Journal of Infrastructure, Policy and Development 2024, 8(7), 4580.
https://doi.org/10.24294/jipd.v8i7.4580

Article

Complex thinking model with sustainable development goals: Analysis with scenario-based learning for future education

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CITATION

Rodés-Paragarino V, Ramirez-Montoya MS, Maure LM, Rosales R. (2024). Complex thinking model with sustainable development goals: Analysis with scenario-based learning for future education. Journal of Infrastructure, Policy and Development. 8(7): 4580. https://doi.org/10.24294/jipd.v8i7.4580

ARTICLE INFO

Received: 7 February 2024
Accepted: 19 March 2024
Available online: 29 July 2024

Abstract: In the present and future of education, fostering complex thinking, especially in the context of the Sustainable Development Goals (SDGs), is critical to lifelong learning. This study aimed to analyze learning scenarios within the framework of a model that promotes complex thinking and integrated design analysis, to identify the contributions of linking design models to the SDGs. The research question was: How does the open educational model of complex thinking link to the SDGs and scenario design? The analysis examined a pedagogical approach that introduced 33 participants to the instructional design of real-life or simulated situations to develop complex thinking skills. The categories of analysis were the model components, the SDGs, and scenario designs. The findings considered (a) innovative design capacity linked to SDG challenges, (b) linking theory and practice to foster complex thinking, and (c) the critical supporting tools for scenario design. The study intends to be of value to academic, social, and business communities interested in mobilizing complex thinking to support lifelong learning.

Keywords: complex thinking; educational innovation; higher education; scenario-based-learning; sustainable development goals

1. Introduction

In a world as complex as the present one, full of uncertainties and emergencies in all areas, education is no exception, mainly within the teaching-learning process. The diversity of personalities involved in this process, in addition to the type of subject matter and context, leads to finding different learning alternatives such as Scenario-Based Learning (SBL) (Sorin, 2013). The SBL is an adaptable, contextual approach to education. Its effectiveness lies in the commitment to student-centered learning and the ability to incorporate technological advances to improve learning outcomes; it is used in traditional classrooms, professional education, and settings enriched by technology (Mamakli et al., 2023; Mills et al., 2020; Mio et al., 2019).

The SBL according (Smith et al., 2018; Shipton, 2023; Zitouniatis et al., 2023) entails presenting learners with realistic situations or scenarios to facilitate learning, this type of learning offers some features. For instance, it provides real-world contexts that help learners grasp and apply the knowledge and skills being taught. It's crucial for engagement to encourage participation by prompting learners to solve problems, make decisions, and apply thinking skills in the presented scenarios. Another aspect is the development of problem-solving skills; scenarios often require learners to analyze information, identify issues, and come up with solutions to enhance their problem-solving abilities. Decision-making skills allow learners to practice making decisions in situations and learn from the outcomes within a scenario setting, which ultimately improves their decision-making capabilities. This approach promotes learning as it encourages learners to explore, experiment, and engage with the content. Reflection comes into play after interacting with a scenario where stakeholders are urged to reflect on their experiences and learning outcomes. Through reflection, learners can deepen their understanding, and pinpoint areas for improvement. Establish connections between theory and practice.

In SBL students are encouraged to collaborate to tackle challenges or reach decisions within a given scenario. Feedback, from teachers, classmates, or automated systems plays a role in helping students grasp concepts, rectify misunderstandings, and reinforce learning goals. Additionally, it’s vital to take into account the flexibility of learners by adapting scenarios in SBL to meet their requirements, preferences, and abilities.

The interaction between adaptable SBL and its various applications invites the analysis of the effectiveness of this pedagogical approach. One primary concern is optimizing instructional design to improve student engagement and learning outcomes. Different methods and structures make SBL effective across various educational media (Christiani et al., 2023; Mazzucato et al., 2020). This effectiveness leads to examining educators’ crucial role in the overall success of this educational approach.

The socioeconomic challenges defined by the 2030 Agenda for Sustainable Development extend the mandate of universities beyond traditional educational and research practices. The role of higher education institutions in advancing the Sustainable Development Goals (SDGs) puts them as powerful agents of social transformation (Aoun et al., 2023; Holmes et al., 2022; Seth, 2023). Their capacity to proactively engage with multiple SDGs has been explored in sustainability studies (Sinnappan, 2023; Yuan, 2022), while universities address social inequalities through pedagogical and social practices, emphasizing their institutional responsibility (Hirsch et al., 2021). This commitment suggests that higher education can be fundamental for economic, social, and environmental sustainability (Pakkan et al., 2023). However, actualizing these roles involves challenges, particularly integrating interdisciplinary approaches and a holistic institutional vision (Cottafava et al., 2022; Du Preez et al., 2022; Newman, 2023). Thus, it is critical to recognize universities’ dual roles in pedagogical innovation and public policy guidance.

Innovation in the future of education requires integrating critical, systemic, scientific, and innovative thinking to reconstruct educational spaces in inclusive ecosystems facilitated by digital technologies, while emphasizing the need for a forward-thinking educational system designed to address the challenges of the present and future (Carlos-Arroyo et al., 2023; Ramírez-Montoya et al., 2022). This research aimed to explore the instructional design of scenario-based learning (SBL) to foster complex thinking skills, specifically within the context of the Sustainable Development Goals (SDGs). Distinguished by its focus on higher education and its application of the Open Education Model for Complex Thinking (OEM4C), this study offers a novel approach to creating learning scenarios that foster both complex thinking and the problem-solving skills essential to address the complexities of the SDGs. The pedagogical approach involved higher education participants, teachers, and researchers in Mexico, in designing scenarios to solve real-life problems to develop complex thinking skills with students. The study reveals that participants could conceptualize and construct learning scenarios that require complex thinking, thus confirming the potential to bridge theoretical and practical learning necessary to address SDG challenges. Furthermore, the structured design tool introduced in the research facilitated a unified and coherent approach to creating educational scenarios, thus highlighting the significant relevance and applicability of the OEM4C model in SBL in complex contexts.

This article first presents a theoretical framework that incorporates Scenario-Based Learning, complex thinking for the future of education, and the Sustainable Development Goals. Next is a section on a Design-Based Research methodology, a description of participants from the Institute for the Future of Education at Tecnologico de Monterrey, the data collection tool, and an analysis based on the OEM4C framework. The final sections include the results, discussion, and conclusions based on the OEM4C framework.

1.1. Scenario-based learning

The role of educators in SBL is a prominent research area, with studies suggesting that the effectiveness of SBL is closely tied to how well educators design and implement scenarios (Bardach et al., 2021; Souza et al., 2022). Educators do not only implement existing frameworks; they actively shape the learning experience. Their pedagogical perspective is fundamental for the exploration of student-centered frameworks in SBL. Research highlights the importance of student-centered designs in SBL. Such frameworks aim to develop essential skills in students, notably problem-solving and decision-making abilities (Daniels et al., 2022; Lin et al., 2020). Alongside this, the relevance of digital tools in crafting and delivering scenarios in online settings has also been studied (Ball et al., 2021; Yilmaz et al., 2020). Thus, amid the explorations of SBL effectiveness in professional settings, emergent technologies enrich the landscape.

In professional education, SBL bridges academic theory and practical applications. Simulated, real-world scenarios enhance knowledge retention and the application of skills in professional settings (Deepa and Durairajan, 2023; Foster and Adjekum, 2022; Giannakas et al., 2023; Samuel and Subramaniam, 2022; Valente and Marchetti, 2019; Yeng et al., 2020). Studies examine emerging technologies such as AR and VR for their potential to improve the effectiveness of SBL. These technologies add a layer of realism, increase student engagement, and promote self-directed learning (Álvarez-Nieto et al., 2023; Wu and Wen, 2020).

1.2. Complex thinking in the future of education

The future of education will continue to encompass the well-being of individuals and society, producing initiatives for change and the formation of high capacities for complex thinking that support flexibility for lifelong learning, sustainable development, social justice, and peace and security for all. Khan (2023) invites institutions to place the solution of the world’s most pressing challenges at the center of their missions, address the complex problems of sustainable development, and promote future-focused leadership skills to navigate global changes. In the future of education, actions must create new forms of participatory leadership, characterized by cooperation, solidarity, trust, and justice (Magno and Becker, 2023). Along the same line, Cruz-Sandoval et al. (2023) urge that future social entrepreneurs develop high capacities to be catalysts for transformative actions. Visualizing the future, one must deconstruct and make sense of the complexities of new realities to have quality learning experiences (Soudien, 2020). Complex learning scenarios are necessary for the future of education.

Such complex learning scenarios encompass flexible technologies and devices that support the integration of environments for specific needs. Fleener (2022) suggests considering social factors as fundamental for transformative educational changes, which challenges traditional curricula, outcomes, and infrastructure. In the field of complexity, Ramírez-Montoya et al. (2022) conceptualize complex thinking as the ability to integrate critical, systemic, scientific, and innovative thinking to provide new solutions and reconstruct the formative spaces of people, envisioning education as part of a new inclusive ecosystem of training, integrating open digital technology as a vehicle for new ideas and connections, and co-constructing new formative processes. This requires policies to develop practical ideas to reshape curricula and produce future-ready educational prototype models (Yousefi Hamedani et al., 2023) and creative, forward-looking teaching-learning ecosystems to transform the future of education (Zamana, 2022). These would be geared to solve the problems and challenges of future environments (Carlos-Arroyo, 2023). Training for complexity requires environments oriented toward lifelong learning.

1.3. Sustainable development goals in higher education

Higher education institutions emerge as relevant actors, due to their pedagogical and research capacities (Hamdan, 2020; Khan, 2023). The intersectionality of poverty within the SDGs makes universities essential for disseminating knowledge and effectively translating it into public policies, changing management strategies to contribute to economic sustainability (Hirsch et al., 2021; Kusi-Mensah et al., 2022). This underlines the importance of universities in fostering a culture of community participation and sustainable development through their academic and research frameworks. The heterogeneity of the associated challenges of poverty and sustainability requires a comprehensive approach incorporating economic and social strategies (Smith et al., 2022); they must address innovation, gender equality, and social justice, among other aspects. In this comprehensive approach, the transformative potential of higher education becomes a fundamental assumption.

Higher education institutions have transformative potential (Hamdan, 2020; Ferreras-García et al., 2022), for technological and community innovation to advance work in the SDGs related to healthcare and education (Ferreira-Oliveira et al., 2022; Lee et al., 2023). Additionally, universities foster a culture that promotes community development and social justice. Gender issues and social imbalances are recognized as critical points in the SDG discourse, requiring higher education institutions to enact gender-sensitive policies and advocate for broader inclusion and diversity (Baena-Morales et al., 2020; Handrahan, 2022; Martínez et al., 2021; Walentowski et al., 2020) because pedagogical innovation is indispensable for sustainable development. Universities, as complex socio-political entities, must engage comprehensively and interdisciplinarily with the countless domains of sustainability to align their institutional missions with global sustainability objectives.

2. Materials and methods

The methodological approach of the study is grounded in design-based research addressing the systemic and complex characteristics of the educational phenomenon. Design-Based Research (DBR) is a methodology tailored to the complexities of educational systems, necessitated by evolving research demands, technological advancements, and a deeper grasp of learning processes among teachers and students (Linn et al., 2013). It addresses the systemic nature and resistance to change inherent in education, with a goal to enhance teaching methods and identify effective interventions. DBR operates through a cycle of designing, testing, and refining instructional strategies, leading to the creation of adaptable design principles. These principles inform future educational innovations, providing a structured approach to the ongoing enhancement of learning environments. It allows a reciprocal relationship between curricular development and the improvement of the theoretical framework, including the creation of teaching materials as well as technology-supported learning environments and curricular projects. Researchers evaluate these designs by gathering evidence through iterative cycles of analysis, adjustment, and theoretical reconceptualization.

The research question was: How does the open educational model of complex thinking link to the SDGs and scenario design? The method conducted design-based research to develop the characteristics of the model, in order to address the complexity and interrelatedness of complex thinking elements, with a view to advancing a pedagogical approach that leads to educational practice, with advanced technologies and guidelines for scenario design, linked to innovation and open education. The designs are shaped by educational objectives and follow instructional frameworks, in this case, the framework, Design-Based Learning, and the Open Education Model for Complexity (OEM4C.) The OEM4C establishes important connections with the conceptions of complex, interdisciplinary and intersectoral knowledge, education, and open science for the democratization of knowledge, social construction linked to the SDGs and integrative and challenging ecosystems for lifelong learning (Ramírez Montoya et al., 2024). This educational model provides essential elements that must be considered in instructional design, such as encouraging critical, scientific, systemic, and innovative thinking based on real situations and linked with contemporary challenges, such as the SDGs.

The scenarios, designed within the OEM4C framework were aimed at a broad application across various contexts in Mexico and internationally, including science clubs and universities (both public and private), to address SDGs challenges. The adoption of SBL is a strategic response to the inadequacies of traditional educational approaches, chosen for its potential to enhance critical thinking and problem-solving skills for tackling the complex issues connected with the SDGs. These scenarios aim to engage a diverse audience, cutting across socioeconomic, gender, age, nationality and disciplinary lines, in both English and Spanish, reflecting a commitment to inclusive, interdisciplinary solutions for sustainable development across the SDGs.

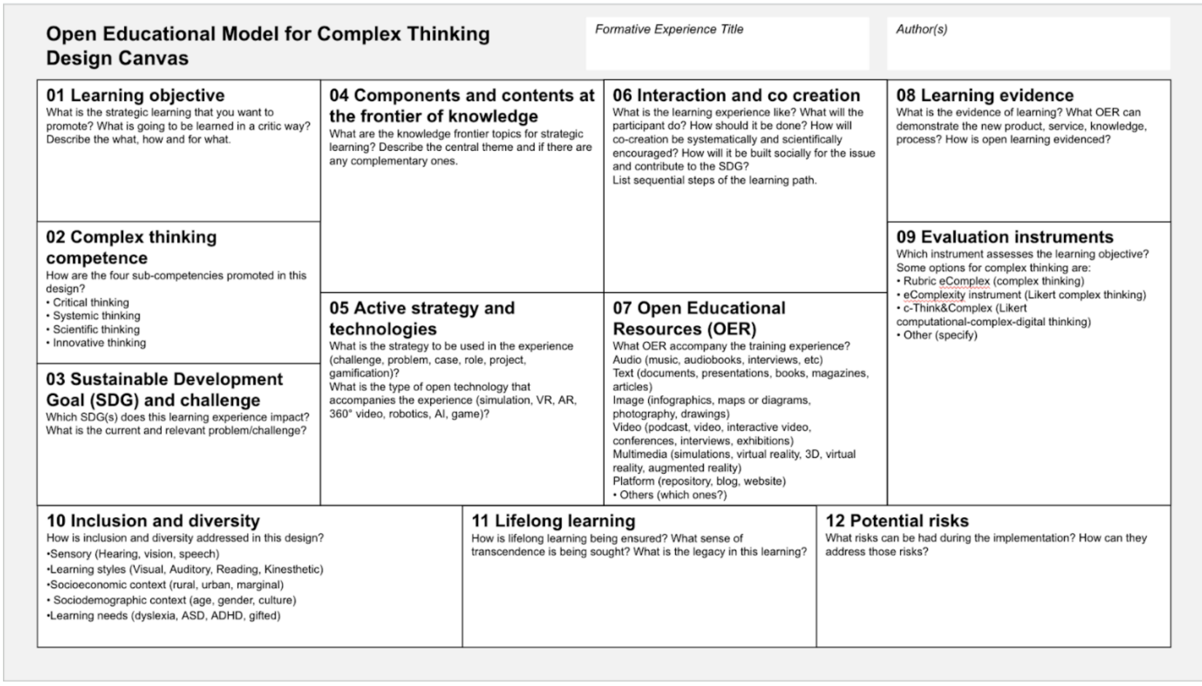
2.1. Participants

The study utilized a convenience sampling strategy, a method frequently employed in qualitative research, selecting participants for their accessibility and significance to the research goals. Participation was voluntary, extended through invitations to ensure autonomy. Invitees received thorough information regarding the study's purposes, their participation, anticipated benefits, potential risks, and safeguards for their anonymity and confidentiality. Informed consent was secured, following the recommendations for the Institutional Committee for Research Ethics (CIEI) of the Instituto Tecnologico y de Estudios Superiores de Monterrey. As a result, the participants comprised 33 individuals, (54.8% men and 45.2% women) who were professors and researchers from the Institute for the Future of Education at Tecnologico de Monterrey, Mexico. Adjoint faculty comprised 21.2% of the sample (7 participants). Associate faculty and doctoral students each accounted for 12.1%, with four participants in both categories. Full Professors comprised 15.2% of the sample with five individuals. The largest group was postdoctoral researchers, making up 39.4% (13 participants). The participants hailed from diverse academic disciplines, providing enriched academic backgrounds. Engineering had the most representation, with 10 participants (30.3%), followed by Education with 9 participants (27.3%). Information Sciences had 3 participants (9.1%), Psychology had two (6.1%), while Sciences, Neurosciences, Design, Mathematics, and Philosophy each had one representative, accounting for 3.0% each.

2.2. Instruments and data collection

The data collection instrument was a structured design tool for educational scenarios (see **Figure 1**). The "Open Educational Model for Complex Thinking Design Canvas" provides a comprehensive framework for instructional design. For the analysis, the designs developed by the participants were considered as data.

The instrument, created under the framework of the OEM4C provides a conceptual architecture for the crafting of educational experiences aimed at empowering learners to enhance societal quality of life and further sustainable development (Ramirez-Montoya et al, 2023). The OEM4C Canvas includes the following sections: Learning Objective, Complex Thinking Competence, Components and Contents at the Frontier of Knowledge, Active Strategy and Technologies, Interaction and Co-Creation, Open Educational Resources, Evidence of Learning, Instruments of Evaluation, Inclusion and Diversity, Lifelong Learning, and Potential Risks.


Open Educational Model for Complex Thinking Design Canvas
Formative Experience Title
Author(s)

01 Learning objective
What is the strategic learning that you want to promote? What is going to be learned in a critic way? Describe the what, how and for what.

02 Complex thinking competence
How are the four sub-competencies promoted in this design?
• Critical thinking
• Systemic thinking
• Scientific thinking
• Innovative thinking

03 Sustainable Development Goal (SDG) and challenge
Which SDG(s) does this learning experience impact? What is the current and relevant problem/challenge?

04 Components and contents at the frontier of knowledge
What are the knowledge frontier topics for strategic learning? Describe the central theme and if there are any complementary ones.

05 Active strategy and technologies
What is the strategy to be used in the experience (challenge, problem, case, role, project, gamification)?
What is the type of open technology that accompanies the experience (simulation, VR, AR, 360° video, robotics, AI, game)?

06 Interaction and co creation
What is the learning experience like? What will the participant do? How should it be done? How will co-creation be systematically and scientifically encouraged? How will it be built socially for the issue and contribute to the SDG?
List sequential steps of the learning path.

07 Open Educational Resources (OER)
What OER accompany the training experience?
Audio (music, audiobooks, interviews, etc)
Text (documents, presentations, books, magazines, articles)
Image (infographics, maps or diagrams, photography, drawings)
Video (podcast, video, interactive video, conferences, interviews, exhibitions)
Multimedia (simulations, virtual reality, 3D, virtual reality, augmented reality)
Platform (repository, blog, website)
• Others (which ones?)

08 Learning evidence
What is the evidence of learning? What OER can demonstrate the new product, service, knowledge, process? How is open learning evidenced?

09 Evaluation instruments
Which instrument assesses the learning objective? Some options for complex thinking are:
• Rubric eComplex (complex thinking)
• eComplexity instrument (Likert complex thinking)
• c-Think&Complex (Likert computational-complex-digital thinking)
• Other (specify)

10 Inclusion and diversity
How is inclusion and diversity addressed in this design?
•Sensory (Hearing, vision, speech)
•Learning styles (Visual, Auditory, Reading, Kinesthetic)
•Socioeconomic context (rural, urban, marginal)
• Sociodemographic context (age, gender, culture)
•Learning needs (dyslexia, ASD, ADHD, gifted)

11 Lifelong learning
How is lifelong learning being ensured? What sense of transcendence is being sought? What is the legacy in this learning?

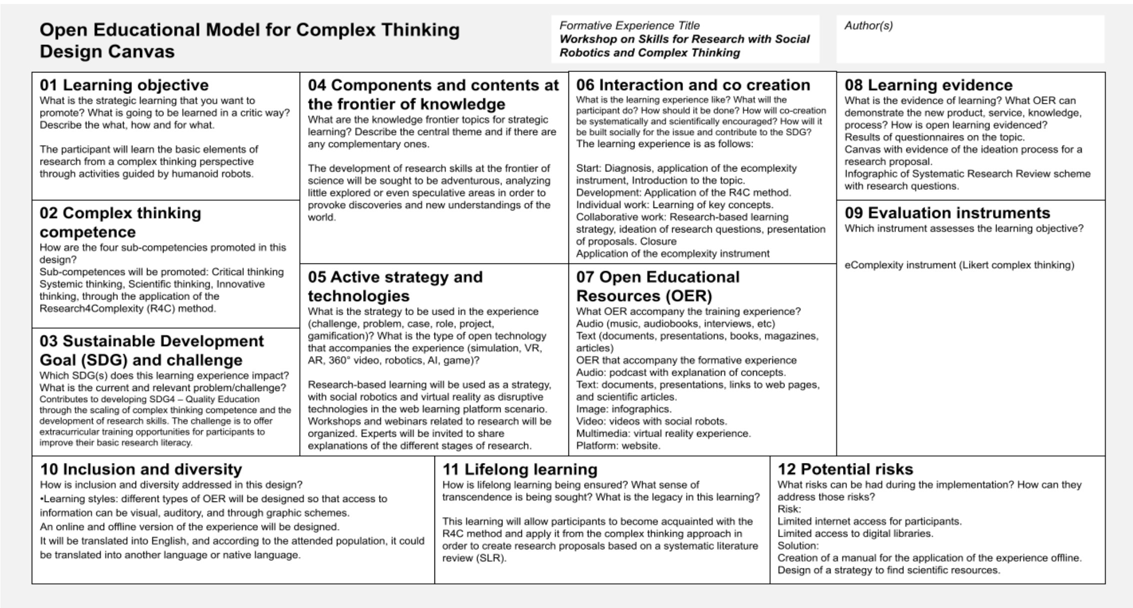
12 Potential risks
What risks can be had during the implementation? How can they address those risks?

Figure 1. OEM4C Design Canvas for learning experiences as in real-life scenarios building.

Source: Ramírez Montoya et al., 2024.

This tool also sought to provide a systematic and coherent approach to SBL design. During 15 days of July 2023, the participants used the OEM4C Canvas to design SBL collaboratively, organized into four interdisciplinary groups, Participants were able to work with any of the SDGs, and to choose any methods, resources and activities to include in the Canvas. As a result of this data collection activity, sixteen scenarios were created to promote Complex Thinking in SDGs in the context of Higher Education.

Following, three examples of the scenarios created by the participants are shown in **Figures 2–4**.


Open Educational Model for Complex Thinking Design Canvas
Formative Experience Title
Workshop on Skills for Research with Social Robotics and Complex Thinking
Author(s)

01 Learning objective
What is the strategic learning that you want to promote? What is going to be learned in a critic way? Describe the what, how and for what.

The participant will learn the basic elements of research from a complex thinking perspective through activities guided by humanoid robots.

02 Complex thinking competence
How are the four sub-competencies promoted in this design?
Sub-competences will be promoted: Critical thinking Systemic thinking, Scientific thinking, Innovative thinking, through the application of the Research4Complexity (R4C) method.

03 Sustainable Development Goal (SDG) and challenge
Which SDG(s) does this learning experience impact? What is the current and relevant problem/challenge?
Contributes to developing SDG4 – Quality Education through the scaling of complex thinking competence and the development of research skills. The challenge is to offer extracurricular training opportunities for participants to improve their basic research literacy.

04 Components and contents at the frontier of knowledge
What are the knowledge frontier topics for strategic learning? Describe the central theme and if there are any complementary ones.

The development of research skills at the frontier of science will be sought to be adventurous, analyzing little explored or even speculative areas in order to provoke discoveries and new understandings of the world.

05 Active strategy and technologies
What is the strategy to be used in the experience (challenge, problem, case, role, project, gamification)? What is the type of open technology that accompanies the experience (simulation, VR, AR, 360° video, robotics, AI, game)?

Research-based learning will be used as a strategy, with social robotics and virtual reality as disruptive technologies in the web learning platform scenario. Workshops and webinars related to research will be organized. Experts will be invited to share explanations of the different stages of research.

06 Interaction and co creation
What is the learning experience like? What will the participant do? How should it be done? How will co-creation be systematically and scientifically encouraged? How will it be built socially for the issue and contribute to the SDG?
The learning experience is as follows:

Start: Diagnosis, application of the ecomplexity instrument, Introduction to the topic.
Development: Application of the R4C method.
Individual work: Learning of key concepts.
Collaborative work: Research-based learning strategy, ideation of research questions, presentation of proposals. Closure
Application of the ecomplexity instrument

07 Open Educational Resources (OER)
What OER accompany the training experience?
Audio (music, audiobooks, interviews, etc)
Text (documents, presentations, books, magazines, articles)
OER that accompany the formative experience
Audio: podcast with explanation of concepts.
Text: documents, presentations, links to web pages, and scientific articles.
Image: infographics.
Video: videos with social robots.
Multimedia: virtual reality experience.
Platform: website.

08 Learning evidence
What is the evidence of learning? What OER can demonstrate the new product, service, knowledge, process? How is open learning evidenced?
Results of questionnaires on the topic.
Canvas with evidence of the ideation process for a research proposal.
Infographic of Systematic Research Review scheme with research questions.

09 Evaluation instruments
Which instrument assesses the learning objective?

eComplexity instrument (Likert complex thinking)

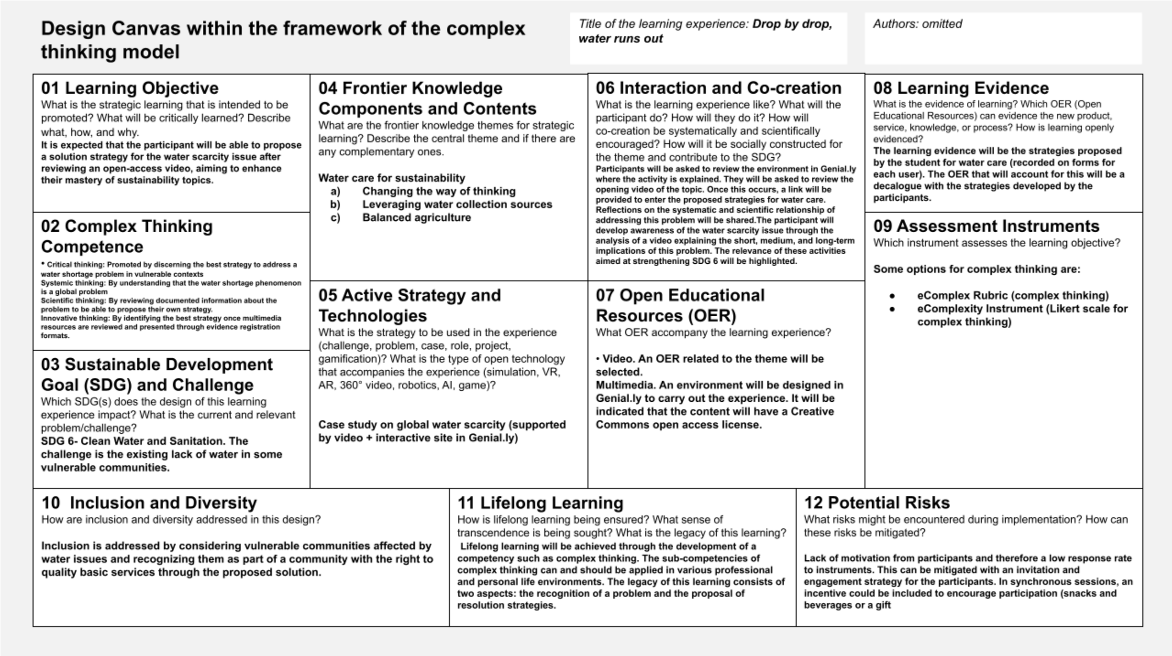
10 Inclusion and diversity
How is inclusion and diversity addressed in this design?
•Learning styles: different types of OER will be designed so that access to information can be visual, auditory, and through graphic schemes.
An online and offline version of the experience will be designed.
It will be translated into English, and according to the attended population, it could be translated into another language or native language.

11 Lifelong learning
How is lifelong learning being ensured? What sense of transcendence is being sought? What is the legacy in this learning?

This learning will allow participants to become acquainted with the R4C method and apply it from the complex thinking approach in order to create research proposals based on a systematic literature review (SLR).

12 Potential risks
What risks can be had during the implementation? How can they address those risks?
Risk:
Limited internet access for participants.
Limited access to digital libraries.
Solution:
Creation of a manual for the application of the experience offline.
Design of a strategy to find scientific resources.

Figure 2. Scenario: Drop by drop, water runs out. Example.



Design Canvas within the framework of the complex thinking model

Title of the learning experience: ***Drop by drop, water runs out***

Authors: omitted

01 Learning Objective
What is the strategic learning that is intended to be promoted? What will be critically learned? Describe what, how, and why.
It is expected that the participant will be able to propose a solution strategy for the water scarcity issue after reviewing an open-access video, aiming to enhance their mastery of sustainability topics.

02 Complex Thinking Competence
• Critical thinking: Promoted by discerning the best strategy to address a water shortage problem in vulnerable contexts
Systemic thinking: By understanding that the water shortage phenomenon is a global problem
Scientific thinking: By reviewing documented information about the problem to be able to propose their own strategy.
Innovative thinking: By identifying the best strategy once multimedia resources are reviewed and presented through evidence registration formats.

03 Sustainable Development Goal (SDG) and Challenge
Which SDG(s) does the design of this learning experience impact? What is the current and relevant problem/challenge?
SDG 6- Clean Water and Sanitation. The challenge is the existing lack of water in some vulnerable communities.

04 Frontier Knowledge Components and Contents
What are the frontier knowledge themes for strategic learning? Describe the central theme and if there are any complementary ones.

Water care for sustainability
a) **Changing the way of thinking**
b) **Leveraging water collection sources**
c) **Balanced agriculture**

05 Active Strategy and Technologies
What is the strategy to be used in the experience (challenge, problem, case, role, project, gamification)? What is the type of open technology that accompanies the experience (simulation, VR, AR, 360° video, robotics, AI, game)?

Case study on global water scarcity (supported by video + interactive site in Genial.ly)

06 Interaction and Co-creation
What is the learning experience like? What will the participant do? How will they do it? How will co-creation be systematically and scientifically encouraged? How will it be socially constructed for the theme and contribute to the SDG?
Participants will be asked to review the environment in Genial.ly where the activity is explained. They will be asked to review the opening video of the topic. Once this occurs, a link will be provided to enter the proposed strategies for water care. Reflections on the systematic and scientific relationship of addressing this problem will be shared.The participant will develop awareness of the water scarcity issue through the analysis of a video explaining the short, medium, and long-term implications of this problem. The relevance of these activities aimed at strengthening SDG 6 will be highlighted.

07 Open Educational Resources (OER)
What OER accompany the learning experience?

• Video. An OER related to the theme will be selected.
Multimedia. An environment will be designed in Genial.ly to carry out the experience. It will be indicated that the content will have a Creative Commons open access license.

08 Learning Evidence
What is the evidence of learning? Which OER (Open Educational Resources) can evidence the new product, service, knowledge, or process? How is learning openly evidenced?
The learning evidence will be the strategies proposed by the student for water care (recorded on forms for each user). The OER that will account for this will be a decalogue with the strategies developed by the participants.

09 Assessment Instruments
Which instrument assesses the learning objective?

Some options for complex thinking are:

- **eComplex Rubric (complex thinking)**
- **eComplexity Instrument (Likert scale for complex thinking)**

10 Inclusion and Diversity
How are inclusion and diversity addressed in this design?

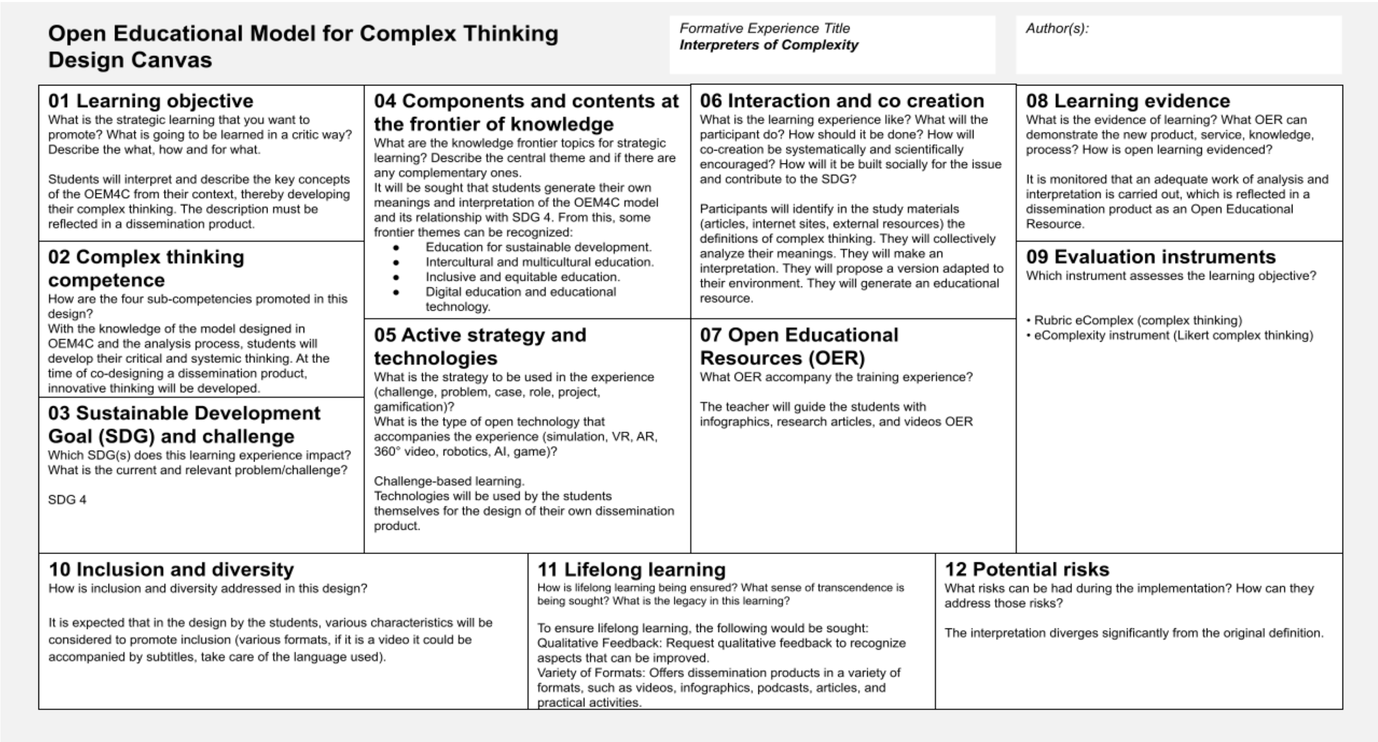
Inclusion is addressed by considering vulnerable communities affected by water issues and recognizing them as part of a community with the right to quality basic services through the proposed solution.

11 Lifelong Learning
How is lifelong learning being ensured? What sense of transcendence is being sought? What is the legacy of this learning?
Lifelong learning will be achieved through the development of a competency such as complex thinking. The sub-competencies of complex thinking can and should be applied in various professional and personal life environments. The legacy of this learning consists of two aspects: the recognition of a problem and the proposal of resolution strategies.

12 Potential Risks
What risks might be encountered during implementation? How can these risks be mitigated?

Lack of motivation from participants and therefore a low response rate to instruments. This can be mitigated with an invitation and engagement strategy for the participants. In synchronous sessions, an incentive could be included to encourage participation (snacks and beverages or a gift

Figure 3. Scenario: Workshop on Skills for Research with Social Robotics and Complex Thinking. Example.



Open Educational Model for Complex Thinking Design Canvas

Formative Experience Title
Interpreters of Complexity

Author(s):

01 Learning objective
What is the strategic learning that you want to promote? What is going to be learned in a critic way? Describe the what, how and for what.

Students will interpret and describe the key concepts of the OEM4C from their context, thereby developing their complex thinking. The description must be reflected in a dissemination product.

02 Complex thinking competence
How are the four sub-competencies promoted in this design?
With the knowledge of the model designed in OEM4C and the analysis process, students will develop their critical and systemic thinking. At the time of co-designing a dissemination product, innovative thinking will be developed.

03 Sustainable Development Goal (SDG) and challenge
Which SDG(s) does this learning experience impact? What is the current and relevant problem/challenge?

SDG 4

04 Components and contents at the frontier of knowledge
What are the knowledge frontier topics for strategic learning? Describe the central theme and if there are any complementary ones.
It will be sought that students generate their own meanings and interpretation of the OEM4C model and its relationship with SDG 4. From this, some frontier themes can be recognized:
- Education for sustainable development.
- Intercultural and multicultural education.
- Inclusive and equitable education.
- Digital education and educational technology.

05 Active strategy and technologies
What is the strategy to be used in the experience (challenge, problem, case, role, project, gamification)?
What is the type of open technology that accompanies the experience (simulation, VR, AR, 360° video, robotics, AI, game)?

Challenge-based learning.
Technologies will be used by the students themselves for the design of their own dissemination product.

06 Interaction and co creation
What is the learning experience like? What will the participant do? How should it be done? How will co-creation be systematically and scientifically encouraged? How will it be built socially for the issue and contribute to the SDG?

Participants will identify in the study materials (articles, internet sites, external resources) the definitions of complex thinking. They will collectively analyze their meanings. They will make an interpretation. They will propose a version adapted to their environment. They will generate an educational resource.

07 Open Educational Resources (OER)
What OER accompany the training experience?

The teacher will guide the students with infographics, research articles, and videos OER

08 Learning evidence
What is the evidence of learning? What OER can demonstrate the new product, service, knowledge, process? How is open learning evidenced?

It is monitored that an adequate work of analysis and interpretation is carried out, which is reflected in a dissemination product as an Open Educational Resource.

09 Evaluation instruments
Which instrument assesses the learning objective?

• Rubric eComplex (complex thinking)
• eComplexity instrument (Likert complex thinking)

10 Inclusion and diversity
How is inclusion and diversity addressed in this design?

It is expected that in the design by the students, various characteristics will be considered to promote inclusion (various formats, if it is a video it could be accompanied by subtitles, take care of the language used).

11 Lifelong learning
How is lifelong learning being ensured? What sense of transcendence is being sought? What is the legacy in this learning?

To ensure lifelong learning, the following would be sought:
Qualitative Feedback: Request qualitative feedback to recognize aspects that can be improved.
Variety of Formats: Offers dissemination products in a variety of formats, such as videos, infographics, podcasts, articles, and practical activities.

12 Potential risks
What risks can be had during the implementation? How can they address those risks?

The interpretation diverges significantly from the original definition.

Figure 4. Scenario: Interpreters of complexity. Example.

2.3. Analysis

The categories of analysis were the model components, the SDGs, and scenario designs. The OEM4C framework sheltered the analysis of the designed scenarios in the intersection of philosophical, political, educational, and theoretical components, as shown in **Figure 5**, "Schematic representation of the Open Educational Model for Complex Thinking, components, contexts of application, resources and expected outcomes" (Ramirez-Montoya et al., 2023).

This educational model provides essential elements that must be considered, such as critical, scientific, systemic, and innovative thinking based on real situations linked with contemporary challenges, such as achieving the SDGs.

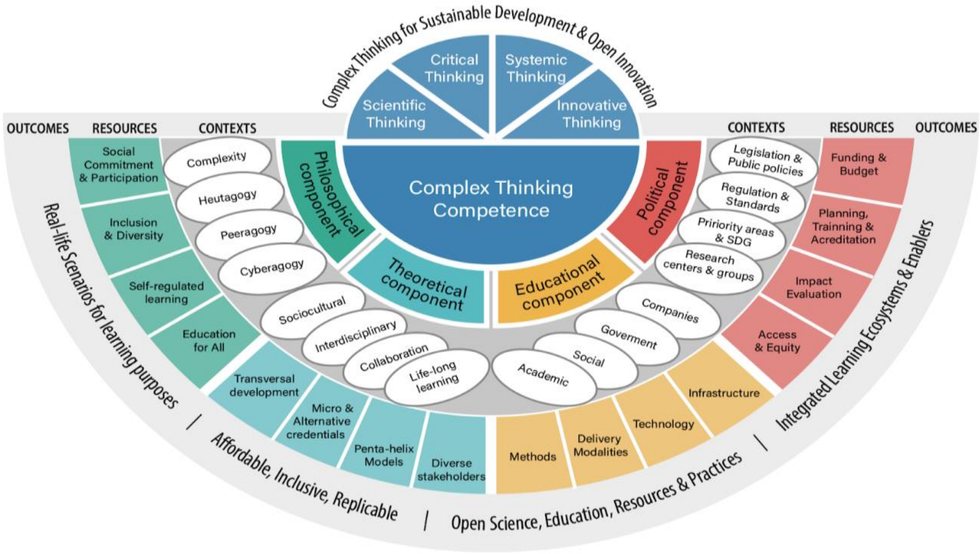


Figure 5. Schematic representation of the Open Educational Model for Complex Thinking, components, contexts of application, resources and expected outcomes. Source: Ramírez Montoya et al., 2024.

3. Results

The research question was: How does the open educational model of complex thinking link to the SDGs and scenario design? Based on the categories of analysis: model components, SDGs and scenario designs, the results of the study are presented.

3.1. Evaluation of Scenario-Based Learning (SBL) designs

A comprehensive evaluation of Scenario-Based Learning (SBL) designs across the twelve critical dimensions: alignment with the Sustainable Development Goals (SDGs), learning objectives, complex thinking competencies, components and content of the Frontier of Learning Knowledge, active strategies and technologies, interaction and co-creation, open educational resources, evidence of learning, evaluation instruments, inclusion and diversity, lifelong learning, and potential risks (see **Figure 6**: Synthetic presentation of scenarios organized by sustainable development goals and canvas categories).

Figure 6 summarizes the interdisciplinary approach for real-world applicability and complex thinking skills. It reveals a commitment to ethical and sustainable solutions based on complex computational thinking, amplified through experiential learning methodologies such as social robotics and virtual reality. Additionally, it emphasizes individual and collaborative learning experiences supported by standardized formative and summative assessment instruments, including specialized tools such as the "eComplexity" instrument. The designs prioritize educational environments that are inclusive and adaptable to diverse learning styles and cultural contexts while highlighting the importance of lifelong learning through continuous feedback and real-world applicability. However, it also recognizes potential risks related mainly to technological limitations and participant participation. Therefore, **Figure 6** serves as an overview that summarizes the diverse nature of SBL designs in their practical dimension and pedagogical richness.

The analysis of learning objectives for the SBL designs took an interdisciplinary approach, focusing on complexity and computational thinking skills. Notable topics included logistics, social and environmental awareness, and technology integration. The objectives were designed with an international scope emphasizing real-world applicability and data-driven decision-making to prepare students for contemporary global challenges. Complex thinking competency combines the sub-competencies of critical, systemic, scientific, and innovative thinking in the analyzed SBL designs. These competencies are contextualized within real-world challenges, such as logistics issues and climate change, highlighting their applied usefulness. The preponderance of critical and systemic thinking suggests the designs' fundamental role, while scientific and innovative thinking adds empirical and creative dimensions.

Moreover, the components and contents in the "Frontier Knowledge of the SBL" designs focus on innovative and sustainable solutions based on ethical considerations and complex computational thinking. Key themes include sustainability, disruptive technologies, and Industry 4.0, all aimed at real-world applicability and active citizen participation. The curriculum seeks to combine technological integration with interdisciplinarity. The designs' Active Strategy and Technologies component focuses on experiential and problem-based learning, augmented by innovative technologies such as social robotics and virtual reality. Through case studies and simulations, these approaches address real-world challenges like water scarcity and climate change. Strategies developed by students and specialized methodologies such as SEL4C are also included. This component shows the academic staff's commitment to participatory learning and methodological diversity.

Furthermore, Interaction and Co-Creation strategies prioritize collaborative and individual learning, often enhanced by simulators and virtual reality technologies. Structured assessments ensure tracking progress, and focusing on real-world issues adds practical relevance. A multimodal approach, encompassing diverse educational media and elements of global collaboration, further enriches the learning experience. Overall, the strategies aim for a comprehensive, technologically augmented, collaborative educational environment focused on real-world applicability.

SDGs	Title of the SBL	Learning Objective	Complex Thinking Competence	Components and Contents at the Frontier of Knowledge	Active Strategy and Technologies	Interaction and Co-Creation	Open Educational Resources	Evidence of Learning	Instruments of Evaluation	Inclusion and Diversity	Lifelong Learning	Potential Risks
4 QUALITY EDUCATION	Research skills workshop with social robotics and complex thinking	Teaching participants the elements of research through complex thinking, guided by humanoid robots.	Critical Thinking, Systemic Thinking, Scientific thinking, and innovative thinking	Exploration of little-studied or speculative areas to provoke new understandings.	Research-based learning and disruptive technologies like social robotics and virtual reality.	Diagnostic tests, introduction to the topic, individual and collaborative work, and a closing assessment.	Podcasts, text documents infographics, videos, and virtual reality experiences through a web platform.	Questionnaires, a canvas with evidence of research proposal ideation, and infographics of systematic research review schemes.	Complex thinking questionnaire eCompexity	Learning styles; online and offline version; translation	Feedback and updates, application of the R4C method for creating research proposals based on systematic literature reviews.	Identifies limited internet access and restricted access to digital libraries as risks, proposing solutions like an offline manual and strategies for finding scientific resources.
	Computational and complex thinking: the keys to saving the universe	To apply computational and complex thinking in solving questions or puzzles	Critical, Systemic, Scientific,Innovative and Computational Thinking	Centralizes on four sub-competencies each in computational thinking (abstraction, decomposition, pattern recognition, algorithmic thinking) and complex thinking	Problem-based learning, supported by an open technology approach, specifically a digital escape room.	Co-creation systematically and scientifically	Videos, multimedia, audios, texts, infographics, and platforms OER	Digital escape room responses, evaluation instruments, and algorithms proposed by the student for initiating someone in programming.	eComplexity and e-Think Complex instruments for assessing complex and computational thinking.	Ensures that content is accessible through multiple multimedia formats, including text, images, and videos.	Evaluating levels of complex and computational thinking and comparing them against student perception.	Identifies potential risks such as puzzles being too difficult or easy and issues with the digital escape room implementation. Pilot testing as a mitigation strategy.
	Open Education supply chains	Fostering critical understanding and application of logistics in open education entrepreneurship; Designing efficient educational resource chains	Critical and systemic, thinking for the logistical challenges in open education entrepreneurship.	Logistical design and planning in open educational entrepreneurship.	Simulation-based approach for experiential learning, supported by open technologies and online educational platforms.	Active team-based interaction to co-create logistical solutions	OER logistical simulation tools for real-world application.	Captured through logistical design, impact analysis, and optimization proposals	eComplex and eComplexity instruments for evaluating complex thinking.	Participation from diverse cultural and ability backgrounds.	Long-term applicability in various educational and professional contexts.	IAcknowledges risks like low participation, resource access limitations, and collaboration challenges.
	Interpreters of complexity	To interpret and describe OEM4C model to develop complex thinking	Critical, systemic, and innovative thinking.	Sustainable, intercultural, inclusive, and digital education.	Challenge-based learning approach, where technologies are student-led for the design of their dissemination products.	Collaboratively analyze and create OER	Infographics, research articles, and videos.	OER dissemination products	"eComplex" rubric for complex thinking and a checklist rubric for the features of a dissemination product.	Features to promote inclusion, such as multiple formats and accessible language.	Qualitative feedback and offers products in various formats like videos, infographics, podcasts, and articles.	Interpretations diverging significantly
	International Collaboration for Complex Thinking	To enhance complex thinking through international collaboration	Critical, Systemic, Scientific and Innovative Thinking	Social entrepreneurship, social innovation, design of socially valuable proposals.	SEL4C methodology	Participate in international teams, collaborating to investigate and develop solutions	OER pitch	final pitch for the presentation of the proposal.	e-Complexity and Social Entrepreneur Profile tools for assessment.	SEL4C is designed to be inclusive	Focusing not just on social entrepreneurship projects but on developing social entrepreneurs	Identifies the risk of segregated activities leading to a lack of real interaction and collaboration among participants from both countries.
	Computational and complex thinking for problem solving. Inventory P(c+c).	To use computational and complex thinking, for addressing social issues.	critical, systemic, scientific, and innovative thinking.	to elevate problem-solving capacities, pushing the boundaries of contemporary knowledge.	Problem-Based Learning, and technologies like social robotics and virtual reality will be deployed within web-based learning platforms.	podcasts and texts to infographics and virtual reality experiences	Concept review questionnaires Canvas illustrating the ideation process Digital presentation detailing the selection and justification of sub competencies based on the P(C+C) inventory	eComplexity (Likert scale for complex thinking) P(C+C) Inventory for computational and complex problem-solving	individual learning of key concepts, and collaborative problem-solving strategies.	cater to diverse learning styles by offering multiple types of RFA. Both online and offline versions of the experience will be available. Language inclusivity will be maintained through translations.	foundation in computational and complex thinking, which could be applied across multiple contexts and disciplines, thereby contributing to lifelong learning.	potential limited internet access among participants. The mitigative action includes the development of an offline manual
	Educational Entrepreneurship for social inclusion	Learn to create educational entrepreneurship proposals for social inclusion using the 4I-4C (identify, ideate, invent and inform from complex thinking) method.	Develop critical, systemic, scientific, and innovative thinking through the 4I-4C method.	Address real-world problems with scientific and technological concepts in educational entrepreneurship.	Use problem-based learning, social robotics, and virtual reality on web platforms.	Begin with diagnosis, progress through the 4I-4C method and collaborative problem solving, and conclude with complex thinking evaluations.	Include podcasts, documents, infographics, videos with experts, virtual reality, and a web platform.	Ideation canvas and proposal pitch video.	Use of eComplexity and e-Cmplex instruments to assessing complex and entrepreneurial thinking..	Design visual, auditory, and schematic OERs for diverse learning styles, offering both online and offline experiences, and provide translations as needed.	Enable understanding and application of educational entrepreneurship's basic concepts for solving educational issues.	Address limited internet access with an offline experience manual.
	Research-Based Learning for Complex Thinking Development	Enhance complex thinking through research-based learning, focusing on social entrepreneurship.	Develop critical, systemic, scientific, and innovative thinking through the SEL4C designed learning activities.	Incorporate research process themes like hypothesis formulation, information searching, citation, and data analysis alongside social entrepreneurship.	Employ research-based learning to strengthen open educational and official information source utilization.	Engage in teams for social innovation proposal creation, emphasizing research stages: Identification, Investigation, Ideation, and Socialization.	Final pitch licensed under Creative Commons	Evaluation through validated instruments at start and end, four activities, and a research-reflective final pitch.	E-Complexity and Social Entrepreneur Profile assess learning objectives.	SEL4C facilitates educational access in social entrepreneurship to diverse individuals.	Encourages continuous learning and social entrepreneur development, enriched by research skills in this experiment.	Potential for inadequate research leading to non-innovative proposals.
5 GENDER EQUALITY	Scientific Entrepreneurship Workshop with Social Robotics from a Gender Equity Perspective	Learn to apply the 4I-4C (identify, ideate, invent and inform from complex thinking) method for designing scientific enterprises with a gender equity focus.	Promotion of critical, systemic, scientific, and innovative thinking through the 4I-4C method.	Focus on STEM to develop advanced skills and stay updated in science.	Use challenge-based learning and disruptive technologies such as social robotics and virtual reality.	Start with diagnostics and introduction, development of key concepts and collaborative work, and end with evaluation.	Inclusion of podcasts, documents, infographics, videos, virtual reality experiences, and web platforms.	Quizzes, ideation canvases, and proposal videos.	Use of eComplexity and e-Cmplex instruments to assess complex thinking and scientific entrepreneurship.	Design of materials for various learning styles and online and offline versions.	Promotion of the 4I-4C method to boost STEM vocations in young women.	Solution to limited internet access through offline application manuals.
6 CLEAN WATER AND SANITATION	Drop by drop the water runs out	To enable participants to propose a solution for the water scarcity issue,	Critical, Systemic, Scientific and Innovative Thinking, in the context of water scarcity.	Water care for sustainability Change the way you think Take advantage of water collection sources Balanced agriculture	Case study approach on global water scarcity, supported by a video and an interactive site on Genial.ly.	The participant will develop awareness about the problem of water scarcity through the analysis of a video.	OER decalogue documenting water conservation strategies proposed by participants.	Strategies proposed by the student for water conservation, recorded in user forms. An REA in the form of a decalogue will also be created.	eComplex and eComplexity instruments for evaluating complex thinking.	including vulnerable communities facing water scarcity issues, recognizing their rights to quality basic services.	Development of complex thinking skills, applicable in various professional and personal settings.	Identifies risks such as lack of participant motivation and suggests mitigative strategies like snacks and gifts to foster participation.
8 DECENT WORK AND ECONOMIC GROWTH	Modelling a Supply Chain (Intermediate Module)	Aims to equip participants with problem-solving skills in logistics and sustainability, targeting real-world applicability for small and medium-sized enterprises.	Critical, systemic, scientific, and innovative thinking, within the challenges of PyMES.	Cutting-edge issues like logistics and sustainability, leveraging simulators for real-world modelling.	Employs a hands-on approach using simulators and interactive digital platforms to facilitate experiential learning.	Active learning through simulators and co-creation of solutions.	OER simulators and supplementary material	Questionnaires and quizzes responses; results obtained in the simulatotor; SMEs. new supply chains developed	eComplex and eComplexity instruments for evaluating complex thinking.	Promotes active participation and respects diverse perspectives to cater to a broad spectrum of learners.	Envisions long-term impact through subsequent modules, aiming to instill a sense of legacy and transcendence in learning.	Address potential implementation risks, including design flaws and technical issues.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Creating case study in Megatrends	To create case studies on challenges in Megatrends.	Critical and Systemic thinking skills	Explore disruptive business models and ethical considerations in Artificial Intelligence.	Case-study-based learning and decision-making games.	Research , reflection and creating case studies	International Case Center. https://cic.tec.mx	Students produce case studies in multiple formats (audio, video, text, or multimedia)	Rubrics for assessing complex thinking and case study components	Socio-economic and contextual inclusivity	Questionnaires and qualitative feedback	Acknowledges implementation risks without detailing mitigation strategies.
10 REDUCED INEQUALITIES	Understanding our environment	To understand and address community issues related to the quality of life in different countries. Aims to foster data-driven analysis and creative problem-solving.	Critical thinking to understand community issues, Systemic thinking to understand global inequities, Scientific thinking to investigate real life data, and Innovative thinking to develop creative solutions.	Factors that influence quality of life; development of creative and sustainable solutions to address complex social problems.	Case study approach based and interactive technological platform for data analysis.	Group work and co-creation of videos based y data narratives.	Open data published by international organizations. Photographs and audiovisual OER	Data narratives and videos	eComplex rubric for complex thinking to evaluate critical analysis and understanding of the issues and proposed solutions.	Consider cultural and social perspectives, promoting an environment of respect and equality among participants.	Learning applicability in various professional and personal environments	Identifies several risks, including lack of motivation, unequal access to technology, potential technical issues, and limitations in the availability of real-life data.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	OER multimedia clip creation	To construct a multimedia clip as an OER to promote responsible production and consumption	Critical, Systemic, and Scientific thinking skills.	Circular economy, sustainable technologies, and active citizen participation.	Research-based learning and simulations	Content creation and audience engagemen	Audio and infographics OER	Production of a multimedia clip that meets specified characteristics and qualifies as an OER	Complex thinking rubrics and a checklist to validate the multimedia clip's attributes.	Inclusive design	Continuous feedback and updates for the multimedia clip, aiming for real-world impact.	Acknowledges technological limitations as a potential risk without detailing mitigation strategies
13 CLIMATE ACTION	Treasure map with Augmented Reality	To construct an augmented reality (RA) sequence, modelled as a 'treasure map' to raise awareness about climate change	Critical, systemic, and scientific thinking, for climate change-related challenges	Complex visualization and interaction through RA, sustainability and ethics.	Challenge-based learning approach, using RA to design scenarios that raise awareness about climate change.	Multi-step process for designing and creating the RA sequence, immersive visualization and expert collaboration.	Podcast, videos and infographics OER	OER RA sequence.	Rubrics for complex thinking and a checklist to evaluate the RA sequence's attributes.	Inclusive design in RA; impact of climate change on vulnerable groups	feedback and updates for the RA sequence, aiming for real-world impact.	Identifies technological limitations and the risk of not achieving the desired effect, without detailing mitigation strategies.
	Modelling a Supply Chain in the framework of the climate crisis	Designing interrelationships in a supply chain in the context of climate crises.	Critical thinking to analyze supply chain dynamics, Systemic thinking to understan interrelations, Scientific thinking to identify key variables, and Innovative thinking to develop adaptive solutions	Designing supply chains that are both resilient and sustainable, while also identifying key actors and variables essential for maintaining supply continuity under adverse conditions.	Use of simulation logistics platform, to model the supply chain considering climate crisis.	To design supply chains that are both resilient and sustainable, while identifying key actors and variables to ensure uninterrupted supply in adverse conditions.	OER from the logistics simulation interactive digital platform; predefined examples of a resilient supply chain	Modelled supply chains; relational diagram; assessments by a separate evaluation team.	eComplex rubric and eComplexity questionare.	To promote collaboration, recognizing and respecting the different perspectives and skills of the participants.	Applicability in professional and personal environments, aiming to generate a sense of transcendence and legacy in learning.	Identifies risks including design gaps, grading errors, and technical issues on the logistics platform

Figure 6. Synthetic presentation of the scenarios designed, organized by canvas categories.

Meanwhile, Evidence of Learning in the SBL designs integrates formative and summative assessment techniques with practical and digital outcomes, reflecting a diversified approach to pedagogical assessment. It includes traditional and experiential metrics and provides evidence of competencies in critical thinking, digital literacy, environmental awareness, and teamwork. In general, the Evidence of Learning aims for a balanced measurement of cognitive, academic, practical, and socio-environmental skills.

The Assessment Instruments mainly include specialized tools such as "eComplexity" and "eComplex" to assess complex thinking, opting for a standardized approach incorporating specific competency rubrics and formative assessment methods. The tools are designed to evaluate individual and collaborative skills, accounting for a comprehensive evaluation strategy aligned with broader educational objectives. Concerning the Inclusion and Diversity component, SBL designs adapt to various learning styles and cultural aspects. Transversal themes address accessibility, attention to vulnerable communities, and linguistic inclusion. Together, these scenarios emphasize the imperative of equitable and inclusive educational environments.

The Lifelong Learning component presents three key elements: continuous feedback, applicability in the real world, and skills development for transcendent learning. Integrating qualitative feedback and a sense of legacy, these utilize iterative and reflective learning with real-world relevance. The SBL approach aims to develop adaptive competencies for diverse future personal and professional contexts, emphasizing an enduring commitment to education that transcends temporal or situational boundaries. Finally, concerning the last component, the Potential Risks identified in the scenarios are primarily focused on technological limitations, participant engagement, and implementation challenges. While most scenarios acknowledge these risks, there is inconsistent attention to mitigation strategies.

3.2. Sustainable Development Goals (SDGs) in SBL

Integrating scenario-based learning (SBL) with the Sustainable Development Goals (SDGs) is an innovative approach to creating meaningful, impact-driven pedagogical experiences. **Figure 7**, "Analysis of Integrated Proposals with a Focus on Sustainable Development Goals," provides a comprehensive analysis of how the various components of the SBL scenarios align with the SDGs selected for development by researchers through scenario design, thus providing a framework for education professionals, policymakers, and academicians. This table synthesizes several dimensions, including learning objectives, cognitive competencies, pedagogical strategies, and evaluation metrics. Each element is analyzed per its alignment with specific SDGs to evidence how implemented SBL designs can address complex and systemic global challenges to foster a more equitable, sustainable, and inclusive future through education.

Component	4 QUALITY EDUCATION	5 GENDER EQUALITY	6 CLEAN WATER AND SANITATION	8 DECENT WORK AND ECONOMIC GROWTH	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	10 REDUCED INEQUALITIES	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	13 CLIMATE ACTION
Learning Objectives	Focused on complex thinking and research skills	Gender equity in scientific enterprise design method	Targeted awareness and solution-generation for water scarcity	Emphasis on real-world applicability in SME logistics	Aimed at understanding challenges in megatrends	Centered on fostering social justice and equal opportunities	Promotes responsible production and consumption	Explicit focus on climate change and resilience
Complex Thinking Competence	Critical, systemic, scientific, innovative thinking	Critical and innovative thinking promotion method	Critical, systemic, scientific, innovative thinking	Critical, systemic, scientific, innovative thinking	Critical and systemic thinking	Critical, systemic, scientific thinking	Critical, systemic, scientific thinking	Emphasis on critical, systemic, scientific, and innovative thinking
Components and Contents at the Frontier of Knowledge	Exploration of less-studied areas, disruptive technologies	ESTEM focus for advanced skill development	Sustainability, water conservation strategies	Cutting-edge issues in logistics and sustainability	Disruptive business models, ethical considerations in AI	Latest theories and methodologies in social justice	Circular economy, sustainable technologies	Cutting-edge methods and technologies for climate action
Active Strategy and Technologies	Research-based learning, robotics, virtual reality	Disruptive technologies and challenges	Case study approach, video-based analysis	Hands-on, interactive digital platforms	Case-study-based learning, decision-making games	Collaborative approaches, participatory methods	Research-based learning and simulations	Challenge-based learning and simulations
Interaction and Co-Creation	Diagnostic tests, individual and collaborative work	Collaborative learning	Awareness-building through video analysis	Active learning through simulators, co-creation	Research, reflection, and case study creation	Dialogue, reflection, and critical discourse	Content creation and audience engagement	Collaborative design and creation processes
Open Educational Resources	Multimedia formats: podcasts, texts, infographics, VR experiences	Diverse educational materials for immersive learning	Decalogue on water conservation strategies	OER simulators and supplementary materials	International Case Center resources	Manuals, guidelines, and checklists as OERs	Multimedia clips as OERs	Accessible and shareable educational resources
Evidence of Learning	Questionnaires, research proposals, infographics	Interactive learning and creative tools	Water conservation strategies, user forms, REAs	Questionnaires, quizzes, simulation results	Student-produced case studies	Social justice projects, group discussions	Multimedia clip adhering to specified characteristics	Measurable learning outcomes through rubrics and assessments
Instruments of Evaluation	Complex thinking questionnaire, eComplexity	Assessment tools for complex thinking in entrepreneurship	eComplex and eComplexity instruments	eComplex and eComplexity instruments	Rubrics for complex thinking and case study components	Rubrics for evaluating social justice competencies	Complex thinking rubrics, checklist for multimedia clip attributes	Complex thinking rubrics and questionnaires
Inclusion and Diversity	Learning styles, language translation	Tailored educational content for diverse learning preferences	Inclusion of vulnerable communities	Promotes active participation and diverse perspectives	Socio-economic and contextual inclusivity	Focus on marginalized communities	Inclusive design	Inclusion of vulnerable communities
Lifelong Learning	Application of R4C method, continuous feedback	STEM motivation for young women through method	Skill applicability in professional and personal settings	Long-term impact envisioned through subsequent modules	Questionnaires and qualitative feedback	Sustainability and applicability beyond the classroom	Aiming for real-world impact	Long-term applicability of skills
Potential Risks	Limited internet access, restricted access to digital libraries	Offline solutions for limited internet access	Lack of participant motivation	Implementation risks like design flaws, technical issues	Implementation risks not detailed	Social resistance to change	Technological limitations	Identified implementation and technological risks

Figure 7. Analysis of integrated proposals with a focus on Sustainable Development Goals (continued).

Figure 7 results reveal a fruitful interaction between SBL, various educational methods, and the general objectives of each SDG. One can observe the alignment with Quality Education (SDG 4), evidenced by incorporating various educational methodologies that promote critical, systemic, and scientific thinking skills. This alignment indicates that educational strategies to achieve SDG 4 would benefit from an integrative approach combining various thinking competencies.

Only one scenario focuses on SDG 5, by embedding gender equity in scientific entrepreneurship, leveraging STEM education and innovative technologies, and offering engaging resources to empower young women in STEM.

The scenarios corresponding to Clean Water and Sanitation (SDG 6) and Climate Action (SDG 13) show a thematic coherence to their objectives. For example, the SDG 6 column predominantly shows awareness-raising designs and solution-oriented approaches specifically designed for water conservation. This alignment suggests that educational strategies related to water and sanitation are oriented toward raising awareness and finding solutions so that they are effectively integrated with the central objectives of SDGs 6 and 13. Similarly, in the case of Decent Labor and Economic Growth (SDG 8), the designs are geared toward applying skills in the real world, particularly in the small and medium-sized enterprise (SME) environment. This thematic alignment supports broader SDG perspectives of economic growth and employment opportunities, thus emphasizing the role of applied learning in economic development.

Component	10 REDUCED INEQUALITIES	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	13 CLIMATE ACTION
Learning Objectives	Centered on fostering social justice and equal opportunities	Promotes responsible production and consumption	Explicit focus on climate change and resilience
Complex Thinking Competence	Critical, systemic, scientific thinking	Critical, systemic, scientific thinking	Emphasis on critical, systemic, scientific, and innovative thinking
Components and Contents at the Frontier of Knowledge	Latest theories and methodologies in social justice	Circular economy, sustainable technologies	Cutting-edge methods and technologies for climate action
Active Strategy and Technologies	Collaborative approaches, participatory methods	Research-based learning and simulations	Challenge-based learning and simulations
Interaction and Co-Creation	Dialogue, reflection, and critical discourse	Content creation and audience engagement	Collaborative design and creation processes
Open Educational Resources	Manuals, guidelines, and checklists as OERs	Multimedia clips as OERs	Accessible and shareable educational resources
Evidence of Learning	Social justice projects, group discussions	Multimedia clip adhering to specified characteristics	Measurable learning outcomes through rubrics and assessments
Instruments of Evaluation	Rubrics for evaluating social justice competencies	Complex thinking rubrics, checklist for multimedia clip attributes	Complex thinking rubrics and questionnaires
Inclusion and Diversity	Focus on marginalized communities	Inclusive design	Inclusion of vulnerable communities
Lifelong Learning	Sustainability and applicability beyond the classroom	Aiming for real-world impact	Long-term applicability of skills
Potential Risks	Social resistance to change	Technological limitations	Identified implementation and technological risks

Figure 7. Analysis of integrated proposals with a focus on Sustainable Development Goals.

Additionally, Industry, Innovation, and Infrastructure (SDG 9) and Reducing Inequalities (SDG 10) cover diverse topics aligned with these goals. Whether about disruptive business models or ethical considerations, scenarios aligned to SDG 9 focus on the importance of innovation to achieve sustainable industries and infrastructure. Likewise, Reducing Inequalities (SDG 10) consistently emphasizes social justice and equality, thus affirming its commitment to its primary objective of reducing inequalities.

3.3. Philosophical, theoretical, educational, and political perspectives in the SBL designs

Figure 8 "Global analysis from the Philosophical, Theoretical, Educational, and Political perspectives of OEM4C" provides a cross-sectional look at the designs for learning based on elaborate scenarios, presenting the results from the analysis of the four key components of the OEM4C (philosophical, theoretical, educational and political) and their respective "Contexts" and "Resources." The main findings focus on complex and self-directed thinking in the philosophical component, interdisciplinary approaches and innovative evaluation metrics in the theoretical component, diverse participation and practical modalities of delivery in the educational component, and considerations of equitable access in the political component.

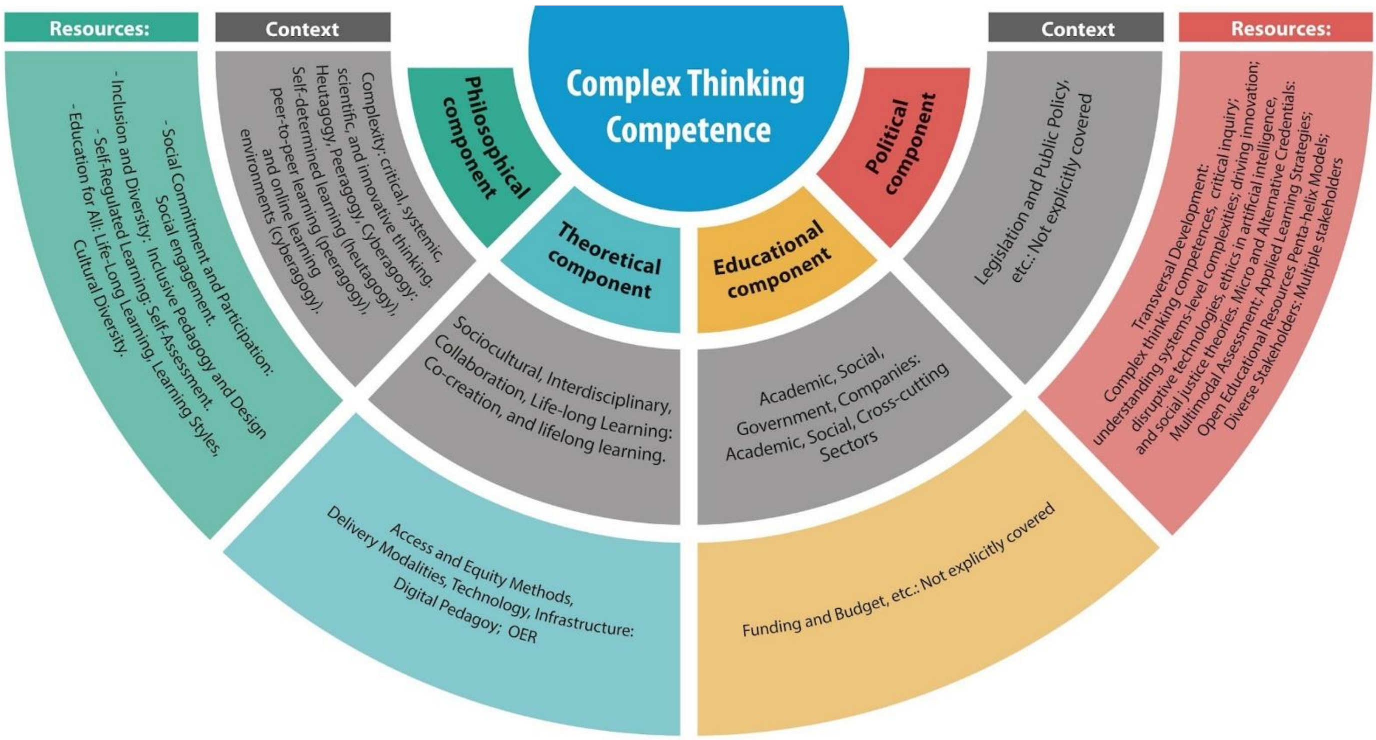


Figure 8. Global analysis from the philosophical, theoretical, educational, and political perspectives of OEM4C.

Regarding the contexts of the Philosophical component, the results identify the need to promote complexity in critical, systemic, scientific, and innovative thinking. Likewise, there are elements of Self-determined learning (heutagogy), peer-to-peer learning (peeragogy), and online learning environments (cybergogy). Elements of Social engagement are identified as participation resources, while concerning Inclusion and Diversity, one can discern the Inclusive Pedagogy and Design proposals. The Self-Regulated Learning dimension concentrates fundamentally on elements of Self-Assessment in the designs, while in Education for All, the presence of Life-Long Learning, Learning Styles, and Cultural Diversity elements is clear.

Meanwhile, in the Theoretical component, aimed at synthesizing various socio-cultural and interdisciplinary frameworks, participants incorporate co-creation and lifelong learning as essential contexts. The resources here focus on transversal development, which alludes to a multidimensional competency-based approach encompassing a range of skills, including complex thinking, critical inquiry, and understanding systems-level complexities. These competencies are especially highlighted in the evidence of designs for disruptive technologies, ethical considerations in AI, and theories of social justice. Micro and alternative credentials and pentahelix models are introduced primarily at initial levels, with flexibility and variety in educational evaluation and stakeholder participation.

The Educational component has a more practical orientation and relates directly to the delivery aspects of scenario-based learning. In this case, the designs focus on multi-sector contexts, spanning academic, social, government, and business stakeholders. To achieve this goal, designers gear resources toward ensuring access, equity, and alignment with delivery methods and modalities, such as digital pedagogy and Open Educational Resources (OER).

The Political component seems less elaborate in the designs; they do not address, for example, aspects of legislation, public policies, or financing, which are not explicitly covered.

The framework provided by OEM4C serves as a multidimensional heuristic for orienting and examining scenario-based learning design. It allows one to focus on philosophical imperatives, places them within broader theoretical constructs, applies them to educational practices, and alludes to the need for political contextualization. The results show that this model significantly enriches both the conceptualization and practical application of scenario-based learning to address the complexity of the challenges of the SDGs.

4. Discussion

While SBL offers a pedagogically rich framework for contemporary education, its optimal implementation requires strategic planning. The OEM4C framework offers support as a critical tool in scenario design, establishing clear guidelines for the instructional design of powerful scenarios that represent the present demands. The comprehensive evaluation of scenario-based learning design (SBL) across twelve critical dimensions, as described in **Figure 6**, offers an understanding of its pedagogical relevance and applicability. SBL's alignment with the Sustainable Development Goals (SDGs) is particularly notable, underscoring the modality's potential to generate impact-driven educational experiences. Integration is multidimensional and addresses learning objectives, cognitive competencies, and pedagogical strategies while providing a solid framework for education professionals, policymakers, and academicians. This pedagogical scaffolding amplifies the transdisciplinary knowledge necessary to address complex problems, thereby providing an educational response to the complexities of the real world (Daniels et al., 2022; Lin et al., 2020). The focus on complex thinking competencies in SBL, particularly critical, systemic, scientific, and innovative thinking, adds empirical and creative dimensions to the designs. Despite the acknowledgment of technological and engagement risks, the discussion could be enriched by exploring how to overcome these specific challenges, such as the development of technological training programs for educators and students, and the implementation of accessible and scalable technological solutions.

The articulation of SBL with the SDGs, as detailed in **Figure 7**, accentuates the potential of the modality to contribute to a more equitable, sustainable, and inclusive future through education. The observed intersection between scenario-based learning (SBL) and the SDGs in the figure shows innovative design capacity linked to SDG challenges, emphasizing the potential of pedagogical innovation to address complex societal challenges. The idea that universities function as powerful catalysts for social improvement prioritizes the relevance of the findings in **Figure 7** because it corroborates the institutional capacity to integrate educational strategies with social imperative challenges (Sinnappan, 2023; Yuan, 2022), clearly identified in the coherence observed in the scenarios. SBL designs based on the OEM4C framework emphasize active learning strategies, co-creation, and long-term applicability, exemplifying the potential of universities to serve not only as educational centers but also as development agents, thus expanding the traditional perspectives of university missions. Therefore, the OEM4C framework incorporated in this analysis validates and enriches the empirical findings presented in **Figure 7**, offering examples of educational scenario design that extends from theoretical constructs to viable pedagogical strategies, thus offering a comprehensive understanding of the relationship between higher education and sustainable development. Future research should also focus on the long-term tracking of graduates to assess how SBL has influenced their career paths and commitment to the SDGs, thus providing a deeper understanding of the sustained value of these pedagogical methodologies.

Understanding the multidimensional challenges inherent in educational practices addressing social complexities is imperative. The OEM4C model provides a solid intellectual framework for designing SBLs that address these complex and global challenges, providing theoretical-practical linkage to foster complex thinking. A more detailed consideration of how public policies can encourage SBL, through support for research and development initiatives, as well as the allocation of financial resources, could provide valuable insights for stakeholders in the educational field. The findings presented in **Figure 8** offer insight into the concerns, methodologies, and aspirations that intersect in these designs, particularly with respect to learning scenarios in the context of the Sustainable Development Goals (SDGs). The potential of SBL to foster inter-institutional and global collaboration, especially in projects that jointly address the SDGs, deserves more attention. Exploring examples of successful collaborations could offer replicable models for future educational initiatives.

The finding that the philosophical foundations of OEM4C promote complex, systemic, innovative, and scientific thinking corroborates the notion that educational models must be dynamic and open, allowing for the incorporation of multiple competencies and perspectives. The Theoretical Component introduces a more focused framework, emphasizing interdisciplinary approaches and innovative evaluation metrics. OEM4C encourages co-creation, transversal development, and socio-cultural frameworks, thus presenting an enriched and multidimensional competency-based approach.

Regarding the Educational Component, the emphasis on multisectoral contexts and resources aimed at ensuring access and equity reiterates the potential of open educational models to serve as transformative tools in various sectors of society. Although less elaborate in the designs, the Political Component also alludes to the integral role of political considerations in educational practices. The findings presented in **Figure 8** offer a sample of educational design that crosses disciplinary boundaries, providing a comprehensive understanding of the interaction between educational practices and broader social complexities. This, in turn, accentuates the nature of OEM4C as a pedagogical framework capable of addressing the challenges posed by the SDGs.

5. Conclusion

The horizon of the present and future of quality education reveals the need to contemplate the complexity of changing environments and postulate high-capacity training as a priority for a society in search of new solutions. This research analyzed learning scenarios where complex thinking was linked to the SDGs. The data indicated that (a) the design of the environments should include challenges with high complexity, like the reality of the problems of the Sustainable Development Goals, (b) fostering high-level thinking involves training in theoretical bases and linking it with problem cases similar to the reality of the participants' environments and (c) technological mediation allow these designs to be applicable and attractive to the participants of the learning environments, with the possibility of significant positive impact.

The implications for educational practice involve interdisciplinary training of teachers, teams, and learning environment designers to devise trajectories to face local and global challenges. It also implies fortifying these scenarios with the technological infrastructure that supports the design requirements. Implications for research include the need for a multidisciplinary approach, integrating multiple perspectives that allow analyzing the potential of implementations in diverse socio-cultural contexts.

A study limitation is that participants carried out the scenario design focused on complex thinking, which is not a very common profile. However, the interdisciplinary background allows the necessary diversity to be nuanced and enhanced to pose high-level, challenging situations. Future studies can broaden the view with scenario designs by participants from diverse socio-educational contexts to contrast the contributions achieved from multiple perspectives. This paper is an invitation to continue increasing the knowledge of complexity and training for high capacities for the present and future of education.

Author contributions: Conceptualization, VRP and MSRM; methodology, VRP and MSRM; validation, VRP and MSRM; formal analysis, VRP; investigation, VRP, MSRM, LMM and RR; writing—original draft preparation, VRP; writing—review and editing, VRP and MSRM; visualization, VRP; project administration, MSRM; funding acquisition, MSRM. All authors have read and agreed to the published version of the manuscript.

Funding: The authors would like to thank the financial support from Tecnológico de Monterrey through the "Challenge-Based Research Funding Program 2022". Project ID # I001-IFE001-C1-T1-E.

Acknowledgments: The authors would like to thank academic support from Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico.

Conflict of interest: The authors declare no conflict of interest.

References

Álvarez-Nieto, C., Álvarez-García, C., Parra-Anguita, L., et al. (2022). Effectiveness of scenario-based learning and augmented reality for nursing students' attitudes and awareness toward climate change and sustainability. BMC Nursing, 21(1). https://doi.org/10.1186/s12912-022-01023-9

Aoun, M., Elhusseini, R., & Mohtar, R. (2023). Implementing the Sustainable Development Goals (SDGs) in Higher Education Institutions: A Case Study from the American University of Beirut, Lebanon. In: The Sustainable University of the Future: Reimagining Higher Education and Research. pp. 199–215. https://doi.org/10.1007/978-3-031-20186-8_12

Baena-Morales, S., Jerez-Mayorga, D., Fernández-González, F. T., & López-Morales, J. (2020). The use of a cooperative-learning activity with university students: A gender experience. Sustainability (Switzerland), 12(21), 1–12. https://doi.org/10.3390/su12219292

Ball, B., Kirby, M., Ketterer, S. J., et al. (2021). Radiotherapy-specific interprofessional learning through simulation. Radiography, 27(1), 187–192. https://doi.org/10.1016/j.radi.2020.07.016

Bardach, L., Klassen, R. M., Durksen, T. L., et al. (2021). The power of feedback and reflection: Testing an online scenario-based learning intervention for student teachers. Computers and Education, 169. https://doi.org/10.1016/j.compedu.2021.104194

Carlos-Arroyo, M., Vázquez-Parra, J. C., Cruz-Sandoval, M., & Romero-Rodríguez, J. M. (2023). Development of complex thinking in a professional training process: An approach to business students of a Mexican University. Journal of Education for Business, 1-9. https://doi.org/10.1080/08832323.2023.2233044

Christiani, N., Tungka, N. F., & Nainggolan, R. (2023). Teachers' role in online learning: Perspectives of prospective Indonesian EFL teachers. Journal of Education and E-Learning Research, 10(2), 187–193. https://doi.org/10.20448/jeelr.v10i2.4504

Cottafava, D., Ascione, G. S., Corazza, L., & Dhir, A. (2022). Sustainable development goals research in higher education institutions: An interdisciplinarity assessment through an entropy-based indicator. Journal of Business Research, 151, 138–155. https://doi.org/10.1016/j.jbusres.2022.06.050

Cruz-Sandoval, M., Vázquez-Parra, J. C., & Carlos-Arroyo, M. (2023). Complex thinking and social entrepreneurship. An approach from the methodology of compositional data analysis. Heliyon, 9(2). https://doi.org/10.1016/j.heliyon.2023.e13415

Daniels, M., Berglund, A., & McDermott, R. (2022). Influencing Student Academic Integrity Choices using Ethics Scenarios. 2022-October. https://doi.org/10.1109/FIE56618.2022.9962607

Du Preez, P., Le Grange, L., Maistry, S., & Simmonds, S. (2022). On sustainability and higher education: Towards an affirmative ethics. Perspectives in Education, 40(3), 118–131. https://doi.org/10.18820/2519593X/pie.v40.i3.8

Ferreira-Oliveira, A. T., Rodrigues, A. S., Rodrigues, P., et al. (2022). Implementation and development of IPVC's equality plan in association with its management system. In P. Sampaio, P. Domingues, A. Costa, M. Casadesús, F. Marimon, A. R. Pires, & P. Saraiva (Eds.), Proceedings book of the 5th International Conference on Quality Engineering and Management, 2022, July 14–15, Portugal (pp. 872–880). International Conference on Quality Engineering and Management.

Ferreras-Garcia, R., Sales-Zaguirre, J., & Serradell-López, E. (2022). Competency assessment and learning results in tourism internships: Is gender a relevant factor? Higher Education, Skills and Work-Based Learning, 12(1), 162–177. https://doi.org/10.1108/HESWBL-05-2021-0096

Fleener, M. J. (2022). Blockchain Technologies: A Study of the Future of Education. Journal of Higher Education Theory & Practice, 22(1). https://doi.org/10.33423/jhetp.v22i1.4956

Foster, A. R., & Adjekum, D. K. (2022). A Qualitative Review of the Relationship between Safety Management Systems (SMS) and Safety Culture in Multiple-Collegiate Aviation Programs. Collegiate Aviation Review, 40(1), 63–94.

Giannakas, F., Troussas, C., Krouska, A., et al. (2023). Blending cybersecurity education with IoT devices: A u-Learning scenario for introducing the man-in-the-middle attack. Information Security Journal, 32(5), 371–382. https://doi.org/10.1080/19393555.2022.2100297

Hamdan, M. A. (2020). Innovation and entrepreneurship in higher education: Enhancing achievement of the United Nations sustainable development goals. In: Higher Education in the Arab World: Building a Culture of Innovation and Entrepreneurship. pp. 269–278. https://doi.org/10.1007/978-3-030-37834-9_12

Handrahan, L. M. (2022). Child Sex Trafficking in Higher Education. Journal of Human Trafficking, 8(1), 82–112. https://doi.org/10.1080/23322705.2021.2019533

Hirsch, J., Jelks, N. O., & Owokoniran, L. (2021). Reducing Inequalities and Empowering Youth through the Multi-Stakeholder SDG Network, RCE Greater Atlanta. Sustainability and Climate Change, 14(3), 193–199. https://doi.org/10.1089/scc.2020.0079

Holmes, J., Moraes, O. R., Rickards, L., et al. (2022). Online learning and teaching for the SDGs – exploring emerging university strategies. International Journal of Sustainability in Higher Education, 23(3), 503–521. https://doi.org/10.1108/IJSHE-07-2020-0278

Khan, S. (2023). Preparing Future-Fit Leaders for the Sustainable Development Era. In: The Sustainable University of the Future: Reimagining Higher Education and Research. Cham: Springer International Publishing. pp. 83–106. https://doi.org/10.1007/978-3-031-20186-8_5

Kusi-Mensah, K., Tamambang, R., Bella-Awusah, T., et al. (2022). Accelerating progress towards the sustainable development goals for adolescents in Ghana: A cross-sectional study. Psychology, Health and Medicine, 27(sup1), 49–66. https://doi.org/10.1080/13548506.2022.2108086

Lee, B., Liu, K., Warnock, T. S., et al. (2023). Students leading students: A qualitative study exploring a student-led model for engagement with the sustainable development goals. International Journal of Sustainability in Higher Education, 24(3), 535–552. https://doi.org/10.1108/IJSHE-02-2022-0037

Lin, K. H., Shih, J. L., & Chuang, T. Y. (2020). An exploration of students' computational thinking performance in a scenario-based robotic learning game <callisto summit> Proceedings of International Conference on Computational Thinking Education, 99–100).

Linn, M. C., Davis, E. A., & Bell, P. (2013). Design-Based Research in Education. In: Internet Environments for Science Education. Routledge.

Magno, C., & Becker, A. (2023). Postcritical school leadership encounters. Prospects, 1–6. https://doi.org/10.1007/s11125-023-09648-7

Mamakli, S., Alimoğlu, M. K., & Daloğlu, M. (2023). Scenario-based learning: Preliminary evaluation of the method in terms of students' academic achievement, in-class engagement, and learner/teacher satisfaction. Advances in Physiology Education, 47(1), 144–157. https://doi.org/10.1152/ADVAN.00122.2022

Martínez, L. A. S., Martín, D. G., & Benítez, J. M. (2021). The gender gap in sport: The case of a historically and socially accepted marginalization. Interdisciplinaria, 38(2), 73–86. https://doi.org/10.16888/INTERD.2021.38.2.5

Mazzucato, A., Caputo, V., Vila, R. R., et al. (2020). Supporting language learning strategies for erasmus students with a mobile tool using tangible user interfaces and interactive storytelling: The EULALIA approach. 2730.

Mills, K., Roper, F., & Cesare, S. (2020). Accelerating student learning in communication and research skills: The adoption of adaptive learning technologies for scenario-based modules. In Technology, Change and the Academic Library: Case Studies, Trends and Reflections. pp. 75–84. https://doi.org/10.1016/B978-0-12-822807-4.00007-5

Mio, C., Ventura-Medina, E., & João, E. (2019). Scenario-based eLearning to promote active learning in large cohorts: Students' perspective. Computer Applications in Engineering Education, 27(4), 894–909. https://doi.org/10.1002/cae.22123

Newman, J. (2023). Towards global equity in higher education. In: Higher Education and SDG17: Partnerships for the Goals. pp. 51–72.

Ramírez Montoya, M. S., Basabe, F. E., Carlos Arroyo, M., et al. (2024). Open educational model of complex thinking for the future of education (Spanish). Available online: https://octaedro.com/wp-content/uploads/2024/01/9788410054141.pdf (accessed on 16 March 2024).

Ramırez-Montoya, M. S., McGreal, R., & Obiageli Agbu, J. F. (2022). Complex digital horizons in the future of education 4.0: insights from UNESCO's recommendations. RIED-Revista Iberoamericana de Educacion a Distancia, 25(2), 9–21. https://doi.org/10.5944/ried.25.2.33843

Ramirez-Montoya, M. S., Patiño, A., Miranda, J. & Álvarez-Icaza, I. (2023). Open Educational Model for Complex Thinking: Present and Future of Education for All. In: International Journal of Sustainability in Higher Education (in press).

Samuel, S. D., & Subramaniam, R. (2022). Using Team-Based Scenario Learning (TBSL) Approach to Teach Audit Risk. In: Collaborative Active Learning: Practical Activity-Based Approaches to Learning, Assessment and Feedback. pp. 269–293. https://doi.org/10.1007/978-981-19-4383-6_11

Seren Smith, M., Warnes, S., & Vanhoestenberghe, A. (2018). Scenario-based learning. UCL IOE Press.

Seth, N. (2023). SDG17 and the role of universities achieving agenda 2030. In: Higher Education and SDG17: Partnerships for the Goals. pp. 19–25.

Shipton, B. (2023). Scenario-Based Learning. In: Signature Pedagogies in Police Education: Teaching Recruits to Think, Perform and Act with Integrity. Cham: Springer Nature Switzerland. pp. 39–52.

Sinnappan, P. (2023). Achieving economic growth and welfare through green consumerism. p. 302. https://doi.org/10.4018/978-1-6684-8140-0

Smith, O. M., Jocson, D. M. I., Lee, B. W., et al. (2022). Identifying Farming Strategies Associated with Achieving Global Agricultural Sustainability. Frontiers in Sustainable Food Systems, 6. https://doi.org/10.3389/fsufs.2022.882503

Sorin, R. (2013). Scenario-based learning: Transforming tertiary teaching and learning. In: Proceedings of the 8th QS-APPLE Conference, Bali. James Cook University. pp. 71–81.

Soudien, C. (2020). Complexities of difference and their significance for managing inequality in learning: Lessons from the COVID-19 crisis. Prospects, 49(1-2), 59-67. https://doi.org/10.1007/s11125-020-09486-x

Souza, M. C., Lima, R. M., Mesquita, D., & Margalho, E. M. (2022). Development and Validation of Scenarios for the assessment of Project Management People Competences. 12, 173–181. https://doi.org/10.5281/zenodo.7057819

Valente, A., & Marchetti, E. (2019). Fables for Teachers and Pupils: Incrementally Defined Scenario-Based, Interactive and Spatial Stories. 11590 LNCS, 206–224. https://doi.org/10.1007/978-3-030-21814-0_16

van Urk, F., van Steen, M., Brose, A., et al. (n.d.). How Challenge-Based Research enhances the impact-driven approach of Europe and European universities.

Walentowski, H., Kietz, B., Horsch, J., et al. (2020). Development of an interdisciplinary master of forestry program focused on forest management in a changing climate. Forests, 11(6). https://doi.org/10.3390/F11060632

Wu, L., & Wen, Y. (2020). A research map to leverage augmented reality in K12 science education. In: Designing, Deploying, and Evaluating Virtual and Augmented Reality in Education. pp. 204–219. https://doi.org/10.4018/978-1-7998-5043-4.ch010

Yilmaz, D. U., Palandoken, E. A., Ceylan, B., & Akbiyik, A. (2020). The effectiveness of scenario-based learning to develop patient safety behavior in first year nursing students. International Journal of Nursing Education Scholarship, 17(1). https://doi.org/10.1515/ijnes-2020-0011

Yousefi Hamedani, E., Taheri Demneh, M., Nasr-Isfahani, A. R., & Abedini, Y. (2023). Educational futures: Alternative scenarios for the primary school curriculum. Policy Futures in Education, 14782103231184930. https://doi.org/10.1177/14782103231184930

Yuan, T. (2022). Higher education beyond SDG 4: China’s scholarship provision in the Global South. International Journal of Chinese Education, 11(3). https://doi.org/10.1177/2212585X221136735

Zamana, F. (2022). The Future of Education as a Creative Ecosystem: A Sociocultural Framework for the Development of Creativity. Journal of Intelligence, 10(4), 99. https://doi.org/10.3390/jintelligence10040099

Zitouniatis, A., Lazarinis, F., & Kanellopoulos, D. (2023). Teaching computational thinking using scenario-based learning tools. Education and Information Technologies, 28(4), 4017–4040.