Complex thinking through a Transition Design-guided Ideathon: testing an AI platform on the topic of sharing economy

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Rationale: The development of the complex thinking meta-competency in the education of university students potentially promotes high capacities, where artificial intelligence (AI) might work as a supporting structure.

Objective: This proof-of-concept study of an AI-based platform aimed to integrate a sequence of activities into the design of an online platform to assess the development of complex thinking competency in higher education students.

Method: The Transition Design method was used within an Ideathon event supported by an AI platform to provide students with a sharing economy challenge. A total of 31 university students from five university campuses in Mexico synchronously participated. An instrument was applied in the pre-test and post-test phases to explore the complex thinking meta-competency and its sub-competencies of critical, innovative, scientific, and systemic thinking.

Results: Two hypotheses were tested, both of which turned out to be true: (a) the functioning of the constructed learning situation and (b) the model of the learning situation.

Conclusion: These findings may be of value to scientific and academic communities, as well as social and business organizations interested in developing high capacities of complex thinking and educational innovations using digital platforms.

KEYWORDS

complex thinking, artificial intelligence, Ideathon, Education 4.0, higher education

1. Introduction

Educational research uses methods that support the analysis of educational trends and priorities in the digital age to develop teaching and learning environments to properly train students to navigate digital transformation and address societal needs. Before the outbreak of COVID-19, Bonfield et al. (2020) provided different possible futures desirable in higher education, including smart campuses, digital assistants, lifelong learning, and online learning. Later, Yang et al. (2022) studied trends in global and digital education, revealing a rapid development phase (September 6, 2018–2022) where the research

hotspots of digital education primarily focused on interdisciplinary fields of practice and adaptive education research supported by Big Data. They predicted that human-computer interdisciplinary teaching models and smart education might become a future development trend of digital education. Other research throughout the pandemic emphasized ensuring continuous and universal education; each country needs to deploy a national (cluster) e-learning platform and ensure free access for all students (Ivanova et al., 2021) to increase the level of education of the population and guarantee continuity of knowledge throughout life (Krasovskiy et al., 2020). The contributions of knowledge generated by educational research in digital, remote, hybrid, and traditional formats should involve educational actors and tasks that include educational policies, changes in the structure of academic programs, new pedagogical approaches, updating of teachers, and the integration of interdisciplinary research groups to capitalize on the use of new technologies.

The global horizon of higher education and the paradigm shifts in educational trends require incorporating technologies that effectively solve problems through virtual and traditional learning interactions that positively impact citizens' skills. Artificial intelligence (AI) refers to the ability of a digital machine to perform tasks commonly associated ith intelligent humans, and its associated technologies are divided into various fields, such as computer vision, speech, machine learning, Big Data, and natural language processing (Chiu, 2021). AI is incorporated into these research technologies to assist in predicting student performance and behavior, especially in platform online education. In particular, machine learning makes predictions using mathematical and statistical operations. In this case, it is convenient to analyze the data obtained from the education processes and evaluate the students' success and the factors affecting success (Akmeşe et al., 2021). For Yu (2021), online learning behavior refers to the learning-related behaviors in the network learning environment. Constructing a predictive model of academic performance in online education requires algorithms based on different languages supporting machine learning methods, regression, clustering, and preprocessing modules.

This paper aims to present the integrated flow of proof-of-concept activities for an AI platform that assesses the development of complex thinking meta-competency in higher education students. The event for running the test was a pedagogical intervention based on an Ideathon, assembled through a methodological sequence based on the Transition Design approach. Studies related to this research because of their approach incorporating AI to assess student behavior are those of Yu (2021), which shows an algorithm that uses a prediction method to help teachers and students conduct better teaching and learning activities. Another research that refers to this was conducted by Hu (2021), highlighting the use and optimization of machine learning algorithms. In turn, Mcginnis et al. (2018) implemented the Scikit-learn (sklearn) toolkit based on Python, which contains various commonly used machine learning methods that facilitate analyzing a data set. Furthermore, Jarke and Macgilchrist, 2021 focused on the data dashboards of learning support systems based on machine learning (ML) and how these systems produce credible knowledge and compelling, persuasive, and convincing narratives as a pedagogical approach.

In this paper, the distinctive contribution is the methodology used, which involves Transition Design as a pedagogical approach to identify learning behaviors through an Ideathon-style event, with the primary objective of assessing participants' level of mastery of the

meta-competency of complex thinking when performing learning activities on an online AI platform. The results are presented for two hypotheses through statistical data revealing students' level of complex thinking at the end of the Transition Design activities.

2. Theoretical framework

2.1. Complex thinking in higher education

Higher education is moving toward rethinking the competencies needed for socio-economic, cultural, and environmental solutions that integrate emerging technologies. Changes in technology, social life and economics call for a change of traditional teaching and research methods (Bengu et al., 2020). Complex thinking is considered a meta-competency comprising four sub-competencies or types of thinking (critical, innovative, scientific, and systemic) (Ramírez-Montoya et al., 2022), which have been successfully applied and measured, for instance, in social entrepreneurial contexts (Vázquez-Parra et al., 2022). Critical thinking can be defined as an individual thought process that begins with the intent to solve a problem or answer a question by examining different options and choosing the most suitable and logical one (Alsaleh, 2020). Innovative thinking is the capacity for creativity, implemented with a high degree of success; four levels of innovation are delineated: incremental, modular, architectural, and radical (Passig and Cohen, 2014). Scientific thinking involves intentional information seeking, including asking questions, testing hypotheses, making observations, recognizing patterns, and making inferences (Kuhn, 2002). Systemic thinking uses methodological tools to manage emerging complexity in local and global contexts (Barile et al., 2018). Developing competencies and motivating learning involves tracking through the different stages of pedagogical approaches that integrate various technologies and consider the emotional support that should be provided to students during their training.

Fostering reasoning for complexity in higher education means enhancing skills to provide solutions to the challenges posed by new digital, social, environmental, and economic interactions. In higher education, complex thinking skills can develop students' competencies, human potential, and the capacity for innovation to solve new problems (Suárez-Brito et al., 2022). The digital transformation trends in teaching and learning are becoming increasingly oriented toward online learning (Marks and Al-Ali, 2022). By the end of 2021, Massive Open Course Online (MOOC) learning platforms enrollment exceeded 220 million students; 950 universities worldwide had announced or launched 19,400 courses (Shah, 2021). According to Cornejo-Velazquez et al. (2020), MOOC platforms offer value propositions to the universities and instructors, such as solid infrastructure in the cloud, marketing, advertising, and other administrative activities that allow for reducing operational costs of maintenance and updating. Although traditional higher education providers remain the dominant institutions, have the best reputation and are where most students aspire to go, MOOCs can work in a complementary way to strengthen the learning that higher education institutions seek to promote, as they are resources designed to respect the learning pace of students, as well as motivation through the inclusion of interactive elements.

Education worldwide is transforming and must consider economic and technological megatrends to connect with the skills and

competencies that students need. On the one hand, a world of possibilities opens up for us with AI. Xia et al. (2022) point to the potential of AI in several critical educational domains, such as (1) teaching, (2) learning, (3) evaluation, and (4) administration; but, on the other hand, Munir and Awan (2022) emphasize the importance of cultivating creative thinking, while considering emotions and intuition. This opens the door to new perspectives and avoids creating solutions based on scientific reasoning alone. One of the guidelines for developing a synergistic relationship between the AI functionalities and the sub-competencies of complex thinking is creating taxonomies of future scenarios through diverse, innovative teaching models where the learner's process is personalized and collaborative to contribute to the social construction of knowledge.

2.2. Creative design with AI in Education 4.0

AI in education (AIEd) gives rise to new opportunities by having structured and unstructured data, introducing the concept of Big Data, robotics, and artificial intelligence, to analyze and process for greater clarity of learning processes. The digital transformation of education allows systems to improve educational quality (Chen, 2021) and analyze the positive or negative effects of teaching by combining computer algorithms (Hou, 2018) and other technologies. Liang and Wang (2020) propose to improve the digital management of teaching through algorithms at various times with data analysis techniques. Also, teaching creativity contributes valuable solutions to any type of problem, including specifying the requirements of a new software or system (Giunta et al., 2022; Ramírez-Montoya et al., 2022). Hybrid learning is gradually taking place in higher education, demanding new teaching and teacher interaction methods.

Various technologies with AIEd monitor and track student and teacher interactions and administrative tasks. Students and teachers accept AIEd because they can perceive that its compatibility can solve their learning needs (Alhumaid et al., 2023). AIEd has enormous potential to improve learning, teaching, assessment, and educational administration and provide anywhere, anytime machine-supported queries and immediate feedback (Xia et al., 2022). Costa-Mendes et al. (2021) argued that selecting student data for classical statistics may not fit AIEd predictive models to probe student performance. Predicting student performance with AIEd in contexts where creative design is taught essentially encompasses inquiring into students' development of reasoning for complexity at the neurological level.

Most e-learning platforms or learning management systems (LMS) offer functionalities to analyze the interactions of students and teachers to create statistics that give clues to the behavior of the actors. Hamal et al. (2022) emphasize that one of the most common applications of AI in education is intelligent tutoring systems (ITS), which can determine step-by-step an optimal path through support and learning activities; they are integrated with three models: (a) domain model represents the knowledge intended for students to acquire, (b) the pedagogical model represents knowledge of effective teaching and learning approaches that have been obtained from pedagogical experts and researchers in the learning sciences (Siemens, 2012), and (c) the learner model refers to the initial representation of the learner's state of knowledge. It is ideal to have these three models

to create AIEd data structures that provide more information on the aspects that need to be addressed to improve student performance.

2.3. Models that support AIEd

Taking into account the intelligent tutoring system created by Hamal et al. (2022), the three proposed models are described below: (a) domain model, (b) pedagogical model, and (c) learner model, which were considered for this research.

2.3.1. The domain model: sharing economy

With the emergence of Technology 4.0 enablers, new opportunities have arisen to exchange goods, services, and knowledge timely and collaboratively, without intermediaries. The phenomenon of enabling technologies for individuals or organizations to share goods or physical assets and reduce costs is called sharing economy (World Economic Forum, 2015). It aims to increase efficiency and optimize societal resources (Muñoz and Cohen, 2017), complementing the definition of Wang and Ho (2017) "… an emerging social and technological phenomenon based on developments in information and communications technology (ICT) that implies the collaborative consumption of physical, virtual, and intellectual goods." Acquier et al. (2017) posit the sharing economy on three fundamental pillars: (1) access economy, (2) platform economy, and (3) community-based economy. The most developed countries have invested in innovation, science, and technology, leading the growth of collaborative technology platforms that reflect new forms of sustainable consumption and have an impact far beyond their borders.

2.3.2. The pedagogical model: Transition Design

Transition Design is one of the pedagogies emerging to teach design with a focus on sustainability. For Di Bella (2022), Transition Design is "a new area of research, study, and practice, whose heuristic model is composed of (a) vision, (b) theories of change, (c) mindset and posture, and (d) new forms of design, which constitute the framework that defines four interrelated areas of knowledge, action, and self-reflection." Transition Design, as a pedagogical approach, could support and facilitate social transition processes by supporting, connecting, or developing interventions to change values, technologies, social practices, and infrastructures intentionally (Irwin, 2015). The need to create a future with a sustainable vision arises from the figure of the transition designer (Irwin, 2012), who must be an actor who provides solutions to the world engaged in complex systems that require a cultural transformation (Di Bella, 2018) considering economic megatrends and technologies. The pedagogical approach of Transition Design using technologies such as AI may provide clues as to what innovative solutions may be optimal for design education.

2.3.3. The learner model: Ideathon

Identifying the personal characteristics, attitudes, and behavior of students who use learning platforms offers knowledge about their behavior in different learning activities. Aligned with the United Nations' Sustainable Development Goals (United Nations, 2015), the Ideathon program aims at undergraduate students between 18 and 23 years old to foster potential change agents through the generation of innovative solutions to the challenges of our society. Ultimately, the Ideathon seeks to promote an ecosystem of high-impact

entrepreneurship in the early stages and foster a culture of innovation through access to knowledge, tools, expert mentoring, and talent linkage, in line with the global trends in innovation and technology (Haro, 2018). However, consolidating an online learning community requires considering the personalities of its members, the attitudes and values that underpin their practices, and their consumption of products and services (Bäro et al., 2022). Evaluating each student's learning based on their interactions and providing them with feedback and activities that allow them to reinforce specific skills is one of the functionalities expected to be solved through AI in learning platforms.

3. Hypotheses development

We hypothesized that since Ideathon-type events tend to trigger ideas and initiatives due to the collaborative energy and involvement they generate, this setting could provide the ideal environment for students between 18 and 23, who usually participate in open events. The focus on problem analysis and solution finding following the Transition Design methodology for a limited number of hours and in a competition-style environment (albeit without winners) led us to our first hypothesis:

> *H1.* A Transition Design-driven Ideathon can be an engaging scenario to develop complex thinking in higher education students.

Secondly, we argued that student behaviors on the platform could be distributed into sections to be tracked by a computer system. Moreover, we envisioned that such behaviors could be recorded and accumulated by the system throughout the event and classified according to specific evaluation criteria, which led us to our second hypothesis.

> *H2.* AI-provided digital platforms can measure the development of complex thinking traits in higher education students.

4. Methodology

Transition Design was the methodology employed in the educational scenario presented in this study (Irwin, 2015). According to Irwin et al. (2022), this approach allows an understanding of wicked problems typified by a diversity of stakeholders and concerns at different spatiotemporal layers, which, to be understood, requires multi-disciplinary and longitudinal interventions. Transition Design is emerging in the global north along with resilient Thinking and Policy Design, all pursuing plurality and synthesis of knowledge in systemic transformation processes (Juri et al., 2021). Examples of its application include the search for solutions to wicked problems faced by the Museum of Environmental Sciences in the framework of the "HUMETAV" project (Sanabria-Zepeda and Santana-Castellón, 2022); the generation of experiential futures in the field of fashion (Cowart and Maione, 2022); and building collaborative media for the transformation of designers' mindsets (Bosch-Gómez et al., 2022). Irwin et al. (2022) describe it as a sequence of six steps that begins by (1) identifying the wicked problems and (2) their stakeholders, (3) mapping their historical origin, (4) creating their desirable long-term vision, (5) designing a pathway from the present to the future, and (6)

proposing synergistic solutions for the ideal future. Therefore, this methodology was chosen for the Ideathon event dynamics because it proceeds in a composite and logical way to analyze and search for solutions to a problem.

For the practical integration of Transition Design into the educational experience, we devised an idea-generation event based on the Ideathon concept. The Ideathon is a hackathon-style event in which a timed challenge is presented to be solved by the participants using innovative learning practices, usually in a competitive or collaborative environment (University of Washington, 2016; Barrow, 2021). The implementation of an Ideathon, which can be either face-to-face or virtual, has been applied to a variety of topics, including developing methodologies to enhance creativity (Yudina et al., 2021), preventing disasters through location-based gaming (Uesugi and Moriyama, 2020), supporting community development and revitalizing urban areas, and providing maker-driven solutions to regional strategic sector issues (SIC, 2021). The Ideathon implementation was based on module II of the program developed by Sanabria-Z et al. (2020), which integrates the following general recommendations: workshop rooms limited to 25 participants at tables with a maximum of 5 individuals; one instructor and one facilitator for mediation per room; 6 h of work including an opening and a closing conference, and a central screen displaying general instructions. Thus, while the Transition Design guides the participants in the operation of the on-screen activities, the Ideathon umbrella marks the big stages of the event to orchestrate the activities in the different rooms or venues.

4.1. Methodology for the Ideathon implementation

A total of 31 students participated in the Ideathon. As for the participant profile, it comprised undergraduate students between 18 and 23 from different disciplinary areas. They belonged to five universities in Mexico: Tecnologico de Monterrey (ITESM), which participated with the Mexico city (ITESM-CCM) and Guadalajara (ITESM-GDL) campuses; Universidad Autónoma de Ciudad Juárez (UACJ), in Chihuahua city; Instituto de Investigacion, Innovacion y Estudios de Posgrado para la Educacion del Estado de Nuevo Leon (IIIEPE), in Monterrey city, and the Instituto Politécnico Nacioanl (IPN), in Mexico city. To manage the event, instructors received and briefed the participants, and facilitators assisted in logistical and technical matters only; neither were allowed to provide support in content issues. Regarding ethical considerations, students were asked to authorize the use of their data for research purposes by clicking on a button when registering on the platform. The Ideathon was run simultaneously in the five venues which were streaming online video from the classrooms throughout the event. Figure 1 shows the methodology followed for the implementation of the Ideathon.

Figure 1 shows the establishment of the Ideathon, which setting was based on Sanabria-Z et al. (2020). The starting point was the provision of an instructional design guideline that contemplated three types of models according to Hamal et al. (2022): domain model (sharing economy), pedagogical model (Transition Design) and learner model (Ideathon). It can be seen that four modules were integrated into the platform for implementation. Prior to the event, students were asked to answer the eComplexity instrument (Castillo-Martínez et al., 2022) to assess their perception of their level of

FIGURE 1
Methodology for Ideathon implementation.
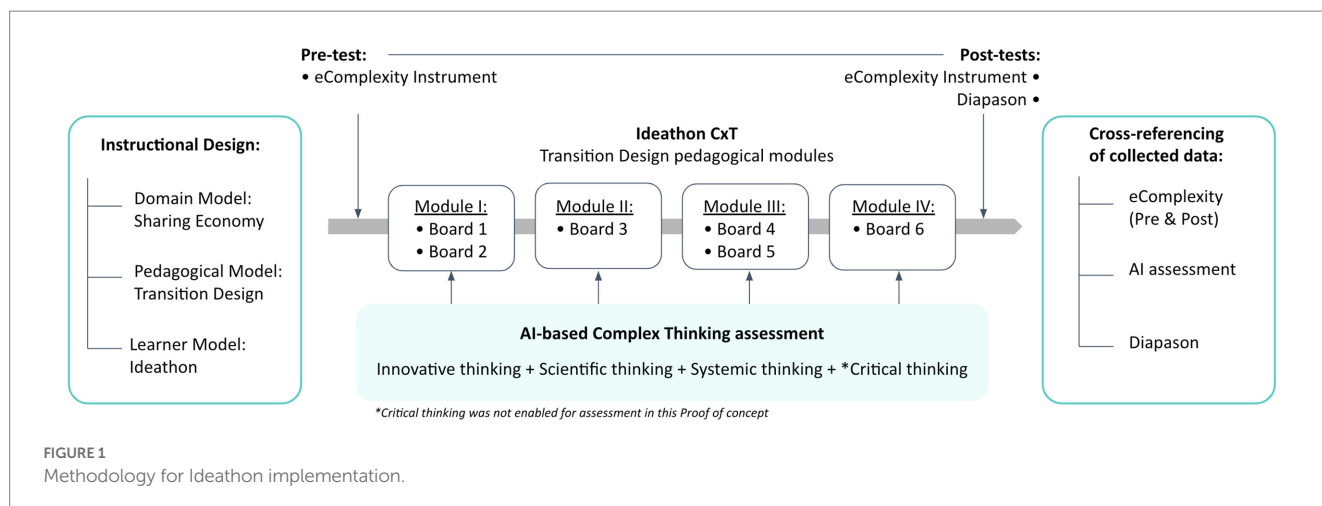
mastery of complex thinking, and also were provided with the sharing economy case study to get familiar with the topic. The day of the Ideathon, each student was assigned a specific theme to be addressed as a problem during the event, namely fashion, education, food industry, or health. Then, they proceeded to work through the 4 modules based on the Transition Design (Irwin, 2015) on the interactive platform as described below.

a) Module 1, "Long-term vision," consisted of boards 1 and 2. For the work on board 1 the participants started by placing an issue in a box related to the thematic problem in each of the 5 categories of social, economic, environmental, political and infrastructure. They reflected on possible connections or ramifications among all categories, aiming at making a full loop around all the categories until they could understand how the problem branched into all the areas. By using connecting lines between boxes they related the available issues to the original topic. On board 2 students mapped positive and negative relationships between stakeholders around the topic.

The main complex thinking subcompetency addressed in this module was systemic thinking.

b) Module 2, "transition pathway," consisted of board 3. Here, participants placed key issues drawn from board 1, then expanded them through three socio-technical levels according to the Transition Design approach: (1) large systems influences, (2) the "stuck" status quo, and (3) micro systems influences. They identified several themes or events at each of the three levels and their interconnections. Whenever they placed text in one of the levels, they were prompted to reflect on the potential connection, cause or what it led to in the other two levels.

In this module, systemic and critical thinking were the complex thinking subcompetencies addressed.

c) Module 3, "medium-term visions" consisted of boards 4 and 5. For board 4 the students developed 3 milestones along the "transition path" from the present to the desired future. They tried to imagine what the situation would be like just before the desired long-term future and described it in narrative form. Then they did the same with the near future: what would a first step toward the long-term future

look like? This exercise taught them to think rigorously about transitions over long periods of time. They formed a narrative about a long-term transition from a problematic present to a desirable/ sustainable long-term future (year 2100). For board 5, participants described 3 to 4 aspects of the vision for the future in each of the domains of daily life. The domains are a way of thinking at the levels of "organic" and nested systems from which everyday life emerges. The categories used to map the problem were set for mapping it, while the domains were aimed at encouraging them to think in a more integrated way about how to reconceive entire lifestyles to be more sustainable and place-based. Students thought of several facets of what daily life would be like at each level if the problem had been solved.

Three subcompetencies were addressed in this module: systemic, critical and scientific thinking.

d) Module 4, "present," consisted of board 6. Participants looked for "fragments" or "aspects" of the long-term vision of the future that may already be here, in the present, and listed them in cloud bubbles on the far right of the board. These "fragments of the future" are used as possible basis for systems interventions. They then developed concepts for potential "interventions" (solutions). They tried to place the interventions, in different areas of a matrix, in the area they wanted to change. The matrix helped them to place different types of interventions at different levels of scale within the social, political, economical, environmental, and technological dimensions, in cross-reference to the contextual nested systems levels consisting of household, neighborhood, city, state/region, nation and planet. Each intervention had to be connected to each other and to a milestone or long-term vision.

Figure 1 also shows the subcompetencies that were considered to be assessed by the AI platform, systemic thinking, scientific thinking and innovative thinking, however, critical thinking was not taken into account for this particular proof of concept test. After completion of the 4 modules, students were asked to answer two types of survey questionnaires, the eComplexity post-test, linked to the pre-test applied, and the Diapason (Alemán de la Garza, 2019) post-test, related to their perception of the interactive experience with the platform. The set of results from the eComplexity pre-and post-tests, the Diapason, and the complex thinking assessment provided by the AI platform were analyzed by examining their different crossovers and mutual influences.

TABLE 1 Three levels of complex thinking criteria for the IA platform.

Basic	Intermediate	Advanced
Innovative thinking		
The participant contributed 1 to 17 ideas in modules 1, 2, 3 (board 5) and 4.	The participant contributed 18 to 36 ideas in modules 1, 2, 3 (board 5) and 4.	The participant contributed more than 37 ideas in modules 1, 2, 3 (board 5) and 4.
Scientific thinking		
Match 1 to 3 terms along the boards of all modules.	Match 4 to 6 terms along the boards of all modules.	More than 7 terms coincide across the boards of all modules.
Systemic thinking		
The participant is able to establish 1 to 4 connections in the maps of modules 1 and 2.	The participant is able to establish 5 to 9 connections in the maps of modules 1 and 2.	The participant is able to establish more than 10 connections in the maps of modules 1 and 2.
Critical thinking		
The participant is able to make more elaborate proposals using a Boolean operator of the type (and, or, or not).	The participant is able to make more elaborate proposals using two to three Boolean operators of the type (and, or, or not).	The participant is able to make more elaborate proposals using more than three Boolean operators of the type (and, or, or not).

To evaluate participants' complex thinking meta-competency through AI, we created basic, intermediate, and advanced-level criteria for each sub-competency: systemic, scientific, critical, and innovative thinking. The criteria implied, for instance, that a participant digitally connects a content (box with words) with another content; or that they develop sentences with a considered construction elaborated by using operators between words (see Table 1).

4.2. Adapted works for the building of the Ideathon

A search for articles related to the subject of the present study was carried out. The search string used was as follows: TITLE-ABS-KEY (platform AND "artificial intelligence" AND competenc*). The inclusion criteria established were that the articles should be open access, that they should have been published in the period from 2019 to 2023 and that the type of document should correspond to articles, conferences, book chapters or books. Forty-seven documents were identified. Documents related to the health area (Lamberti et al., 2019; McNamara et al., 2019; Shorey et al., 2019; Rajadhyaksha, 2020; Zhao et al., 2020; Cheng et al., 2022; Creed et al., 2022; Liaw et al., 2022; Lokala et al., 2022; Shah et al., 2023), industry (Barykin et al., 2020; Mokhtarname et al., 2020; Sandner et al., 2020; Dmitrievsky et al., 2022; Obermayer et al., 2022; Zakharkina et al., 2022), education (Hrich et al., 2019; Tsalapatas et al., 2019; Cortés et al., 2020; Paba-Medina et al., 2020; Raj et al., 2020; Yang et al., 2020; Demchenko et al., 2021; Hurajová, 2021; Jiang, 2021; Petrescu et al., 2021Ghnemat et al., 2022; Polak et al., 2022; Ramírez-Montoya et al., 2022; Rataj and Wojcik, 2022), science (Bruneckiene et al., 2019; Desnos et al., 2022; Ramírez-Montoya et al., 2022; Zhu et al., 2022), evaluation

(Kiran et al., 2019; Prom et al., 2019; Konys, 2020; Bachiri and Mouncif, 2023; Rashidi Fathabadi et al., 2023), engineering (Kaspar and Vielhaber, 2019; Telnov and Korovin, 2019), geography (Abd Alsammed, 2022), social problems (Tubaro, 2022), e-recruitment support (Aljuaid and Abbod, 2020; Krasovskiy et al., 2020), ethics (Hauer, 2022) were found. It was possible to establish that there is no study on the use of platforms with AI to measure the competency of complex thinking, which is why this research is valuable.

The establishment of the Ideathon was framed by several studies. The studies that served as the basis for determining the use of the Transition Design technique were those of Irwin, (2015), Juri et al. (2021), Bosch-Gómez et al. (2022), Cowart and Maione (2022), Irwin et al. (2022) and Sanabria-Zepeda and Santana-Castellón (2022). The studies that served as guidance for the choice of an Ideathon to carry out the proof of concept of the platform with AI were those of the University of Washington (2016), Sanabria-Z et al. (2020), Uesugi and Moriyama (2020), Barrow (2021), SIC (2021) and Yudina et al. (2021) and the latter was key for the implementation because the recommendations regarding space, furniture, duration and the number of facilitators and instructors per mediation and room were considered. On the other hand, the studies by Castillo-Martínez et al. (2022) and Alemán de la Garza (2019) were considered because they address the design and validation process of the instruments that were applied for the present study, the first corresponds to the eComplexity instrument to measure the perception of students regarding their level of mastery of the complex thinking competency and the second corresponds to the Diapason instrument, which allows measuring the perception of the interactive experience with the platform.

5. Results

The general results of the Ideathon proof of concept are presented below in three sections: (5.1) experience of the Ideathon educational situation, (5.2) perception of complex thinking via eComplexity instrument, and (5.3) AI-based platform performance to measure complex thinking traits. The theoretical justification for the analysis of results, general outcomes of the proof of concept, and specific results observed in the event are presented below.

5.1. Experience of the Ideathon educational situation

The implementation of the Ideathon using the Transition Design technique with the theme of sharing economy allowed us to assess the following four aspects regarding students experience: (1) level of response, (2) implementation context, (3) mediation experience, and (4) challenge design.

Figure 2 shows the four aspects considered above in relation to students participation and experience in Ideathon.

5.1.1. Student level of response

When it comes to planning an event, timing is often a critical point that can greatly affect an occasion if it intersects with a school schedule of calendar events such as vacations, exams and academic events (University of Waterloo, n.d.). According to Ljubisic (2017), some motivations for students to attend college related events include

FIGURE 2
Analysis of key aspects in the development of the Ideathon.
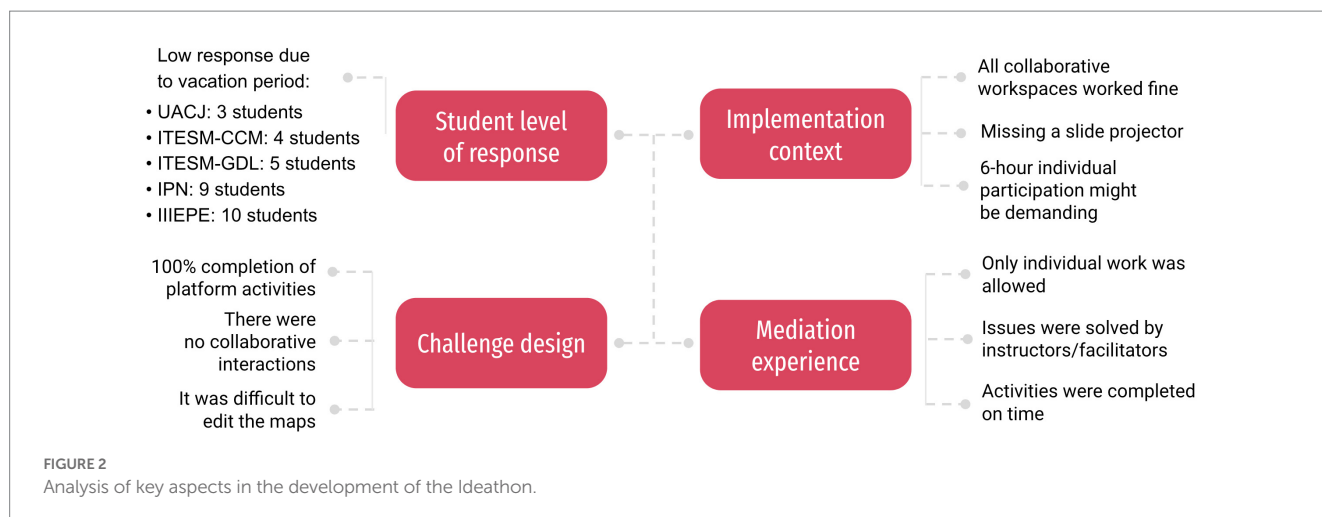
the possibility of socialization in a light atmosphere, be provided with food and beverage, listen to guest speakers, and participating in thought-provoking workshops. Regarding these aspects, the conditions at Ideathon were as follows. Students were either directly invited by their teachers or recommended by other teachers to participate. Each setting was different, some were traditional formal classrooms while others were informal settings (e.g., design thinking classroom), but the atmosphere was relaxed in all settings since this was a non curricular activity, and some campus were already in winter vacations. Food and non-alcoholic drinks were provided in each location (e.g., pizza and soda). Although there was no speaker *per se*, the principal investigator gave a welcome address and explained the significance of the Ideathon. The event was promoted through social networks with a poster encouraging participation with the title "Ideatón: future of sharing economy," including the key themes of Transition Design, AI, sharing economy and complex reasoning.

As for the specific results related to this aspect, timing was certainly a major drawback that yielded little student participation because two or the four participant universities were already on winter vacation. A total of 31 students participated in the event, both the IIIEPE (10 students) and the IPN (9) had more participation because the instructors were still having sessions with their students. Moreover, the day of the event also turned out to be a special occasion for administrative acts in three venues, UACJ (3), ITESM-CCM (4) and ITESM-GDL (5). Considering that each location had the capacity to receive about 20 students in each classroom for a potential grand total of 100, the attendance of 31 students was considered particularly low. Among the recommendations for future studies is to ensure that the times in which activities are carried out as part of the AI platform are optimal for greater participation.

5.1.2. Implementation context

De Pretto et al. (2019) mention the importance of classroom design, facilities and conditions to stimulate the learning experience in higher education, where improved equipment, arrangement flexibility, attractive decoration, and adding natural elements play a key role. According to these aspects, the configuration was as follows. Regarding equipment, all sites provided Internet connection via Wi-Fi or Ethernet cable. Some campuses provided desktop computers while others asked students to bring their laptops or tablets. As for the

classroom configuration, the distribution of the desks varied by venue, including semicircular, square, linear and double line arrangements. Almost all classrooms provided a main screen where the main and other classrooms' broadcasts were projected and heard. The interior design was also varied by venue, including formal classrooms with desks covered with tablecloths, robotics classrooms surrounded with electronic accessories, and design thinking classrooms with inflatables hanging from the ceiling. No natural elements were identified in the classrooms, except that some were surrounded by large windows while others were closed classrooms.

As for the particular results in this area, the UACJ could not provide a space for the event, so they had to resort to using a classroom at the Tecnologico de Monterrey, Ciudad Juarez campus, while in the ITESM-CCM students use the Robotics Laboratory because of graduation events, as noted by their instructor: "We lacked a monitor to project the synchronous participation from the other venues, which made it difficult to listen to the instructions and hold the participants' attention." Despite the logistical complications, the overall spaces, furniture, and equipment were adequate for the students to complete on time all the activities on the agenda.

5.1.3. Challenge design

According to Ifenthaler et al. (2018), research on the employment of challenges in online learning environments emphasizes their relationship to learning performance, where the number of activities started and completed in a challenge-based online platform are the most reliable predictor of student learning performance, also linked to the individual investment of time and effort. In terms of the AI-based platform used in the Ideathon, its instructional design included six activities that had to be completed in sequence in order to complete the challenge. Each activity was represented on a board that included instructions and examples of how to respond to the specific challenge using text and digital elements (e.g., connecting lines and boxes). In order to advance from one board to the next, it was necessary for the student to save the achievement of the section, and press the button to continue to the next section.

In terms of the specific results of this aspect, the following is observed. Of the total number of registered participants, not all completed the pre-test or post-test questionnaires, and not all

showed up for the event. However, as far as fulfilling the platform activities is concerned, all students went through the 6-board sequence, which translates into 100% of the participants successfully completing the sharing economy challenge. The takeaway is that both the instructional design and performance of the platform functioned according to the expectations of the proof of concept. Regarding the time an effort, the configuration of the platform was designed for individual work, which was adequate according to expectations, however, it is acknowledged that 6 hours of ideathon on an individual basis can be demanding. Also, the possibility of collaborative work and its effects on the development of competencies were not factored in this proof of concept. Furthermore, some difficulties in using the AI platform were reported as part of the interactive experience. One of the instructors stated this issue as: "The platform did not save its maps. It was difficult to edit the maps because they were out of configuration. It was not possible to add colors to the rectangles. It was not possible to use different types of figures to make the maps." Although this was not necessarily a common occurrence, there were several different difficulties in using the AI platform that were collected through the Diapason instrument that should make it possible to establish further improvements regarding usability and functionality.

5.1.4. Mediation experience

Distinctive features of mediation in hybrid single events such as the Ideathon are similar to those that apply to online workshops. According to the German management software company SAP (Steinmetz, 2022, November 9), best practices for digital workshop mediation include frequent contact with participants, overcommunicating, and designing for maximum engagement. The design of the Ideathon experience integrated the participation per classroom of an instructor, in charge of providing instructions and time supervision, and a facilitator, in charge of taking care of logistical contingencies, while both could mediate regarding the use of the platform and technical problems. However, none should provide assistance on questions related to the content of the challenges. Each desk was intended to have a maximum of 4 students, each working individually to solve a challenge on a different topic from that of the neighboring students. They were allowed to talk about topics not related to the activity, but in case they had any related questions, they could approach the instructor or facilitator.

In this context, the specific results were as follows. General directions were given by the main researcher during an introductory explanation broadcasted to all the participants who were in the different venues. Instructors and facilitators properly played their role as observers of the conduct and performance of the participants, guiding the students if questions arose, but taking care that they could advance independently by following the instructions that were integrated into the platform. Although the physical facilities may well allow for collaborative work, the AI platform did not yet provide the algorithm possibilities to measure team performance; therefore, instructors and facilitators supervised that only individual work was conducted during the event. Furthermore, the event design and mediation appeared to contribute to engaging the students since they were able to overcome all stages according to the time limits.

5.2. Perception of complex thinking via eComplexity instrument

Students' perception of their competency in complex thinking was conducted by applying the eComplexity instrument before and after the Ideathon. The eComplexity instrument (Ramírez-Montoya et al., 2022) is a five-point Likert-type scale questionnaire: do not agree at all (1), slightly agree (2), neither agree nor disagree (3), agree (4) and strongly agree (5). The instrument consisted of the following indicators: Knowledge, skills and attitudes or values for the four dimensions of innovative thinking, scientific thinking, systemic thinking, and critical thinking, which were integrated into 25 items. It was applied as a pre-test and post-test to identify whether the participants' perceptions had changed when they finished the four blocks of the Ideathon.

Table 2 shows the mean scores obtained before and after the Ideathon.

As shown in Table 2, although 31 students participated in the Ideathon, only 18 students answered both the pre-test and post-test eComplexity instrument. The Student's t-test performed on the 18 cases indicates that the means obtained in the pre-test and post-test had statistically significant differences, implying that the results are

TABLE 2 Pre test and post test means of eComplexity questionnaire.

Type of thinking	Item	Mean pre test	Mean post test
Critical thinking	14	4.47	4.35
	15	4.00	4.24
	16	4.29	4.41
	17	4.18	4.41
	18	4.06	4.29
	19	4.71	4.53
Innovative thinking	20	3.94	4.18
	21	4.00	4.41
	22	3.82	4.12
	23	3.94	4.29
	24	4.41	4.35
	25	4.41	4.41
Scientific thinking	7	3.94	4.06
	8	4.00	4.06
	9	4.18	4.18
	10	4.00	4.12
	11	4.00	4.18
	12	4.00	4.29
	13	4.35	4.35
Systemic thinking	1	4.18	4.29
	2	4.47	4.41
	3	4.24	4.41
	4	4.41	4.24
	5	4.82	4.65
	6	4.41	4.41

reliably different. The result of the Student's t-test was $t(18) = 2.06$; $p = 0.008$. When performing an analysis by types of thinking, we observed that the mean for scientific thinking increased in the post-test, indicating that the students perceived a higher level of mastery in this sub-competency.

5.3. AI-based platform performance to measure complex thinking traits

The AI-based platform was enabled to identify features of the complex thinking competency, which could complement the results of the students' own perception of complex thinking from the eComplexity instrument. To this end, a rubric was used with three levels of mastery of complex thinking, basic, intermediate and advanced (see Table 1), which were programmed into the platform through identifying student interaction behaviors with the platform as well as the characteristics of the texts they inserted. The rubric was then transformed into an algorithm which, by analyzing the boards using a decision tree classifier (Jijo and Abdulazeez, 2021), was able to extract from each board the number of ideas, logical conjunctions, and existing connections; this was done by converting the boards into JSON format files, so that all the contents can be read as text strings. Of the four sub-competencies of complex thinking, this proof of concept test focused on three, innovative, scientific, and systemic thinking, leaving the integration of critical thinking to be tested in a future edition. Specifically, complex thinking traits were calculated according to the following programming on the platform. The innovative thinking trait was measured by calculating the number of ideas inserted throughout the 4 blocks, where the intermediate level is considered to be the range between 18 and 36 ideas along all boards; an idea was equivalent to a sentence placed in a box, which was identified by the system by tracking what was written between periods. For the scientific thinking trait, terms were identified that appeared in more than one board across the four blocks, where the intermediate level is considered to be the range between 4 to 6 terms along all boards; a term consisted of a word or construct, which was identified by the system as distinct from pronouns and articles. The systemic thinking trait was addressed through identifying the number of connections made in the maps, along blocks 1 and 2, where the intermediate level is considered to be the range 5 to 9 connections in both blocks; the connections were equivalent to the lines made between boxes by the students, which the system identified as a single line (and not the use of arrows or other connecting elements).

The results of the mastery levels are shown in Table 3.

Table 3 shows that concerning scientific and systemic thinking, there was a clear predominance at the advanced level with 23 students

on each, contrary to innovative thinking where only 3 students reached the advanced level. However, the majority of participants achieved an intermediate level in the innovative thinking trait, with a total of 26 students.

6. Discussion

Carrying out learning activities through an Ideathon using the Transition Design approach under a time limit encouraged participants to generate innovative solutions to complex problems. Figure 1 showed the challenges that arose before and during the Ideathon: low response from students due to the winter vacation and difficulty in designing the maps requested in the Transition Design activities with the theme of sharing economy; however, despite the difficulties, all participants managed to complete the agenda activities on time. Against the unexpected in the process, following the recommendations by Sanabria-Z et al. (2020) regarding what should be taken care of when carrying out an Ideathon contributed to the successful completion of the activities (e.g., duration, numbers of students per table). Furthermore, the overall Ideathon setting was in line with what Haro (2018) mentioned regarding the role of the Ideathon: promoting a culture of innovation was achieved by using 4.0 technology, the event was held simultaneously in different venues, and the products generated by the participants were shared online. Combining the Ideathon with Transition Design to achieve a learning target was an optimal pedagogical formula that can be replicated using other megatrends as a central theme, as was the case with the sharing economy.

Applying the eComplexity instrument makes it possible to identify changes in the student's perception of mastery of the complex thinking meta-competency after an Ideathon-style intervention. Table 2 shows that changes in students' perception of mastery occurred, for instance, the high increase in the scientific thinking sub-competency. The effectiveness of measuring complex thinking sub-competencies in the context of the sharing economy is consistent with the results of the study by Vázquez-Parra et al. (2022). The application of the eComplexity instrument allows us to know precisely whether an intervention with university students improves students' perception of the level of mastery of their complex thinking competency.

The tested IA platform goes beyond measurement in perceptual terms, identifying levels of participants' mastery of complex thinking sub-competencies. Table 3 shows that most participants were at an intermediate level of mastery of innovative thinking, contrary to the systemic and scientific types of thinking, in which they were at an advanced level. AI has been used to monitor and track student interactions, showing enormous potential to improve learning, teaching, assessment, and educational administration (Xia et al., 2022). Through the proof of concept, it was possible to identify that an AI platform has the potential to measure the levels of mastery of the complex thinking meta-competency and can serve as a basis for the design of strategies that strengthen its sub-competencies.

Using a variety of instruments to measure complex thinking competency allows for a more robust assessment outcome. The results regarding the perception of the participants thanks to the application of the eComplexity instrument are important (Table 2), but it is valuable to be able to have intersected results that allow us to know practical

TABLE 3 Complex thinking subcompetencies' levels of mastery through the AI platform.

Level of mastery	Innovative thinking	Scientific thinking	Systemic thinking
Basic	2	4	2
Intermediate	26	4	6
Advanced	3	23	23
Total	31	31	31

levels of mastery through the measurement through the platform with the use of AI (Table 3). Xia et al. (2022) point out that assessment is one of the educational domains where there is potential for the use of AI. The analysis of instrument outputs in the process of interpreting the results showed that there was an increase in student perceptual terms with respect to their level of mastery of the four sub-competencies of complex thinking (i.e., critical, innovative, scientific, and systemic thinking), which was in accordance with the results for the three complex thinking sub-competency traits identified by the AI-based platform (i.e., innovative, scientific, and systemic thinking), since most participants achieved intermediate (innovative thinking) and advanced (systemic and scientific thinking) levels of mastery.

7. Conclusion

The stated hypotheses were validated for the development of complex thinking. H1, regarding the event as a pedagogical situation, was true because the Ideathon and the guide of the Transition Design achieved the expected performance in the allotted time. H2, related to the use of AI for measuring complex thinking traits, also proved true because the criteria created for each sub-competency allowed us to assign basic, intermediate, or advanced values for the mastery level of complex thinking.

The implications for practice are that an implementation model has been produced that can be replicated to test different themes beyond the sharing economy megatrend. This combination of physical (Ideathon) and digital (Transition Design) environment gives us a guideline to generate research on hybrid achievement in pedagogy in an accelerated and somewhat competition-driven fashion. Likewise, the exercise of making a proof of concept using AI to measure mastery of complex thinking is a pedagogical experience that can be transposed to different subjects of study and even be incorporated into LMS platforms that are used daily.

The present research focused on a first proof of concept. We note limitations in the quality of the graphics and usability of the platform; the lack of collaborative activities that can be integrated with individual ones to be measured by the platform; the testing of different event lengths to measure performance over days, weeks, or months; the sparse content entered into the platform by students which does not yet allow AI to flourish, for example, by replacing facilitators with a chat system for student queries. Future studies could test different event lengths to measure performance over days, weeks, or months. Other opportunities include using additional criteria to measure the developmental behaviors of complex thinking, its traits, and its sub-competencies in greater detail; monitoring other types of competencies such as problem-solving, computational thinking, or collaboration; and testing functional interactive aspects that are

relevant to make the use of the platform more user-friendly, functional and attractive.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Regarding ethical considerations, students were asked to authorize the use of their data for research purposes by clicking on a button when registering on the platform.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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.

Publisher's note

References

Abd Alsammed, S. M. Z. (2022). Advanced GIS-based multi-function support system for identifying the best route. *Baghdad Sci. J.* 19:631. doi: 10.21123/bsj.2022.19.3.0631

Acquier, A., Daudigeos, T., and Pinkse, J. (2017). Promises and paradoxes of the sharing economy: an organizing framework. *Technol. Forecast. Soc. Chang.* 125, 1–10. doi: 10.1016/j.techfore.2017.07.006

Akmeşe, Ö. F., Kör, H., and Erbay, H. (2021). Use of machine learning techniques for the forecast of student achievement in higher education. *Inf. Technol. Learn. Tools* 82, 297–311. doi: 10.33407/itlt.v82i2.4178

Alemán de la Garza, L. (2019). Modelo de indicadores de calidad para cursos en-línea, masivos y abiertos (mooc). Caso de un MOOC para el desarrollo profesional docente. Ciudad de México, México: Editora Nómada.

Alhumaid, K., Naqbi, S., Elsori, D., and Mansoori, M. (2023). The adoption of artificial intelligence applications in education. *Int. J. Data Netw. Sci.* 7, 457–466. doi: 10.5267/j.ijdns.2022.8.013

Aljuaid, A., and Abbod, M. "Artificial intelligence-based E-recruitments system," (2020) 2020 IEEE 10th International Conference on Intelligent Systems (IS), Varna, Bulgaria, 144–147.

Alsaleh, N. J. (2020). Teaching critical thinking skills literature review. *Turkish Online J. Educ. Technol.* 19, 21–39.

Bachiri, Y.-A., and Mouncif, H. (2023). Artificial intelligence system in aid of pedagogical engineering for knowledge assessment on MOOC platforms: open EdX and moodle. *Int. J. Emerg. Technol. Learn.* 18, 144–160. doi: 10.3991/ijet.v18i05.36589

Barile, S., Orecchini, F., Saviano, M., and Farioli, F. (2018). People, technology, and governance for sustainability: the contribution of systems and cyber-systemic thinking. *Sustain. Sci.* 13, 1197–1208. doi: 10.1007/s11625-018-0621-y

Bäro, A., Toepler, F., Meynhardt, T., and Velamuri, V. K. (2022). Participating in the sharing economy: the role of individual characteristics. *Manag. Decis. Econ.* 43, 3715–3735. doi: 10.1002/mde.3624

Barrow, J. (2021). Hack 2040: an Ideathon event for engaging students in university policy while enhancing their enterprise skills. In Hack 2040

Barykin, S., Borovkov, A., Rozhdestvenskiy, O., Tarshin, A., and Yadykin, V. (2020). Staff competence and training for digital industry. *IOP Conf. Ser.: Mater. Sci. Eng.* 940:012106. doi: 10.1088/1757-899X/940/1/012106

Bengu, A., Abrignani, E., Sabuncuoglu, I., and Yilmaz, C. (2020). Rethinking higher education for the emerging needs of society. *Glob. Solutions J.* 5, 178–187.

Bonfield, C. A., Salter, M., Longmuir, A., Benson, M., and Adachi, C. (2020). Transformation or evolution?: Education 4.0, teaching and learning in the digital age. *Higher Educ. Pedagogies* 5, 223–246. doi: 10.1080/23752696.2020.1816847

Bosch-Gómez, S., Ortega-Pallanez, M., and Dorn, E. (2022). Diseño para la Transición: Entretejiendo saberes por medio de la conversación. Cuadernos del Centro de Estudios en Diseño y Comunicación. *Ensayos* 157, 65–86. doi: 10.18682/cdc.vi157.6845

Bruneckiene, J., Robertas, J., Ineta, Z., Jonas, R., and Mantas, L. (2019). Assessment of investment attractiveness in European countries by artificial neural networks: what competences are needed to make a decision on collective well-being? *Sustainability* 11:6892. doi: 10.3390/su11246892

Castillo-Martínez, I. M., and Ramírez-Montoya, M. S. (2022). Instrumento eComplexity: Medición de la percepción de estudiantes de educación superior acerca de su competencia de razonamiento para la complejidad. https://hdl.handle.net/11285/643622

Chen, G.. (2021). Design of cooperation platform based on HTML5 framework. In International Conference on Machine Learning and Big Data Analytics for IoT Security and Privacy. 233–238. Springer, Cham.

Cheng, W., Zhang, Z., Hoelzer, S., Tang, W., Liang, Y., Du, Y., et al. (2022). Evaluation of a village-based digital health kiosks program: A protocol for a cluster randomized clinical trial. *Digital Health*. 8. doi: 10.1177/20552076221129100

Chiu, T. K. (2021). A holistic approach to the design of artificial intelligence (AI) education for K-12 schools. *TechTrends* 65, 796–807. doi: 10.1007/s11528-021-00637-1

Cornejo-Velazquez, E., Clavel-Maqueda, M., Perez-Lopez-Portillo, H., and Lyubimova, E. (2020). Business model of learning platforms in sharing economy. *Electron. J. e-Learn.* 18, 102–101. doi: 10.34190/EJEL.20.18.1.008

Cortés, D., Molina, A., and Ramírez, J. (2020). Open innovation laboratory: Education 4.0 environments to improve competences in scholars. Proceedings of the 18th LACCEI International Multi-Conference for Engineering, Education and Technology.

Costa-Mendes, R., Oliveira, T., Castelli, M., and Cruz-Jesus, F. (2021). A machine learning approximation of the 2015 Portuguese high school student grades: a hybrid approach. *Educ. Inf. Technol.* 26, 1527–1547. doi: 10.1007/s10639-020-10316-y

Cowart, A., and Maione, D. (2022). Transitioning toward the slow and long: developing experiential futures approach toward system change in fashion. Cuadernos del Centro de Estudios en Diseño y Comunicación. *Ensayos* 157, 29–63. doi: 10.18682/cdc.vi157.6844

Creed, T. A., Salama, L., Slevin, R., Tanana, M., Imel, Z., Narayanan, S., et al. (2022). Enhancing the quality of cognitive behavioral therapy in community mental health through artificial intelligence generated fidelity feedback (Project AFFECT): a study protocol. *BMC Health Serv. Res.* 22:1177. doi: 10.1186/s12913-022-08519-9

Demchenko, M. V., Gulieva, M. E., Larina, T. V., and Simaeva, E. P. (2021). Digital transformation of legal education: problems, risks and prospects. *Eur. J. Contemp. Educ.* 10, 297–307. doi: 10.13187/ejced.2021.2.297

Desnos, K., Bourgoin, T., Dardaillon, M., Sourbier, N., Gesny, O., and Pelcat, M. (2022). Ultra-fast machine learning inference through C code generation for tangled program graphs. IEEE Workshop on Signal Processing Systems (SiPS), 1–6.

De Pretto, L., Hii, C. L., Chiang, C. L., Ong, S. P., Tan, D. E. S. Y., and Pang, C. H. (2019). *On the key factors in higher education classroom design: Physical aspects of the undergraduate teaching and learning experience in Malaysia.* doi: 10.20944/PREPRINTS201908.0089.V1

Di Bella, D. (2018). "Impacto de la experiencia Diseño en Perspectiva" in *Cuadernos del Centro de Estudios en Diseño y Comunicación [Ensayos]*, vol. *80* (Buenos Aires: Facultad Diseño y Comunicación. Universidad de Palermo), 173–219.

Di Bella, D. V. (2022). Experiencia Diseño en Perspectiva: Diseño para la Transición 2° Informe de Impacto (2018–2022). *Cuadernos del Centro de Estudios de Diseño y Comunicación* 158. doi: 10.18682/cdc.vi158.6954

Dmitrievsky, A. N., Eremin, N. A., Safarova, E. A., and Stolyarov, V. E. (2022). Implementation of complex scientific and technical programs at the late stages of operation of oil and gas fields. *SOCAR Proc.* 2022, 1–8. doi: 10.5510/OGP2022SI 200728

Ghnemat, R., Shaout, A., and Al-Sowi, A. M. (2022). Higher education transformation for artificial intelligence revolution: transformation framework. *Int. J. Emerg. Technol. Learn.* 17, 224–241. doi: 10.3991/ijet.v17i19.33309

Giunta, B., Burnay, C., Maiden, N., and Faulkner, S. (2022). Creativity triggers: extension and empirical evaluation of their effectiveness during requirements elicitation. *J. Syst. Softw.* 191:111365. doi: 10.1016/j.jss.2022.111365

Hamal, O., El Faddouli, N. E., Harouni, M. H. A., and Lu, J (2022). Artificial intelligent in education. *Sustainability* 14:2862. doi: 10.3390/su14052862

Haro, C. (2018). Festival de Innovación Epicentro. *Soc. Innov.J.*. Available at: https://socialinnovationsjournal.org/editions/issue-7-spring-summer-2011/75-RED. Revista de Educación a Distancia. 62, 20, 01, 2020, 10.6018/red.398381

Hauer, T. (2022). Incompleteness of moral choice and evolution towards fully autonomous AI. *Humanit. Soc. Sci. Commun.* 9, 1–10. doi: 10.1057/s41599-022-01060-4

Hou, M. (2018). Construction and evaluation of a blending teaching model of linear algebra and probability statistics in the internet+ background by using the gradient Newton combination algorithm. In International Conference on Frontier Computing. 1525–1532. Springer, Singapore

Hrich, N., Lazaar, M., and Khaldi, M. (2019). MAPSS an intelligent architecture for the pedagogical support: experiment, results & discussion. *Int. J. Emerg. Technol. Learn.* 14, 61–79. doi: 10.3991/ijet.v14i21.11012

Hu, J. (2021). Teaching evaluation system by use of machine learning and artificial intelligence methods. *Int. J. Emerg. Technol. Learn.* 16, 87–101. doi: 10.3991/ijet.v16i05.20299

Hurajová, Ľ. (2021). Can close cooperation between ESP/CLIL experts and disciplinary teachers in higher education lead to fostering English education environment. *J. Teach. Eng. Specific Acad. Purp.* 9, 129–136. doi: 10.22190/JTESAP2101129H

Ifenthaler, D., Gibson, D., and Zheng, L. (2018). "Attributes of engagement in challenge-based digital learning environments" in *15th International Conference on Cognition and Exploratory Learning in Digital Age CELDA 2018*. https://eric.ed.gov/?id=ED600598

Irwin, T. (2012). *Wicked problems and the relationship triad* En grow small, think beautiful: ideas for a sustainable world from Schumacher College, Floris Books.

Irwin, T. (2015). Transition design: a proposal for a new area of design practice, study, and research. *Des. Cult.* 7, 229–246. doi: 10.1080/17547075.2015.1051829

Irwin, T., Tonkinwise, C., and Kossoff, G. (2022). Transition Design: an educational framework for advancing the study and design of sustainable transitions. *Cuadernos del Centro de Estudios de Diseño y Comunicación* 105, 31–72. doi: 10.18682/cdc.vi105.4188

Ivanova, A. O., Ignatieva, T. A., and Pilyavsky, V. P. (2021). Trends, opportunities and perspectives of digital education development in the global economy. *IOP Conf. Ser.: Earth Environ. Sci.* 666:032033. doi: 10.1088/1755-1315/666/3/032033

Jarke, J., and Macgilchrist, F. (2021). Dashboard stories: how narratives told by predictive analytics reconfigure roles, risk and sociality in education. *Big Data Soc.* 8:20539517211025561. doi: 10.1177/2053951721102556

Jiang, L. (2021). Virtual reality action interactive teaching artificial intelligence education system. *Complexity* 2021, 1–11. doi: 10.1155/2021/5553211

Jijo, B. T., and Abdulazeez, A. M. (2021). Classification based on decision tree algorithm for machine learning. *Evaluation* 6. doi: 10.38094/jastt20165

Juri, S., Zurbriggen, C., Bosch Gómez, S., and Ortega Pallanez, M. (2021). Transition Design in Latin America: enabling collective learning and change. *Front. Sociol.* 6:725053. doi: 10.3389/fsoc.2021.725053

Kaspar, J., and Vielhaber, M. (2019). Cooperative and application-oriented learning in engineering design—systems design methodology educated on solutions for mousetrap-powered vehicles. Proceedings of the 21st International Conference on Engineering and Product Design Education: Towards A New Innovation Landscape, E and PDE 2019

Kiran, A., Butt, W. H., Anwar, M. W., Azam, F., and Maqbool, B. (2019). A comprehensive investigation of modern test suite optimization trends, tools and techniques. *IEEE Access* 7, 89093–89117. doi: 10.1109/ACCESS.2019.2926384

Konys, A. (2020). How to support digital sustainability assessment? An attempt to knowledge systematization. *Procedia Comput. Sci.* 176, 2297–2311. doi: 10.1016/j.procs.2020.09.288

Krasovskiy, I. N., Pilyavski, V. P., Shendrikova, S. P., and Nazrieva, M. V. (2020). Mechanism of the innovation development in the university. In International Scientific Conference" Far East Con"(ISCFEC 2020). 2297–2311. Atlantis Press

Kuhn, D. (2002). "What is scientific thinking, and how does it develop?" in *Blackwell handbook of childhood cognitive development*. ed. U. Goswami (Oxford: Blackwell Publishing), 371–393.

Lamberti, M. J., Wilkinson, M., Donzanti, B. A., Wohlhieter, G. E., Parikh, S., Wilkins, R. G., et al. (2019). A study on the application and use of artificial intelligence to support drug development. *Clin. Ther.* 41, 1414–1426. doi: 10.1016/j.clinthera.2019.05.018

Liang, Y., and Wang, Y. (2020). "Integration of information technology and three-dimensional teaching mode" in *Data processing techniques and applications for cyber-physical systems (DPTA 2019). Advances in intelligent systems and computing.* eds. C. Huang, Y. W. Chan and N. Yen (Singapore: Springer), 1088.

Liaw, W., Kueper, J. K., Lin, S., Bazemore, A., and Kakadiaris, I. (2022). Competencies for the use of artificial intelligence in primary care. *Ann. Fam. Med.* 20, 559–563. doi: 10.1370/afm.2887

Ljubisic, I. (2017). Student Engagement in College Related Events. [Master's Thesis, Rochester Institute of Technology]. *RIT Scholar Works Repository*. https://scholarworks.rit.edu/theses/10030/

Lokala, U., Lamy, F., Daniulaityte, R., Gaur, M., Gyrard, A., Thirunarayan, K., et al. (2022). Drug abuse ontology to harness web-based data for substance use epidemiology research: ontology development study. *JMIR Public Health Surveill.* 8:e24938. doi: 10.2196/24938

Marks, A., and Al-Ali, M. (2022). Digital transformation in higher education: a framework for maturity assessment. In *COVID-19 challenges to university information technology governance* 61–81). Springer, Cham.

Mcginnis, W. D., Siu, C., Andre, S., and Huang, H. (2018). Category encoders: a Scikit-learn-contrib package of transformers for encoding categorical data. *J. Open Source Softw.* 3:501. doi: 10.21105/joss.00501

McNamara, D. M., Goldberg, S. L., Latts, L., Atieh Graham, D. M., Waintraub, S. E., Norden, A. D., et al. (2019). Differential impact of cognitive computing augmented by real world evidence on novice and expert oncologists. *Cancer Med.* 8, 6578–6584. doi: 10.1002/cam4.2548

Mokhtarname, R., Safavi, A. A., Urbas, L., Salimi, F., Zerafat, M. M., and Harasi, N. (2020). Toward HAZOP 4.0 approach for managing the complexities of the hazard and operability of an industrial polymerization reactor. *IFAC-PapersOnLine* 53, 13593–13600. doi: 10.1016/j.ifacol.2020.12.852

Munir, A., and Awan, O. A. (2022). Creative thinking: its importance and how to cultivate it. *Acad. Radiol.* 29, 1610–1612. doi: 10.1016/j.acra.2021.06.001

Muñoz, P., and Cohen, B. (2017). Mapping out the sharing economy: a configurational approach to sharing business modeling. *Technol. Forecast. Soc. Chang.* 125, 21–37. doi: 10.1080/02635143.2013.878328

Obermayer, N., Nagy, V., Tóth, V. E., and Kiss, D. (2022). Overcoming the challenges of digitalisation in Hungarian manufacturing companies. Proceedings of the European Conference on Knowledge Management, ECKM, 23, 845–851

Paba-Medina, M. C., Acosta-Medina, J. K., and Torres-Barreto, M. L. (2020). Design of a gamified tool for the development of citizenship competencies. International Conference on Higher Education Advances, 743–750

Passig, D., and Cohen, L. (2014). Measuring the style of innovative thinking among engineering students. *Res. Sci. Technol. Educ.* 32, 56–77. doi: 10.1080/02635143.2013.878328

Petrescu, D., Enache, D., and Duta, L. (2021). Collaborative decision-making in online education. *Procedia Comput. Sci.* 199, 1090–1094. doi: 10.1016/j.procs.2022.01.138

Polak, S., Schiavo, G., and Zancanaro, M. (2022). Teachers' Perspective on Artificial Intelligence Education: an Initial Investigation. *Conference on Human Factors in Computing Systems - Proceedings.* doi: 10.1145/3491101.3519866

Prom, N. A., Litvinova, E. A., Shokhnekh, A. V., Yovanovich, T. G., and Lomakin, N. I. (2019). Perseptron for assessing the students' task performance in learning a foreign language according to the competencies using bi data. *IOP Conf. Ser.: Mater. Sci. Eng.* 483:012048. doi: 10.1088/1757-899X/483/1/012048

Raj, R. K., Romanowski, C. J., Impagliazzo, J., Aly, S. G., Becker, B. A., Chen, J., et al. (2020). High performance computing education: current challenges and future directions. Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE, 51–74

Rajadhyaksha, V. D. (2020). Medical affairs post-COVID 19: are we ready to take the baton? *Perspect. Clin. Res.* 11, 124–127. doi: 10.4103/picr.PICR_164_20

Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., and Miranda, J. (2022). Complex thinking in the framework of education 4.0 and open innovation—a systematic literature review. *J. Open Innov.: Technol., Market, Complex.* 8. doi: 10.3390/joitmc8010004

Rashidi Fathabadi, F., Grantner, J. L., Shebrain, S. A., and Abdel-Qader, I. (2023). 3D autonomous surgeon's hand movement assessment using a cascaded fuzzy supervisor in multi-thread video processing. *Sensors* 23. doi: 10.3390/s23052623

Rataj, M., and Wojcik, J. (2022). The impact of COVID-19 on online final exam scores among computer science students. Proceedings of the European Conference on Knowledge Management, ECKM, 23, 955–964

Sanabria-Z, J., Davidson, A.-L., Romero, M., and Quintana, T. (2020). Macro-dissemination of maker cultures: 21st century competencies through an Ideaton. *Rev. Educ. Distancia.* 20. doi: 10.6018/red.398381

Sanabria-Zepeda, J., and Santana-Castellón, E. (2022). TD-HUMETAV: Análisis de problemas perversos para el Museo de Ciencias Ambientales, con base en el Diseño para la Transición. *Cuadernos del Centro de Estudios de Diseño y Comunicación* 157. doi: 10.18682/cdc.vi157.6851

Sandner, P., Lange, A., and Schulden, P. (2020). The role of the CFO of an industrial company: an analysis of the impact of blockchain technology. *Future Internet* 12, 1–16. doi: 10.3390/fi12080128

Shah, D., (2021). By the numbers: MOOCs in 2021—class central. Available at: https://www.classcentral.com/report/mooc-stats-2021/ (Accessed: June 11, 2021)

Shah, C., Davtyan, K., and Nasrallah, I. (2023). Artificial intelligence-powered clinical decision support and simulation platform for radiology trainee education. *J. Digit. Imaging* 36, 11–16. doi: 10.1007/s10278-022-00713-9

Shorey, S., Ang, E., Yap, J., Ng, E. D., Lau, S. T., and Chui, C. K. (2019). A virtual counseling application using artificial intelligence for communication skills training in nursing education: development study. *J. Med. Internet Res.* 21:e14658. doi: 10.2196/14658

SIC (2021). SIC online Ideathon. (Accessed January 25, 2023) Available at: https://s-ic.cz/en/sic-online-ideathon-welcome-office/

Siemens, G. (2012). Learning analytics: envisioning a research discipline and a domain of practice. In Proceedings of the 2nd International Conference on Learning Analytics and Knowledge. 4–8).

Steinmetz, S. (2022). How to Master Digital Facilitation: Best practices and an easy guide for online workshops. *SAP Community - Personal Insights.* https://blogs.sap.com/2022/11/09/how-tomaster-digital-facilitation-best-practices-and-an-easy-guide-for-online-workshops/

Suárez-Brito, P., López-Caudana, E. O., Baena-Rojas, J. J., and Ramírez-Montoya, M. S. (2022). Eliciting complex thinking through open educational resource projects. *J. Soc. Stud. Educ. Res.* 13, 56–77.

Telnov, V., and Korovin, Y. (2019). Semantic web and knowledge graphs as an educational technology of personnel training for nuclear power engineering. *Nucl. Energy Technol.* 5, 273–280. doi: 10.3897/nucet.5.39226

Tsalapatas, H., Heidmann, O., Pata, K., De Carvalho, C. V., Bauters, M., Papadopoulos, S., et al. (2019). Teaching design thinking through gamified learning. CSEDU 2019—Proceedings of the 11th International Conference on Computer Supported Education, 278–283

Tubaro, P. (2022). Learners in the loop: hidden human skills in machine intelligence. *Sociol. Lav.* 163, 110–129. doi: 10.3280/SL2022-163006

Uesugi, M., and Moriyama, T. (2020). Regional disaster preventon with cloud-based GIS mapping and location-based gaming: disaster prevention go!. In Proceedings of the 22nd IAHR-APD Congress 2020.

United Nations (2015) Transforming our world by 2030: A new agenda for global action zero. *Draft of the outcome document for the UN summit to adopt the post-2015 development agenda.* New York: United Nations. Available at: https://sdgs.un.org/2030agenda

University of Washington (2016). C21: the center for 21st century liberal learning. *Ideathon.* (Accessed 25 January, 2023) Available at: https://c21.washington.edu/our-programs/ideathon

University of Waterloo (n.d.). *University relations: Determing event objectives.* https://uwaterloo.ca/university-relations/resources/campus-eventplanning/planning-considerations

Vázquez-Parra, J. C., Cruz-Sandoval, M., and Carlos-Arroyo, M. (2022). Social entrepreneurship and complex thinking: a bibliometric study. *Sustainability* 14:13187. doi: 10.3390/su142013187

Wang, Y. B., and Ho, C. W. (2017). No money? No problem! The value of sustainability: social capital drives the relationship among customer identification and citizenship behavior in sharing economy. *Sustainability* 9:1400. doi: 10.3390/su9081400

World Economic Forum (2015). *Understanding the sharing economy.* Retrieved from: https://www3.weforum.org/docs/WEF_Understanding_the_Sharing_Economy_report_2016.pdf

Xia, Q., Chiu, T. K., Zhou, X., Chai, C. S., and Cheng, M. (2022). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Comput. Educ.: Artif. Intell.* 4:100118. doi: 10.1016/j.caeai.2022.100118

Yang, C., Huan, S., and Yang, Y. (2020). A practical teaching mode for colleges supported by artificial intelligence. *Int. J. Emerg. Technol. Learn.* 15, 195–206. doi: 10.3991/ijet.v15i17.16737

Yang, D., Zhou, J., Shi, D., Pan, Q., Wang, D., Chen, X., et al. (2022). Research status, hotspots, and evolutionary trends of global digital education via knowledge graph analysis. *Sustainability* 14:15157. doi: 10.3390/su142215157

Yu, J. (2021). Academic performance prediction method of online education using random Forest algorithm and artificial intelligence methods. *Int. J. Emerg. Technol. Learn.* 16, 45–57. doi: 10.3991/ijet.v16i05.20297

Yudina, V., Skrupskaya, Y., Taratukhin, V., Kozlova, E., and Pulyavina, N. (2021), Bringing together engineering and management students for a project-based global idea-thon: towards next-gen design thinking methodology. Paper Presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference

Zakharkina, L., Rubanov, P., Alibekova, B., Zakharkin, O., and Moldashbayeva, L. (2022). The impact of digital transformation in the accounting system of fuel and energy complex enterprises (international experience). *Int. J. Energy Econ. Policy* 12, 152–161. doi: 10.32479/ijeep.13317

Zhao, X. X., Wu, S. P., Wang, J. Y., Gong, X. Y., He, X. R., Xi, M. J., et al. (2020). Comparison of multiple quantitative evaluation indices of theoretical knowledge and clinical practice skills and training of medical interns in cardiovascular imaging using blended teaching and the case resource network platform (CRNP). *Med. Sci. Monit.* 26:e923836. doi: 10.12659/MSM.923836

Zhu, Q., Zhang, F., Huang, Y., Xiao, H., Zhao, L. Y., Zhang, X. C., et al. (2022). An all-round AI-chemist with a scientific mind. *Natl. Sci. Rev.* 9:nwac190. doi: 10.1093/nsr/nwac190