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Toward a continuous learning educational model: insights from the experience of a Mexican private university

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The rapidly evolving and technology-driven labor market underscores the need for continuous education and lifelong learning to ensure individuals remain adaptable and professionally relevant. It demands institutions that effectively bridge the gap between education and the workforce by promptly and pertinently modifying its programs and curricula, led by educators who are highly experts in specific skills and knowledge, as well as with pedagogical knowledge. In this address, robust educational models become essential. The TEC21 Educational Model (TEC21), introduced in 2019 by Tecnologico de Monterrey, addresses these challenges by fostering disciplinary and transversal competencies critical for success in the professional and personal spheres. This study explores two key research questions: (1) How do students in international experiences perceive the implementation of TEC21's four components—inspiring professors, flexibility, challenge-based learning (CBL), and memorable university experiences—at their home and host universities? (2) How does TEC21 align with the European Commission's Industry 4.0 Curriculum Guidelines? Semi-structured interviews were conducted with 13 Mexican engineering undergraduates during their international study experiences using a cross-sectional qualitative design. The findings reveal that Inspiring Professors—characterized by continuous pedagogical training and deep expertise in industry, consulting, or research—stood out as pivotal in preparing students for complex, real-world contexts. Flexibility and accessibility enable students to balance diverse priorities through hybrid learning environments, a critical feature for lifelong learners. For CBL, the model's emphasis on interdisciplinary, real-world projects fosters employability, although collaboration with socio-formative organizations was less evident at host universities. The Memorable University Experience component highlighted the transformative nature of internationalization despite limited engagement with extracurricular activities and student organizations at host institutions. This study demonstrates TEC21's alignment with the European Commission's Industry 4.0 Curriculum Guidelines, addressing key pillars such as collaboration, quality assurance, and curriculum content. This model can inspire continuous education institutions to bridge the gap between education and industry demands. It equips graduates with adaptability, interdisciplinary collaboration skills, and global readiness, positioning TEC21 as a cornerstone for lifelong learning and sustainable societal advancement in the Artificial Intelligence era.

KEYWORDS

TEC21, competency-based education, educational models, studying abroad experience, higher education, educational innovation, lifelong learning, continuous education

1 Introduction

Over the last decades, higher education has faced multiple challenges demanding urgent attention and innovative solutions to sustain its role in fostering individual growth and societal progress. Access and equity remain significant hurdles; with disparities in enrollment and resources, its role as a social mobility factor has diminished, particularly in developing countries (Vieira Do Nascimento et al., 2020). Simultaneously, funding constraints have forced institutions to rely mainly on tuition fees, exacerbating affordability issues and promoting elite systems (Vieira Do Nascimento et al., 2020; Pascuci and Fishlow, 2023).

Universities have frequently failed to meet the labor market requirements, missing intellectual and practical skills that make them productive and enhance their employability (Vieira Do Nascimento et al., 2020). Furthermore, in the Artificial Intelligence (AI) Era, industries demand a highly skilled workforce under continuous upskilling and reskilling (Li, 2022), especially in technological sectors facing talent shortages and skills gaps (Borisov and Tanțău, 2013; Muller et al., 2014).

This context enhances the United Nations' Sustainable Development Goal 8, which promotes sustainable economic growth, productive employment, and decent work by integrating continuous education and lifelong learning into job culture (United Nations Department of Economic and Social Affairs, 2023; Mejía-Manzano et al., 2022).

The education approach has evolved from a terminal to a lifelong mindset. Continuous education enhances individual motivation, professional development, and societal progress (O'Neill et al., 2015) and is crucial for vulnerable communities such as refugees and migrants (Bagiati et al., 2022). The National Academy of Engineering emphasizes the importance of lifelong learning strategies for engineers (National Academies of Sciences, Engineering and Medicine, 2018). However, challenges include adapting teaching methods for various life stages (Bagiati et al., 2022; National Academies of Sciences, Engineering and Medicine, 2018), keeping interdisciplinary curricula up to date (Bagiati et al., 2022; Qiu, 2011; Ktoridou and Eteokleous, 2014), providing flexible learning options (Bagiati et al., 2022; National Academies of Sciences, Engineering and Medicine, 2018), developing soft skills and deep scientific knowledge (Ktoridou and Eteokleous, 2014; Viegas et al., 2021), implementing effective assessments (Viegas et al., 2021), and offering affordable programs (Bagiati et al., 2022).

Educational models guide trainers and institutions in creating environments that enhance student learning and development through aligned materials, teaching practices, and assessments (Kremneva et al., 2020; Reichenbach, 2016; Vorontsova et al., 2015). In this sense, they are highly useful in continuous education where trainers' proficiency and expertise are so specific that they frequently lack pedagogical knowledge and teaching experience.

In 2019, Tecnologico de Monterrey implemented TEC21, an innovative educational model for higher education, to address the demands of the productive and research sectors and the changing world (Pérez and Campos, 2021). It was developed in response to technological advancements and the need to adapt to economic, social, and industrial demands (de los Dolores González-Saucedo, 2021).

Recognizing the relevance of tertiary education for the development of individuals, societies, and countries, identifying their achievements of TEC21 is imperative, firstly to determine the effectiveness of its implementation by their senior students; secondly, to evaluate whether it is on track to achieve the needs of industry 4.0; and thirdly, to assist in designing evidence-based educational models that guide institutions and trainers in addressing the needs of lifelong learners.

The following questions guided current research:

1. How do students in international experiences perceive the implementation of the TEC21 educational model's components (inspiring professors, flexibility, challenge-based learning, and memorable university experience) at their home and host universities?
2. How does the TEC21 educational model, particularly its four pillars, align with the Industry 4.0 Curriculum Guidelines established by the European Commission?

We aimed to offer innovative strategies and effective practices to help educational stakeholders, institutions, and governments design educational models for continuous education.

2 Theoretical framework

The term "educational model" can be defined in various ways, including theoretical frameworks (Gardner, 2006), curriculum designs (Rao et al., 2014), didactic approaches (Levett-Jones et al., 2010), learning models (Rauth et al., 2010), and delivery methods (Lopez-Garcia et al., 2019). An educational model guides institutions and educators in organizing and strategizing to achieve desired academic outcomes (Bagiati et al., 2022). Professors and trainers in lifelong education need specific competencies for innovative teaching methods, which often do not align with having pedagogical content knowledge (Zhu et al., 2013).

Higher education institutions frequently prioritize pedagogical experience and postgraduate credentials over requiring formal pedagogical education for hiring professors (Kovshikova et al., 2019). This preference may stem from the need for specialized knowledge and the research-based belief that professors with deep content expertise enhance student learning and achievement (Filgona et al., 2020). Professors with solid pedagogical content knowledge are better equipped to address students' needs, foresee misconceptions, and provide clear explanations (Filgona et al., 2020; Heinonen et al., 2023).

However, student engagement and outcomes can suffer without effective pedagogy, and active learning strategies may be underused (Crisol-Moya et al., 2020). Therefore, robust educational models are essential for higher and continuous education. Adhering to educational model guidelines becomes particularly important when trainers lack pedagogical skills.

2.1 The components of education according to the TEC21 model

TEC21 emerged as Tecnologico de Monterrey's response to the educational challenges and opportunities of the 21st century. Four components or pillars sustain its values: inspiring professors,

flexibility, challenge-based learning (CBL), and memorable university experience (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2018; Membrillo-Hernández et al., 2021). While CBL and competency-based education pivot TEC21's pedagogical approach, the other components are structural reforms that permit the transition toward an integral education (Olivares et al., 2021).

2.1.1 Inspiring professors

According to Tecnologico de Monterrey (Tec), the profile of a TEC21 professor, lecturer, or instructor encompasses five characteristics: inspiring, updated, connected, innovative, and digitally competent.

Faculty members should inspire and motivate students to excel both academically and personally. According to Berikkhanova et al. (2015), effective educators promote professional success and self-improvement while staying updated with current pedagogical methods and advancements in their fields.

Additionally, TEC21 educators are distinguished by their active engagement in their professional fields. Participation in programs such as research projects supports professors' professional development and helps them connect students with networks, internships, and real-world experiences (Guerrero-Hernández and Fernández-Ugalde, 2020).

Lastly, professors must possess innovative pedagogical resources and proficiency in computational and information technologies (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2018). They must also effectively use technological resources, as the integration of information technologies in education is increasingly replacing traditional methods (Khaled et al., 2022). This necessity compels professors to continually train in emerging technologies and teaching strategies, greatly enhancing their teaching performance.

Tecnologico de Monterrey has funds called Novus to carry out educational innovation projects (Portuguez-Castro et al., 2022). Sotelo et al. (2023) and Ramirez-Lopez et al. (2021) highlight several innovations that occurred in the classroom. Almanza-Arjona et al. (2019) contribute by adding a research perspective to teaching innovation.

2.1.2 Flexibility

TEC21 emphasizes flexibility, allowing students to personalize their learning experience. The model's curricular pathway comprises the phases of exploration, focus, and specialization (Olivares et al., 2021). It draws inspiration from Stanford's 2025 project (Munro, 2019). In the exploration stage, students are introduced to their field of study to determine their interests. The focus stage involves learning and experiencing the chosen professional environment, while the specialization stage offers options for more profound apprenticeship through research, internships, exchange programs, or specific courses.

Technology advancements support flexibility in TEC21, including various teaching formats and modalities for student participation and homework submission (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2018; Membrillo-Hernández et al., 2021). This approach enables learning anytime and anywhere (Veletsianos and Houlden, 2019) and has proven beneficial during the COVID-19 lockdown (Chans et al., 2023). The model supports face-to-face, hybrid, or online lectures, with materials and assignments delivered physically or digitally via a learning management system (LMS). This format aligns with Education 4.0, which advocates for adaptable and flexible higher education programs providing personalized content (Miranda et al., 2021).

2.1.3 Challenge-based learning

The CBL component is central to TEC21, emphasizing the acquisition of knowledge, abilities, attitudes, and values through solving real-life "challenges" (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2018). CBL involves analyzing unresolved real-world situations, fostering problem-solving skills, and understanding requirements for solutions rather than simply solving the problem (Membrillo-Hernández et al., 2019; van den Beemt et al., 2023).

This active-learning approach promotes multidisciplinary abilities, creativity, and leadership in a team-oriented environment, reflecting today's collaborative work settings (Olivares et al., 2021). Challenges in TEC21 are realistic experiences where students tackle relevant, complex cases in their fields of study, enhancing competencies like collaboration and innovation (Gallagher and Savage, 2020).

CBL's roots are in experiential learning, suggesting active participation in open-ended experiences where theory meets practice is more beneficial than closed-structured activities (Kong, 2021). This freedom allows students to explore, research, and discover unique solutions (Moore, 2013). Challenges are often designed in collaboration with social partners, including non-governmental organizations (NGOs), governmental institutions, or companies, to leverage students' perspectives and abilities.

Challenges are implemented in special interdisciplinary courses called blocks. For example, engineering students in the exploratory stage engage in blocks requiring contributions from mathematics, computers, and physics. In contrast, like mathematics, single-discipline subjects use contextualized projects known as "problem situations." (Olivares et al., 2021).

Regarding evidence of the student's competencies, TEC21 includes various products or deliverables, like oral presentations, videos, project reports, prototypes, and even argumentative exams; meanwhile, this model also applies a variety of evaluation instruments like observation scales, checklists, and rubrics (Membrillo-Hernández and García-García, 2020).

2.1.4 Memorable university experience

This component refers to creating the best university experience through four dimensions:

a. *Personal Dimension:* This dimension focuses on students' engagement in personal growth within their learning environment (Gruppen et al., 2018). During "Week 18" periods, students refine their expectations and objectives as autonomous individuals. Throughout their academic journey, students are supported by mentors and program directors who assist with educational and personal challenges (Olivares et al., 2021).

b. *Social Dimension*: Seeks to enhance relationships through co-curricular activities facilitated by the LiFE program (*Liderazgo y Formación Estudiantil*; Leadership and Student Formation) (Olivares et al., 2021; Gruppen et al., 2018). These activities foster personal and academic growth, self-identity, self-confidence, work ethic, and academic performance (Gibbs et al., 2015) while developing emotionally, physically, and spiritually self-regulated students who uphold values such as honesty, responsibility, and respect (Olivares et al., 2021).

c. *Organizational Dimension:* Provides structured support through curricular materials, accreditation guidelines, and organizational policies, offering opportunities in internationalization, entrepreneurship, research, and leadership. Student mobility, an essential aspect of internationalization, offers academic, cultural, and social opportunities, fostering personal growth, cultural sensitivity, and adaptability (de Wit and Altbach, 2021; Streitwieser and Light, 2018). Students can participate in international exchanges with over 500 host universities on five continents. It promotes professional development through networking and global industry practices, encouraging lifelong learning (Yılmaz, 2019; Jibeen and Khan, 2015; Drake et al., 2015; Cheng, 2016).

d *Physical and Virtual Spaces:* TEC21 supports learning in both physical and virtual environments, such as online and offline courses, and provides resources and facilities for exercise, meditation, and well-being. The shift to online learning during the COVID-19 pandemic highlighted the importance of virtual spaces, enhancing technological skills and knowledge for both students and professors (Olivares et al., 2021; Aristovnik et al., 2023).

2.2 Educational models for continuous education

The Fourth Industrial Revolution relies on automating production methods (Oosthuizen, 2022), exponentially increasing the use of digital tools like robots, cobots, the Internet of things, telecommunication systems, data centers, high computational power, and energy consumption (Raja Santhi and Muthuswamy, 2023). This evolution demands reshaping education from traditional methods to new mindsets and competencies. To exemplify this statement, García and de los Ríos (García and Ríos I, 2021) emphasize the need for new educational methods to help graduates adapt to the digital transformation era, addressing the lack of essential competencies for sustainable practices.

The European Commission proposed Curriculum Guidelines for Industry 4.0 (European Commission, 2020), focusing on the new industrial paradigm. This framework provides educational stakeholders a base for developing curricula to meet Industry 4.0 workforce needs. The governing body aims to guide the creation of new academic programs and the improvement of existing ones.

Once the values, purposes, and foundational documents of the educational or training institution have been defined, the guidelines established by the European Commission related to the institutional strategy framework are:

1. Collaboration. It enhances collaboration between educational institutions and other societal representatives.
2. Recognition. It includes formal and informal acknowledgment of the skills and competencies learners acquire during training.
3. Quality Assurance. It identifies key factors in education and training quality to align with the expectations of both students and employers.

The guidelines related to the educational model are:

4. Curriculum Content. It continuously updates educational resources to ensure they remain pertinent and reflect the competencies required for Industry 4.0.
5. Learning Environment. It fosters a setting that supports interdisciplinary study, encourages critical analysis, and stimulates innovation.
6. Delivery Mechanisms. It leverages diverse educational technologies and platforms to impart knowledge effectively and efficiently.
7. Assessment. It develops various evaluation methods to effectively measure skills and competencies acquisition.

A noteworthy case that fulfills these guidelines is the Massachusetts Institute of Technology's (MIT) framework proposal called Agile Continuous Education (ACE). Concerning institutional strategies, ACE proposes:

- A range of modalities: online, on-site on campus, and at work.
- The possibility to customize their learning path based on the student's preferences, employer needs, or career goals.
- The possibility of earning credentials along their learning path that can subsequently accredit a full-time academic program.

ACE's educational model has three components: individual, group, and real-life mentored learning. Learners must experience all three modalities: individual courses to build a digital portfolio, group activities like hands-on, project-based sessions, and mentored real-life learning through apprenticeships or university/industry projects (Bagiati et al., 2022).

Multiple studies have evaluated the design, implementation, and outcomes of the Tecnologico de Monterrey educational model. However, this model aims to prepare students for future labor and societal demands, for which a lifelong learning mindset is fundamental (Mejía-Manzano et al., 2022). The present work contributes to this existing body of knowledge, identifying how the TEC21 proposal can inspire continuous education models.

3 Methodology

3.1 Objectives and study design

This study aims to gather evidence from students' perspectives on the TEC21 Educational Model (TEC21) in an international study context to assess its proper implementation. For this purpose, we conducted a cross-sectional qualitative study in November 2022. Additionally, it aims to identify whether TEC21 offers a possible pathway to define

educational models for continuous education through a comparison with European Commission curriculum guidelines for Industry 4.0.

3.2 Participants

Through a non-randomized convenience sampling approach, this study's participants were 13 Mexican students enrolled in a course called "Immersion Week 18." This course, held at the end of each semester, serves as a means of reflection and feedback on the learning outcomes of the entire semester (Caudillo, 2023).

Participants were required to meet the following criteria:

- Be undergraduate engineering students in their seventh semester at Tecnologico de Monterrey.
- Be enrolled in a study abroad program facilitated by Tecnologico de Monterrey at the time of the interview.
- Be at least 18 years old at the time of the interview (the minimum age for Mexican citizenship).

Several studies have been conducted to find how many interviews are necessary to saturate the results and obtain a broad enough range of opinions. Firstly, considering Guest et al.'s framework (Guest et al., 2006), a population of at least 12 individuals is sufficient to saturate the study satisfactorily. Furthermore, Cobern and Adams (2020) argued that population size is not as crucial for qualitative studies as it may be for quantitative studies, concluding that a number between 15 and 20 interviewees is adequate to explore most answers or opinions. Finally, through a systematic review, Hennink and Kaiser (2022) determined that qualitative studies with a homogeneous population tend to achieve saturation within 9–17 interviews. Thus, the study's sample size is sufficient to present satisfactory qualitative results.

3.3 Interview design

Semi-structured interviews with the participants were conducted in Spanish via online video conferencing since they were abroad during their semester. Each interview session lasted between 45 and 60 min and was recorded in MP4 video format. Before the interview, the students were informed about the purpose of the research, the anonymity of their responses, and their rights to pause the interview at any moment; they also provided their informed consent to record the conversation.

The interview consisted of open, unbiased questions to gather their demographic information and perspectives on the TEC21's four components during their international experience. Concerning the current object of study, besides the demographic questions (biological sex, program, semester, host country, and host university), the key questions regarding the components were the following:

1. How flexible is the educational offer from your host university? For instance, the format of the courses, activities, projects, and learning materials.
2. What is the teaching and evaluation approach in your courses? For instance, lectures, theory-practice, challenges, exams/projects, etc.
3. How do other social entities (industries, non-governmental organizations or NGOs, civil society, government, etc.) participate in your education?
4. What are the advantages or disadvantages of having worked with challenges?
5. How would you describe the vivency and university experience at your host university? Have you participated in student groups, extracurricular activities, or special events for international students?
6. What has been your biggest challenge in being part of this international experience?
7. What is your perception of the teaching strategies and lecturer's expertise?

3.4 Data collection and analysis

We performed a content analysis using the transcripts of the interview video recordings. We categorized and summarized valuable information, including demographic details and comments on TEC21's components. This organization facilitated the identification of the participants' perceptions regarding each of the four pillars of TEC21 during their internationalization experience. It allowed us to systematically identify themes and patterns for implementing this educational model. To further ensure the robustness of the findings, a second author independently reviewed and validated the categorized themes.

We used a dual-review process of publicly available documents and scholarly publications to conduct a robust comparative analysis of TEC21 with Curriculum Guidelines for Industry 4.0 (European Commission, 2020). The main objective was to benchmark TEC21 initiatives against global best practices and recommendations for lifelong training and continuous education programs. The process involved an independent comparison of both frameworks by two researchers. Each researcher critically examined TEC21 components and Industry 4.0 Guidelines, interpreting their features, outcomes, and objectives. Later, the researchers engaged in a collaborative discussion to resolve discrepancies and arrive at a consensus on the definitive findings.

To strengthen the validity of the results, we performed methodological triangulation by incorporating multiple data sources. In addition to interview transcripts, public institutional documents (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2018; Olivares et al., 2021) and published literature (Membrillo-Hernández et al., 2021; Miranda et al., 2021; Molina et al., 2022; Bautista, 2024; Zavala, and editor Integration of physics, mathematics and computer tools using challenge-based learning, 2020) were analyzed to corroborate the identified patterns. This combination of qualitative and quantitative data gave a more comprehensive understanding of TEC21's implementation.

4 Results and discussion

4.1 Demographic information of the study sample

Following the guiding principles established in the Methodology section for the study sample, demographic data was collected to

TABLE 1 Demographic data of the sample gathered for the present study.

Participant ID	Age	Biological sex	Current undergraduate engineering program	Host country	Type of host university
1	21	Male	Industrial and systems	Argentina	Private
2	21	Male	Industrial and systems	Germany	Private
3	22	Male	Mechatronics	Netherlands	Public
4	21	Female	Industrial and systems	Germany	Public
5	22	Female	Mechatronics	Spain	Public
6	21	Female	Industrial and systems	Spain	Public
7	21	Male	Industrial and systems	Germany	Public
8	21	Female	Industrial and systems	Sweden	Public
9	21	Female	Industrial and systems	England	Public
10	21	Male	Industrial and systems	Germany	Public
11	21	Female	Industrial and systems	Spain	Public
12	22	Female	Mechatronics	Austria	Public
13	21	Female	Industrial and systems	Chile	Public

characterize and better understand the participants' context (Table 1). The participants were senior engineering students visiting universities settled in the European Union and Latin America. Gender equity was neither achieved nor required for our work; there were more females than males.

4.2 The perception of senior students of the TEC21 educational model during their study abroad stay

4.2.1 Students' perception of the inspiring professors component

Regarding the inspiring professors' component, our findings support the claims of Filgona et al. (2020) and Kovshikova et al. (2019) regarding higher education institutions' high standards for employing faculty members, prioritizing credentials and pedagogical experience. They also align with Guerrero-Hernández and Fernández-Ugalde (2020) statement about professors' active engagement in their professional fields. In this matter, well-engaged professors benefit students in gaining professional connections.

Ten participants reported that professors at host universities held master's or doctoral degrees. Additionally, eight professors were involved in activities complementary to their teaching, such as research, consultancy, entrepreneurship, or leading roles within public or private organizations.

In terms of pedagogical approaches, the host university professors employed a variety of teaching strategies. Six participants mentioned collaborative work, three mentioned case studies, four mentioned gamification, and two mentioned debates or discussion forums. Most of them alternated these methods with slide-assisted lectures. Only one participant indicated that all his courses were based exclusively on lectures. These findings align with those of Perez-Encinas and Rodriguez-Pomeda (2018), who highlight good teaching as a crucial aspect that students studying abroad value, including the requirement for qualified professors who use appropriate teaching methodologies and fair evaluations.

These results suggest that an educational model incorporating well-qualified and professionally engaged professors is valuable for fostering students' employability and lifelong learning. The literature demonstrates that continuous education institutions emphasize faculty credentials, proficiency, and expertise; however, guidelines for effective and varied teaching techniques centered in adaptable skill-based education will enhance learners' readiness to thrive in evolving professional landscapes.

4.2.2 Students' perception of flexibility

The Flexibility Component of TEC21 gives students choices regarding when, how, where, and from whom they learn. Two key approaches define this component: the delivery mechanisms and educational resources (Salas Rivas et al., 2022) and the academic path for personalization (Olivares et al., 2021; Casanova et al., 2019). Our findings primarily focus on the first approach, emphasizing the lesson formats that students encountered during their international experiences.

Our study found limited evidence of flexibility concerning learning environments and delivery methods in the participants' experiences at foreign universities. Ten students reported having only face-to-face lessons, while the remaining three participants—4, 8, and 12—experienced a combination of face-to-face sessions and remote coursework for specific courses. About the lessons' format, interviewees 8 and 12 provided the following comments:

> "*Yes, they are synchronous [face-to-face], and some are hybrid. [...] It depends on the subject. [...] In the hybrid courses, for example, the professor delivers the lecture. Still, when it comes to working on the final project or explaining something that is not exactly a lecture but rather a contribution to the work, they require everyone to be [physically] present. This is done through 'Teams', the platform they use here [...]. The professor also conducts the course with two other professors who are not physically present in Sweden [...].*" —Student 8.
>
> "*They have been... in some subjects; for example, four in-person and one hybrid day. But there were times when the lecturers could*

> *change it, so they would say, 'We are going to be in-person all week.' It depended on the lecturer's preference.*" —Student 12.

Student 4 described two distinct types of courses: one was entirely face-to-face, while the other employed a variable format. In the latter, professors decided whether to incorporate online lessons alongside traditional in-person sessions each week. This flexible format was exclusively available to international students, whereas local students attended only face-to-face lessons.

Accessibility to learning materials and flexible delivery formats are vital for continuous education due to the imperatives of lifelong learners. TEC21's flexibility was fundamental during the COVID-19 pandemic, enabling Tecnologico de Monterrey's successful continuity despite the lockdown (Molina et al., 2022).

While learning materials accessibility was not a topic during the interviews, it is notable that only four participants were aware that their professors recorded lessons to provide learning materials accessible outside the classroom. Participants 2, 8, 9, and 12 responded positively when asked if their classes were recorded. Taking students 2 and 9 responses as evidence:

> "*Yes, all the classes are recorded. For example, if I'm studying for an exam and have a question about a specific session, I can access the platform where all the recordings are stored and watch the replay of the class.*" —Student 2.

> "*Yes, they upload the recording of the presential session […]. We can watch them through Canvas.*" —Student 9.

This practice has sparked discussions among higher education institutions, particularly during the mentioned pandemic, addressing privacy (Turnbull et al., 2021) and intellectual property (Gilmour and Barranco, 2021). However, this strategy could significantly expand the reach of education, akin to the Massachusetts Institute of Technology's OpenCourseWare initiative (Massachusetts Institute of Technology, 2024), by adopting a flexible approach that makes education more accessible, inclusive, and equitable (Veletsianos and Houlden, 2019).

Regarding the evidence of learning outcomes, eight participants reported that their host universities accepted reports and oral presentations as valid assessment methods. For example, interviewee 3 expressed being evaluated by both techniques. When asked about the type of submissions he was asked:

> "*Reports. We are required to complete the project, and at the end, we prepare an individual 10-page report with only content, no images. Then the report is submitted, and we give an individual presentation.*" —Student 3.

Additionally, 12 participants observed that individual face-to-face exams remain the most common evaluation form. Using the responses of interviewees 5 and 10 as evidence for this result:

> "*The exams are presented individually […]. They are held during class, and so far, they have all been on paper.*"—Student 5.

> "*Yes, the entire exam is individual […]. We attend the and take the exam right there […]. All exams are printed.*"—Student 10.

These findings highlight the critical role of flexibility in educational delivery mechanisms and resources as a key component for continuous education. While participants' experiences at foreign universities revealed limited evidence of adaptable learning environments and formats, the TEC21 model stands out as a forward-thinking framework that addresses the evolving needs of lifelong learners. Institutions offering continuous education must remain attentive to these changing requirements when developing new programs, curricula, or training that prioritize efficient and accessible approaches (Miranda et al., 2021). By enabling hybrid delivery, personalized learning pathways, and expanded access to educational materials, TEC21 not only fosters inclusivity and accessibility but also meets the demands of educating for an increasingly dynamic and interconnected world.

4.2.3 Students' perception of challenge-based learning

Solbrekke and Helstad (2016) emphasize the significance of employing diverse teaching approaches in nurturing students as future professionals. Participants identified several teaching approaches in their courses when discussing how students learn at the host international universities. Two participants (Students 5 and 12) strongly emphasized hands-on learning and laboratory practices, while four others focused on theoretical instruction. Three participants experienced a balanced integration of theoretical and practical teaching methods. The differentiation between teaching approaches becomes evident in the following responses from Students 5, 6, and 11:

> "*For a class, I have weekly readings and practices related to the week's topic. We get questions that require research and must also answer the practice. For example, in programming, before and after each class, we create small programs related to the topic […].*" —Student 5.

> "*Most of them are theoretical tasks that involve researching information […]. And the majority are done in teams*" —Student 6.

> "*Sometimes they involve presentations, essays on a topic, or research to submit on the platform. We also have quizzes, but it depends on the subject. For instance, last Friday, I had three quizzes and a presentation. There are also individual tasks, like summarizing a reading, topic, or lecture […]. Quizzes are theoretical, but I have also had a completely practical exam.*"—Student 11.

However, nine participants (students 1, 2, 4, 6, 7, 9, 10, 11, and 13) explicitly stated that their host universities did not incorporate challenge-based or problem-based scenarios. Although these students frequently engaged in team projects, they pointed out the absence of assignments that resembled challenges when reflecting on their experiences abroad. In contrast, only participants 3, 5, 8, and 12 reported working on projects with a similar format to that of TEC21. Examples that evidence the disparity of project formats are the responses from participants 3 and 7 when they were asked if they had worked with problem situations or challenges as they did commonly at TEC:

> "*Yes, we work with challenges.*"—Student 3.

> "*No, for what I know, there is nothing similar to that [challenges or problem situations].*"—Student 7.

Teamwork, or collaborative work, is crucial for CBL. While all 13 respondents participated in team projects or collaborative learning, few specifically mentioned engaging in a CBL approach, and none reported taking interdisciplinary courses similar to the TEC21 blocks (Zavala, 2020). Although teamwork within project-based learning is beneficial for student learning (Parrado-Martínez and Sánchez-Andújar, 2020), one of the critical advantages of CBL is its emphasis on multidisciplinary collaboration (Gallagher and Savage, 2020; Mesutoglu et al., 2022), an essential skill in the modern workplace.

The presence of partnerships with external organizations is a critical element that fosters continuous education through CBL, as highlighted by TEC21 (Membrillo-Hernández et al., 2021; Bautista, 2024). Interestingly, only Student 12 confirmed the existence of projects that involved collaboration with a socio-formative organization in their host university:

> "[…] *We have not interacted yet. I think it's because of the type of program we are in. However, outside my building are the automotive and aerospace areas. They sometimes have car prototypes there, and they work with Red Bull.*"

In contrast, the other participants acknowledged that their host universities maintained active relationships with NGOs, government organizations, and industries, but none reported collaborating with these entities on their projects. The absence of such partnerships during challenges likely led students to perceive their projects as routine schoolwork rather than meaningful endeavors recognized by external entities. According to Kong (Kong, 2021), engaging students in experiential learning, where they apply knowledge to real-world situations relevant to their professions, is highly beneficial. This approach encourages active learning, deepening students' understanding and retention of the material.

Student 10 provided insight into the teaching approach at their host university when talking about how they work with challenges or similar methods:

> *"No, we do not work [with challenges] here. The closest thing we have to that is when they give us already-made case studies. But as far as challenges or problem-solving situations, we do not focus on them [...]. It's mostly theory and the projects they assign us.*"

Regarding the advantages or disadvantages of working with challenges, he affirmed:

> *"I believe that the advantages of working on challenges at Tec have given me a better understanding of how things work in the real world compared to my peers here who have only studied theory [...]. The only downside is that the pace can be quite fast.*"

Similarly, other participants described their work at host universities as homework, case studies, or simple group projects confined to a single discipline. Most participants noted the absence of an interdisciplinary approach in these assignments, contrasting with the CBL they experienced in TEC21, as described by Zavala (2020). Student 13 provided a meaningful answer about her perception of the coursework she had to do during her stay at the foreign university:

> "*In class, we do activities, but they are basically homework assignments you can complete during class or take home. However, they are very few compared to those at Tec […]. They are mostly theoretical, based on what we learn in class.*"

In summary, implementing CBL in TEC21 enabled participants to recognize several advantages of this teaching-learning methodology. Their observations highlighted the benefits of hands-on learning, collaborative work, and interdisciplinary and societal involvement in education. Developing these disciplinary and transversal skills is highly valued by future employers (Membrillo-Hernández et al., 2021; Membrillo-Hernández et al., 2019) and lifelong learners, positioning CBL as a valuable component of an educational model for continuous learning (Mejía-Manzano et al., 2022; Membrillo-Hernández et al., 2024).

4.2.4 Students' perception of memorable university experience

As the theoretical framework outlines, this component aims to provide an exceptional experience for Tec students, primarily through student communities, extracurricular activities, and exclusive events organized by the institution (Olivares et al., 2021; Gruppen et al., 2018). However, three participants reported their absence when talking about student communities within their host universities, and two were uncertain. Even though eight students acknowledged the existence of such groups, they were unclear about the specific activities available, and most expressed little interest in participating or cited other reasons for not doing so. An interesting example of this last case was Student 1. He described a specific student community and its activities, but he did not take part in any of the events:

> "*Yes, there's an Economics Club. I did not join, but they organized various activities. A big dinner was one of the main ones; each table had an economist with some political relevance in Argentina. They would talk with students. I did not participate, so I cannot say much more.*"

This trend was also observed in their perception of extracurricular activities at their host universities. While nine students knew about these events, only two had ever participated. The following responses to question 6 about extracurricular activities illustrate this finding:

> "*Yes, there's the basketball team, the soccer team, the choir group, the singing group [...] I have not [participated]in those, no.*"—Student 8.

> "*Yes, there are many sports; there are many options—[...] Artistic... yes. I saw an invitation to participate in something musical in the mail, but honestly, I wasn't interested. [...] But as for participating, honestly, no.*"—Student 11.

The participants' responses cannot fully explain their lack of interest in extracurricular activities or student communities. However, it is possible that this phenomenon arose mainly from the inherent challenges of being an exchange student —foreigners navigating an unfamiliar cultural landscape. While most participants acknowledged

the overall value of their international experience, they all reported difficulties adapting to the new academic and social environment. Specifically, linguistic barriers related to comprehension and expression emerged as the primary challenge for four participants, while five noted struggles with living independently. Six participants faced complications adjusting to a distinct educational system or field of study. Additionally, several reported difficulties with cultural and social integration, and one individual mentioned experiencing loneliness.

Studying abroad—or participating in other forms of international experiences— plays a crucial role in developing transverse competencies, a core objective of the TEC21 model (Chans et al., 2023). These experiences foster outcomes ranging from multilingual and professional aptitudes to cross-cultural competencies, encompassing cognitive, behavioral, attitudinal, and global awareness outcomes (Iskhakova and Bradly, 2021). Such competencies are increasingly essential as "Skills for the Future" in modern professional and academic contexts (Ehlers, 2020).

Given these circumstances, participants may have prioritized academic performance and the unique learning opportunities provided by immersing themselves in a foreign culture over engaging in extracurricular activities or joining organizations offered by host universities. In this context, studying abroad reflects TEC21's commitment to creating diverse learning environments and experiences that promote students' personal and academic growth.

TEC21 prepares its learners to navigate complexity, embrace innovation, and adapt to evolving professional landscapes by integrating structured academic activities with cross-cultural encounters and international learning opportunities. Although the degree of student engagement in international experiences may vary, these opportunities collectively nurture a global mindset, enhance linguistic proficiency, and foster intercultural adaptability—attributes vital for both professional success and personal development.

In summary, despite the differences between higher education and continuous education, providing diverse environments, activities, and communities positively impacts learning outcomes. Regarding economic constraints (Iskhakova and Bradly, 2021), particularly in developing countries, one viable solution is implementing online alternatives, such as Collaborative Online International Learning (COIL) (Montaño-Salinas and Páez-Borrallo, 2023).

4.3 TEC21 educational model alignment to the industry 4.0 curriculum guidelines

To identify strategies for optimizing the implementation and outcomes of continuous education, we analyzed TEC21 compared with the European Commission's Industry 4.0 Curriculum Guidelines. Figure 1 highlights how TEC21's components align with these standards and shows which components were recognized by senior students during their international study experience.

TEC21 aligns seamlessly with every Industry 4.0 Curriculum Guideline established by the European Commission (European Commission, 2020). Figure 1 outlines how each component of this educational model addresses the various Industry 4.0 Curriculum Guidelines, as supported by institutional documentation and validated through student experiences during internationalization. This alignment is promising, demonstrating that once a continuous education institution is firmly rooted in foundational values, principles, and policies, TEC21 can be an inspiring and effective educational model.

"Collaboration" with other institutions and societal representatives is a core feature of TEC21, exemplified by the engagement of socio-formative partners across various formation units and academic semesters. These partnerships—from government agencies and

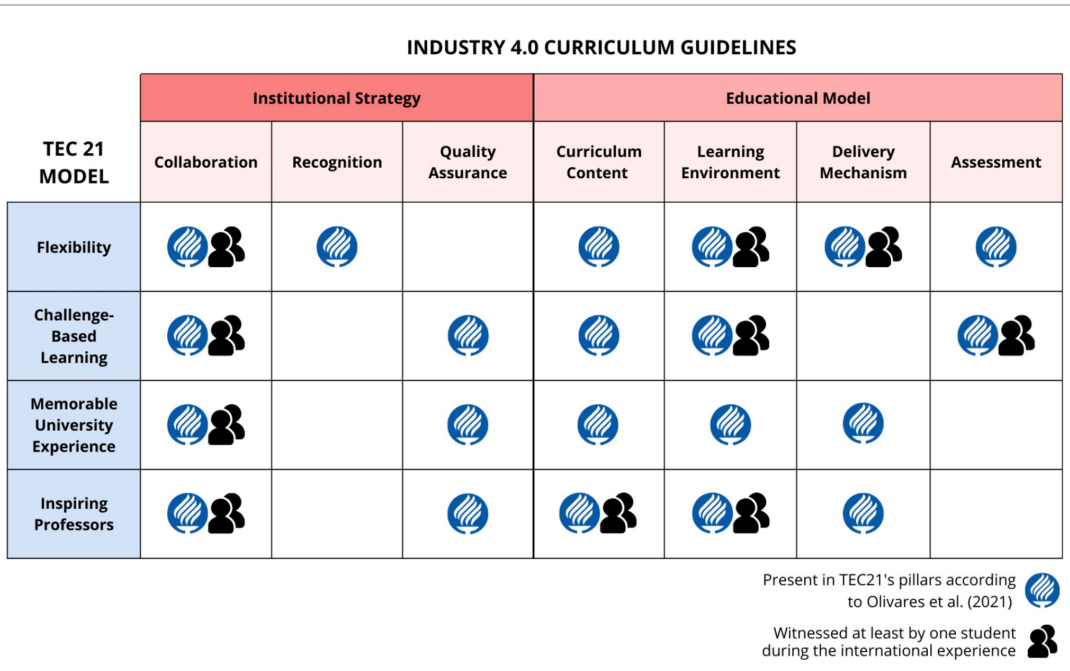

FIGURE 1
Comparative analysis of how the four components of the TEC21 Educational Model address every Industry 4.0 Curriculum Guideline (European Commission, 2020), preparing students in higher and continuous education for the demands of Industry 4.0.

non-governmental organizations (NGOs) to industry leaders and enterprises—provide real-world contexts for students, facilitating hands-on, experiential learning and engaging students in addressing local and global challenges. By integrating these collaborations into the curriculum design and implementation, TEC21 aligns seamlessly with the Industry 4.0 guideline on relevant and updated competencies for the labor market; it ensures learners are equipped to navigate complex, collaborative environments, bridging disciplines and industries. Moreover, TEC21's partnerships extend beyond traditional coursework to create pathways for continuous education, such as offering industry-aligned learning objectives, internships, and mentorship opportunities.

Regarding "Recognition," TEC21 incorporates digital badges and credentials to acknowledge various achievements and certifications. For instance, participation in Collaborative Online International Learning (COIL), particular entrepreneurship challenges, and specific Massive Open Online Courses are recognized through digital credentials (Farías-Gaytán et al., 2023). These credentials not only serve to validate learners' accomplishments but also provide a tangible measure of their competencies. However, this strategy should be extended to other courses and workshops since it is particularly significant in continuous education and lifelong learning, where micro-credentials and skill-based recognitions often supplement formal degrees.

Continuous education must implement "Quality Assurance" daily and transversely across all institution levels. In this address, CBL, in collaboration with socio-formative partners, ensures that the curriculum remains current and aligned with labor market demands. The hands-on learning, interdisciplinary teamwork, and real-world environments that characterize CBL create memorable learning experiences, promoting significant learning and strengthening disciplinary and transversal skills in the students. These skills are highly valued by employers (Membrillo-Hernández et al., 2021; Membrillo-Hernández et al., 2019) and, therefore, by lifelong learners, positioning CBL as a valuable component of an educational model for continuous learning (Mejía-Manzano et al., 2022; Membrillo-Hernández et al., 2024).

Senior employees or experts often become trainers in continuous education despite lacking formal pedagogical training (Sarkar et al., 2024). Therefore, the credentials, content knowledge, and pedagogical expertise of professors and instructors are especially relevant to the Industry 4.0 guideline on quality assurance. The "inspiring professors" component ensures that educators possess a basic competency in diverse teaching and assessment methods, essential for providing a quality education that meets the needs of a diverse range of lifelong learners (Berikkhanova et al., 2015).

The Industry 4.0 Guidelines stress the importance of relevant "Curriculum Content" aligned with the workforce's and society's evolving needs. As indicated in Figure 1, each TEC21 component plays a vital role in addressing this guideline. Flexibility ensures an accessible curriculum that can adapt to emerging technologies and individual learning needs. CBL grounds the curriculum in real-world challenges and interdisciplinary knowledge, reflecting the latest industry trends. The emphasis on creating a Memorable Learning Experience ensures students are engaged, motivated, and prepared for lifelong learning. Lastly, inspiring professors ensure an expert-driven curriculum design, providing the curriculum is academically rigorous and practically relevant.

TEC21 components collectively create a "Learning Environment" well-aligned with the Industry 4.0 Guidelines. Flexibility allows the environment to adapt to lifelong learners' diverse learning needs, schedules, and budgets. CBL transforms the learning environment into one that mirrors real-world industry settings, fostering collaboration and innovation. The emphasis on a memorable learning experience ensures an empathetic, engaging, and motivating environment that extends into professional applications. Finally, inspiring professors fosters an intellectually stimulating and supportive learning environment, equipping students with the skills and mindset needed to thrive in the Industry 4.0 era.

Enhanced by technology, TEC21 creates a robust and dynamic "Delivery Mechanism" for continuous learning and professional development. Integrating flexibility, memorable learning experiences, and inspiring professors meets the needs of modern learners. Flexibility supports adaptive and blended learning models that allow students to personalize their education. These technologies enable access to learning material anytime and anywhere, allowing lifelong learners to balance their professional and personal commitments. Meanwhile, memorable learning experiences trigger engaging, immersive, and community-oriented educational environments enhanced by digital tools that bring interactivity and global connectivity to the classroom. Complementing this, inspiring professors leverage technology to deliver innovation and personalized instruction, ensuring that learners are well-prepared to meet the demands of Industry 4.0.

Regarding "Assessment," TEC21 redefines traditional evaluation approaches by integrating flexibility and CBL components. Flexibility offers students several options for where and when evaluation occurs, suiting their busy schedules and responsibilities. On the other hand, CBL goes beyond traditional examination methods by encouraging learners to tackle complex, real-world problems that require alternative evaluation methods, often from an argumentation-driven perspective (López-Guajardo et al., 2023). These methods, including self- and peer assessments (Badea and Popescu, 2019) and process-focused, content-based, and portfolio assessments (Tai and Yuen, 2007), are particularly effective in evaluating the interdisciplinary knowledge, collaborative efforts, and entrepreneurial mindset required in Industry 4.0 (Lazendic-Galloway et al., 2021). Through this technological integration, TEC21 positions itself as a forward-thinking educational model that prepares learners for continuous growth in an interconnected, innovation-driven world.

5 Limitations

TEC21 was initially designed for higher education, but our study explores its potential as an educational model for continuous education. However, the study's methodology is based on the perceptions of participants and authors, which may have introduced certain limitations. The semi-structured format of the interviews and the open-ended nature of the responses sometimes led to students not providing the intended valuable information, either by not directly addressing the questions or by offering less informative responses due to the conversational style of the interviews.

Specifically, the impact of the flexibility component on a student's personalized academic path requires further exploration, as the interviews primarily focused on their perceptions during the final year of studies (third stage). Participants did not comment on the programs' initial "Exploration" stage, where they could personalize their curriculum.

The sample size and nature limit the study's scope to a narrow perspective on students' views of their educational model and its application for continuous education. With only 13 participants from the school of engineering within a similar context, our findings must be taken cautiously, mainly considering the economic imperatives and the lack of internationalization policies, as Fakunle stated (Fakunle, 2020). Furthermore, the purpose of our work, which focuses explicitly on the educational model currently being implemented at Tecnologico de Monterrey, restricts the inclusion of other higher education institutions. Instead, future research should involve a more extensive and diverse sample through a quantitative research approach and analysis of different educational models.

Moreover, while this study assesses the relevance of TEC21 for continuous education, we recognize that the disparity between the pace of adjustments in educational programs and training curricula and the rapid evolution of technologies remains a critical issue. Collaboration with other societal organizations and innovative delivery methods are two guidelines that could help address this challenge. However, we need a deeper understanding of the issue to develop strategies and policies that effectively bridge this gap.

6 Conclusion

Beyond terminal education, sustainable societies today and tomorrow require continuous education and lifelong learning to equip citizens with the skills to thrive in dynamic, technology-driven professional environments. The European Union's Curriculum Guidelines for Industry 4.0 recognize these needs and outline institutional strategies and educational frameworks to address evolving workforce and societal challenges. These guidelines emphasize the necessity of adaptable educational models that respond to labor market demands while fostering innovation and resilience.

Trainers in continuous education are often selected for their specialized knowledge and industry expertise but may lack pedagogical experience. At the same time, institutions must rapidly update programs, curricula, and syllabi to align with changing workforce requirements. A well-structured educational model is essential, providing trainers and institutions with a clear framework to achieve impactful learning outcomes.

This research is among the first to provide empirical evidence of the effectiveness of the TEC21 Educational Model (TEC21) in preparing students for the demands of Industry 4.0. Drawing on qualitative insights from study-abroad experiences, institutional documentation, and scholarly literature, the study reveals that TEC21's core components—Inspiring Professors, Flexibility, Challenge-Based Learning, and Memorable University Experiences—offer a comprehensive framework for lifelong learning and continuous education, addressing both professional and societal needs.

Participants perceived TEC21's components as forward-thinking and holistic. The Inspiring Professors component highlights diverse pedagogical approaches and real-world expertise, equipping students to navigate complex, dynamic environments. While TEC21 professors are highly skilled in industry, consulting, or research, they stay at the forefront of educational innovation through continuous pedagogical training. The model's Flexibility accommodates diverse delivery formats, allowing lifelong learners to balance personal and professional priorities while pursuing academic goals. Its Challenge-Based Learning approach enhances employability by engaging students in interdisciplinary, hands-on projects involving societal stakeholders. Lastly, the Memorable University Experience fosters holistic development through extracurricular activities, organizational participation, and internationalization opportunities. Collaborative Online International Learning (COIL) offers a cost-effective alternative to study-abroad programs for learners facing economic constraints.

TEC21 aligns seamlessly with the European Commission's Industry 4.0 Curriculum Guidelines, addressing key areas such as collaboration, recognition, quality assurance, curriculum content, learning environments, and assessment. These elements position TEC21 as a robust lifelong learning and professional development framework.

Despite its limitations, this study provides a foundation for future research into TEC21's scalability across disciplines and regions. The model exemplifies how continuous education institutions can address labor market demands, fostering innovation and resilience in an ever-changing world.

In conclusion, the TEC21 Educational Model is a cornerstone for continuous education and lifelong learning. It prepares individuals to integrate effectively into the labor market and drive meaningful societal progress. It inspires institutions worldwide to bridge the gap between education and the demands of a dynamic global landscape. By fostering employability, supporting professional growth, and promoting sustainability, TEC21 is a catalyst for building inclusive, future-ready societies.

Data availability statement

The datasets presented in this article are not readily available because, through the informed consent signed by the participants, no information can be shared to third parties. Requests for further information about the datasets should be directed to guillermo.chans@tec.mx.

Ethics statement

Ethical approval was not required for the studies involving humans because the research methodology employed solely online interview measures, deliberately excluding sensitive content. No biological samples were collected, nor were experimental interventions applied. Consequently, these precautions classify the study as low-risk. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. The present study followed the ethical principles of the Declaration of Helsinki (World Medical Association, 2013) and the Belmont Report (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979). All procedures were rigorously followed and aligned with applicable guidelines and regulations. Participants were informed about the voluntary nature of their participation, the confidentiality of their responses, the lack of any incentive for participation, and their right to withdraw from the study at any time. The research methodology employed solely online interview measures, deliberately excluding sensitive content. No biological samples were collected, nor were experimental interventions applied. Consequently, these precautions classify the study as low-risk.

Author contributions

CC-Z: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. SS-M: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. AV-A: Data curation, Formal analysis, Visualization, Writing – review & editing. PC: Funding acquisition, Writing – review & editing. GC: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

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