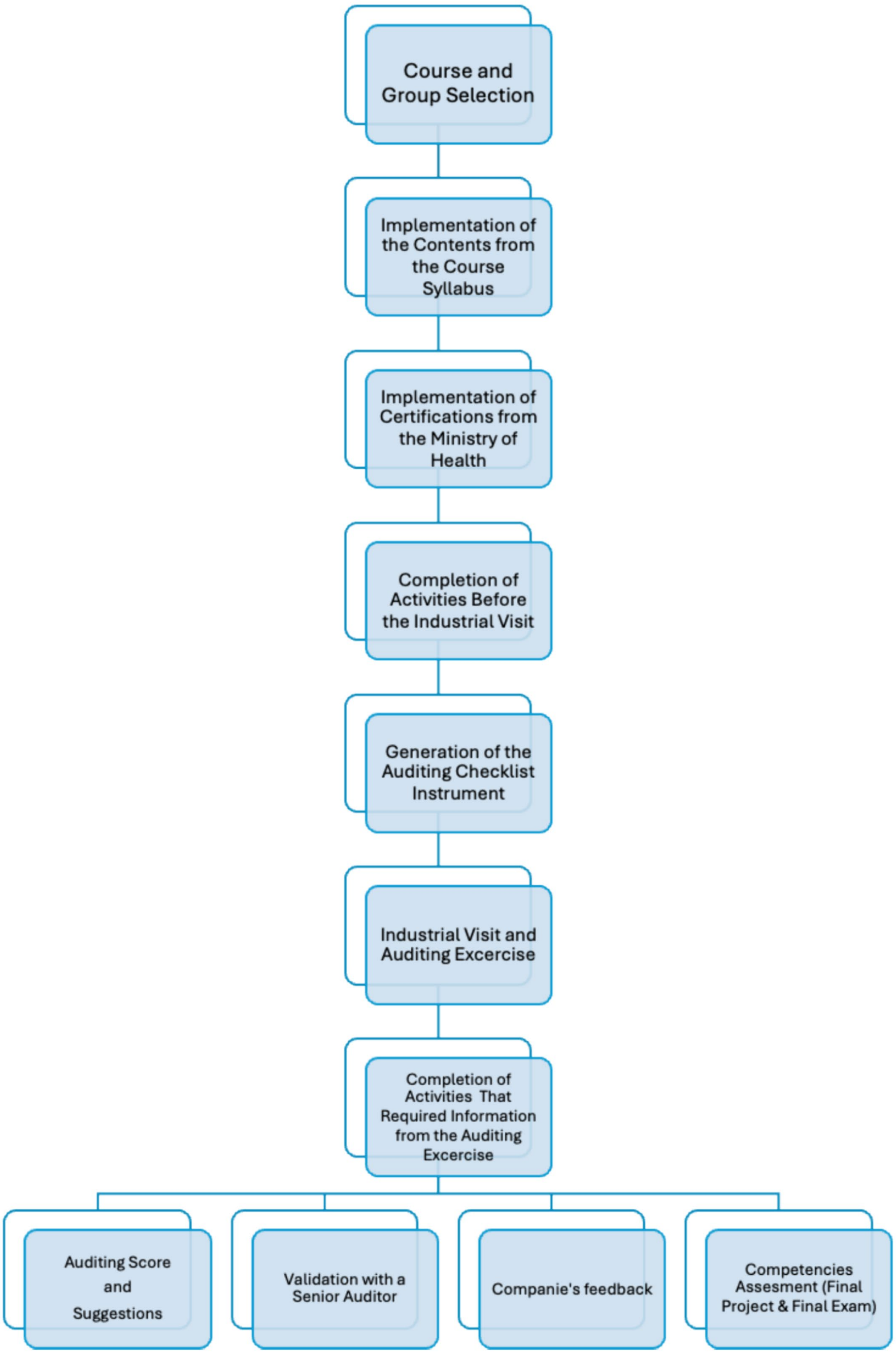

FIGURE 1
Phases of the auditing project as part of the TA2006B course.

management) that are highly correlated to the market and employers' needs (Ajit and Deshmukh, 2013). They are proposed in line with a more practice-oriented pedagogy that can permeate engineering programs and be enriched with skill-oriented courses (Shekhawat, 2020). For this reason, integrating continuous education courses from an official organism such as Secretaría de Salud was appropriate for contextualizing and preparing the work-based challenge, as these courses add value to the curriculum vitae and provide applicable and transferable knowledge to the students. These types of courses are usually taken by employees and recent graduates, depending on the company's needs. However, their inclusion in higher education courses is a chance for the students to face and immerse themselves into real industrial needs and their expected performance in the work environment.

Depending on the region, the type of higher education institution (public or private), or the engineering area, the integration of industrial training partners can be limited by the absence of a collaborative approach from universities with low partnership and

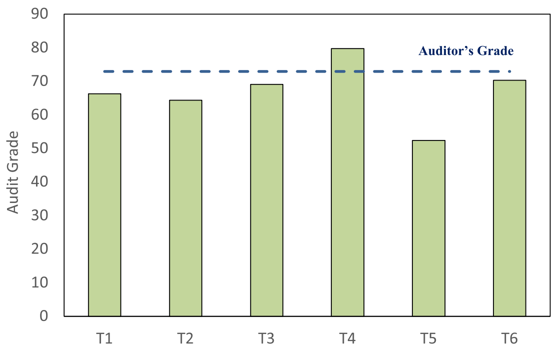

FIGURE 2
Audit grades given by the students in teams (green bars) in comparison to the audit grade provided by the senior auditor (blue dotted line).

TABLE 4 Percentage of students (%) at different competency achievement ($n = 25$).

Competency	Outstanding	Solid	Basic
STA0204. Management of Food Processes.	44	24	32
STA0302. Management of food safety systems	80	20	0
SEG0303. Effectiveness in negotiation	60	32	8
SEG0302. Collaboration	96	0	4
SIBQ0401. Application of Standards and Norms	84	12	4

networking efforts, the adjustment to a more traditional curriculum from certain universities where access to industrial challenges is not considered when designing programs, the accessibility to real industrial cases at regional, national or even international levels, the perception from the industrial companies regarding the prestige and expertise of the higher education institution, as well as the openness to collaborate depending on the scope and magnitude from each company. Nevertheless, based on the model from Tecnologico de Monterrey, the learning structure presented in this work can be replicated in other parts of the world, where different industrial sectors can participate as training partners from the initial stages of higher education programs. This has already been accomplished in this Mexican institution due to diverse factors including the existence of a department in charge of attracting industrial training partners and creating a catalog of interested companies. Besides, the Tecnologico de Monterrey has been regarded as one of the most important universities in Mexico, which can also be linked to some companies' interest in collaborating and participating as training partners. In the case of curriculum design, its Tec21 model is based on the development of competencies through challenge-based learning, which requires the participation of companies to provide real-life challenges. Furthermore, the role of teachers for pitching the scope of collaboration along with the course structure and expectations is relevant for the successful establishment of collaboration with industrial training partners.

The combination of continuous education with a work-based challenge functioned as a laboratory for the students, where they can obtain technical knowledge in combination with fundamental, personal, and cooperative skills, which are recognized as necessary for the success of the employees towards the new challenges from globalization (Idkhan et al., 2021). As the Técnológico de Monterrey enables a whole on-campus experience towards human and professional flourishing, the focus of this implementation is far from the industrialization of the curriculum or the specific industrial-oriented curriculum from technical schools. Despite the latter, the high approximation percentage outlined in Table 3, where the students accomplished similar results accounting for 71.87–109.35% of those from an experienced auditor, demonstrated the effectiveness of this exercise on the students for performing accordingly and delivering the expected outcomes in front of a real industrial challenge.

Apart from the technical validation from the comparison of the students' grades with the result from an experienced auditor, the audit exercise grade assigned by the teachers corresponded with the final course grades ($r = 0.915$), which are presented in Table 3. On the contrary, no correlation was found between the audit grade and the received audit activity grade ($r = 0.156$) and the final course grade ($r = 0.227$). Regardless of this result, the results similarities from the student's audit to the result from the auditor reflected the necessity for including more problem-solving/work-based challenges in engineering courses, as all the associated competencies and skills can be refined and reinforced with subsequent challenges, as the denoted by the competency level obtained for competencies STA0302 Management of food processes and STA0204 Management of food safety systems, were only 80 and, 40% of the students, respectively, achieved an outstanding level of competency. This also corresponds with the auditors' opinion, who stated that she gathered all her experience over 8 years, in which she fulfilled quality assurance and food safety management roles and finished different courses, certifications, and diplomas, as she mentioned, "*Almost all my work experience has been in quality assurance and food safety, I also have experience with R&D, yet in all those positions I had to implement and develop good manufacturing practices, personnel training, ISO 22000 schemes, global market actions, and HACCP from the start. I have also been audited for certification purposes and have taken many HACCP courses, particularly a course from which I was certified as a HACCP alliance gold seal auditor.*" Therefore, many practice skills are usually mastered through work experience, however, promoting auditing activities in real work environments with the enrichment of continuous education courses during higher education studies is a good starting point for maturing a set of employability skills in engineering students.

The Training Partner validated the final instrument and answered an audit service feedback form, as shown in Table 5 and Supplementary Figure S3. From his role as manager and employer, the training partner denoted her satisfaction with the audit service and the efficiency of exploring all the company's areas. In addition, the Training Partner rated the students with the highest grade in terms of professionalism. This course implementation was relevant from the industrial perspective and helped the Training Partner identify undetected needs and requirements, which led to changes and corrective actions. This is a medullar point for developing

TABLE 5 Translated questions and answers received from the Training Partner through RedJade.

Question	Possible answers	Training partner's answer
Q1. What is your name?	NA	ND
Q2. Regarding the audit service, how do you grade it?	1) Very unsatisfied 2) Unsatisfied 3) Neutral (Neither satisfied nor unsatisfied) 4) Satisfied 5) Very satisfied	Very satisfied
Q3. Regarding the audit deepness, how would you grade its efficiency?		Very satisfied
Q4. What was the professionalism level that the service brought in?	1) Not at all professional 2) Not very professional 3) Neither professional nor unprofessional 4) Professional 5) Very professional	Very professional
Q5. Do you consider it relevant to repeat this audit activity?	1) Yes 2) No 3) Not sure	Yes
Q6. Did you identify any need that had not been detected?		Yes
Q7. Have you made any changes or corrective actions based on the established observations?		Yes
Q8. Have you observed any improvement in the general company's operation?	1) Totally disagree 2) Disagree 3) Indifferent 4) Agree 5) Totally agree	Agree
Q9. As a user, would you recommend this academic activity to other companies?		Totally agree
Q10. How relevant do you consider this academic activity for reinforcing skills related to quality assurance and food safety auditing in students before graduating?	1) Not at all important 2) Less important 3) Indifferent 4) Important 5) Totally important	Totally important

NA, Not applicable, ND, Not disclosed.

employability skills, as the students could propose applicable solutions to a real-life problem without an aged experience or the fulfillment of their engineering studies. Moreover, the Training Partner recommended this activity to other companies and considered this audit exercise as an essential platform for reinforcing auditing skills in students who are close to graduate.

Different outcomes regarding the integration of work-based, project-based and challenge-based learning have been reported and are outlined in Table 6. Different actors are positively affected by this type of implementation. The teacher or instructor has a key role from the academia side as, depending on the higher education institution, he/she could participate in designing the program curriculum and course structure, to include industrial partners and real-life challenges for the students (Stephens et al., 2014.,. Furthermore, the teacher participates as a process facilitator throughout the whole project (Romero-Yesa et al., 2023), where another key aspect is the project selection by the teacher, in which a successful implementation could depend on aspects such as the applicability of the project, the clarity of its requirements and steps, and its relation with the course contents and activities.

In the case of the industrial partner, the collaboration should start under clear terms established by both the partner and the coordinating teacher. At Tecnologico de Monterrey, each course with a project-based challenge has a coordinating teacher, who finds, communicates, and launches the collaboration during the course. In addition, due to their busy agendas and common working speed, industrial partners are interested in straightforward, valuable, and fruitful collaborations, where students can solve real issues with professionalism and respect the company's confidentiality. As observed on the Tec21 model, by informal comments from the students, when industrial partners seem interested, collaborate in an accessible manner, provide the necessary information, and give effective feedback, the students feel more motivated and engaged in their projects and learning process. For those reasons, and because of the existing academia-industry gap, industrial partners not only are relevant for designing challenges for specific courses but are equally necessary for participating and proposing in any curricular design implementation and modifications at higher education institutions (Stephens et al., 2014). In the case of the students, when properly applied, CBL is important for improving their learning experience in terms of engagement and motivation (Detoni et al., 2019; Manresa Matas et al., 2020). Besides, in CBL the students must change their approach to a more autonomous way of solving real-life problems, which allows them to develop transversal and soft skills (Membrillo-Hernández et al., 2021; Doulougeri et al., 2024).

As observed in previous studies, there is a broad understanding and exploration of the role of teachers, students, and industrial partners in challenge-based learning. However, their research is

TABLE 6 Different work, project and challenge-based learning strategies and their main findings.

Programme/Studied group	Country	Implementation	Findings	Reference
Software Engineering	UK	Work-based learning as graduate apprenticeships	Communication with employers is necessary to rethink curriculum design. This communication occurs through collaboration.	Barr and Parkinson (2019)
Business Administration	Spain	Project-based learning	The course was more enjoyable, engaging, promoted deep learning, and skills development. The project required more time to be completed.	Manresa Matas et al. (2020)
Academics, employees and employers	Ireland	Work-based learning	Employers want a partnership that is valuable, does not alter the company's schedule, positively impacts on the employees and the organization, and is based on trust and communication. Employers and academics should participate when designing programmes and curricula.	Stephens et al. (2014)
Electronics Engineering	Mexico	Challenge-based learning with industry training partner	Competency-based learning indicated better results than content-based learning for achieving a competency domain level. An industrial partner was relevant for the student's engagement, motivation.	Dieck-Assad et al. (2021)
Robotics	Spain	Challenge-based learning	The engagement of students is required. Project-based learning and challenge-based learning should consider current required competencies (21st century), and foresee future skills.	Conde et al. (2021)
Electronics	Spain	Challenge-based learning	A successful implementation depends on the role of the teacher as facilitator, a good challenge selection, and the establishment of the stages for solving it.	Romero-Yesa et al. (2023)
Computer science and software engineering	Brazil	Challenge-based learning	CBL can be linked to the students' motivation and engagement. Short implementation times are a constraint, especially for inexperienced students. Teachers have a relevant role in linking students to real life scenarios.	Detoni et al. (2019)
Engineering education	Worldwide (Review)	Challenge-based learning	CBL can be implemented as a course or project, and is more focused on socio technical challenges, as the students acquire knowledge and develop transversal skills. Teachers should align the real-life challenges with the learning objectives, and assume a coaching/scaffolding role, in which the students are autonomous. Both individual and group assessment should consider the learning process and the quality of the generated product. More research is needed on how CBL promotes the development of different skills in students, and the skill qualifications required from teachers to truly assume the aforementioned roles.	Doulougeri et al. (2024)
Mechatronics and Biotechnology	Mexico	Challenge-based learning	CBL is multidisciplinary and teachers commonly encounter challenges when allowing the autonomy in students for solving the project, while adjusting his/her expertise to a very specific challenge. On the other hand, with CBL, students feel more engaged, with a deeper understanding and involvement, as well as being exposed to real-life experiences with scope to practice communication and other skills.	Membrillo-Hernández et al. (2021)

(Continued)

TABLE 6 (Continued)

Programme/Studied group	Country	Implementation	Findings	Reference
Mechatronics	Mexico	Competency-based education and challenge-based learning.	CBL promotes competencies development and promotes the collaboration between the academia and the industry.	Félix-Herrán et al. (2019)
Aerospace Engineering	Spain	Challenge-based learning and concurrent engineering	There is a positive outcome on the students' motivation and overall learning of technical knowledge and soft skills. The teacher-student relationship improved due to the side by side work with the students.	López-Fernández et al. (2020)
Food Engineering	Mexico	Challenge and project-based learning with competency-based learning	The sequenced implementation of auditing-related activities on a real-life challenge provided by an industrial training partner, resulted in the development of auditing skills and recommendations from the students, with similar results to those from an experienced auditor. The students developed satisfactory domain levels in competencies required for auditing and managing an industrial process.	This work

usually focused on one of those roles. In this work, the academic design for this type of implementation was presented as part of the methodology utilized by the implementing teachers. Then, the results from the students were indicated and compared to a result from an experienced professional, which evidenced the effectiveness of this implementation for developing the desired skills not only by assessing the skills according to the learning objectives and the course rubric, but from a professional perspective. Moreover, the training partner's feedback and opinions were recorded, and the skills development was also confirmed from its industrial and professional input. Therefore, this work presents the development of auditing skills from the on-site application of different activities and skills in a real industrial process, whose novelty is related to the assessment and validation of competencies and skills from the feedback and contribution of the different actors involved in the implementation (teachers, professionals and industrial partners).

4 Conclusion

The application of an on-site auditing exercise was relevant for developing auditing skills in the students, which granted similar results to those from an experienced auditor. This validated the efficiency of the exercise for successfully solving real-life problems commonly faced when the students graduate and begin working. This activity was enriched by integrating continuous education materials, which denoted the need to include these contents in higher education curricula to solidify those skills and increase the students' employability. The aforementioned was supported by the opinion of the audited company, which indicated the need for the students to practice these skills before their insertion into the industry. For those reasons, we proposed that continuous education should start at higher education institutions so that professionals can become more competitive and ready to resolve different industrial challenges.

To successfully continue this type of strategy, course transferences should be carried out after the finalization of each semester. This will allow the continuous improvement of the course, especially when a different teacher is expected to apply CBL in a similar class with an on-site auditing project and is expected to obtain similar results. Teacher turnover does not represent the only limitation, particularly in institutions such as Tecnologico de Monterrey, where training partners are constantly changing throughout the semesters, once they fulfill their needs and requirements, and as their real problem gets solved by the students. In this regard, teachers and coordinating teachers should know and meet the collaboration standards for each challenge, through an agreement on the expected outcomes from the collaboration with the industrial partner, as this will result in more clarity for the students and a possible improvement in their learning experience.

Another key aspect to be considered is the integration of online and in-person continuous education courses and certifications that could enrich the learning process and bring the students closer to the real needs, legislation, and solutions to industrial challenges from certified institutions. This is another opportunity for connecting universities with government bodies and certifying organizations, which opens the opportunity for exploring the effect of such collaborations on the acquisition of competencies. Apart from these recommendations, as noted in this work, the overall assessment of competencies and skills could be based on the input from the industrial partner, the teacher's side-by-side monitoring, and a comparative approach based on the performance of an expert auditor.

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 authors.

Ethics statement

The studies were conducted according to local and institutional requirements. The participants provided their written informed consent to participate in this activity and signed a confidentiality agreement with the Training Partner.

Author contributions

RG-G: Writing – review & editing, Project administration, Investigation. CG-C: Investigation, Project administration, Writing – review & editing. RV-L: Data curation, Writing – review & editing, Investigation. VM-M: Data curation, Writing – original draft, Visualization, Conceptualization, Investigation.

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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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Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1416110/full#supplementary-material

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