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

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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.
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.

Figure 1. OEM4C Design Canvas for learning experiences as in real-life scenarios building. Source: Ramírez Montoya et al., 2024.

Figure 2. Scenario: Drop by drop, water runs out. 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](image)

**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.
<table>
<thead>
<tr>
<th>Mds</th>
<th>Title of the Scenarios</th>
<th>Learning Objective</th>
<th>Component of Competence</th>
<th>Crosscutting Content at the Frontiers of Knowledge</th>
<th>Active Strategy and Technologies</th>
<th>Intension and Ends of Civilizations</th>
<th>Open Educational Resources</th>
<th>Endgame in Learning</th>
<th>Instruments of Evaluation</th>
<th>Inclusion and Diversity</th>
<th>Lifelong Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Improving trust and trustworthiness</td>
<td>Enhancing the system of knowledge through innovative and transparent decision-making and left practical solutions</td>
<td>Critical Thinking</td>
<td>Knowledge-based decision-making, cognitive flexibility, and problem-solving</td>
<td>Open-ended, problem-based learning, and collaborative inquiry</td>
<td>Empirical evidence</td>
<td>Innovation</td>
<td>Information society, technological change, and sustainable development</td>
<td>Critical thinking and analytical skills, computational thinking, and creativity</td>
<td>Reflective assessment</td>
<td>Diverse participation and equitable outcomes</td>
</tr>
<tr>
<td>2</td>
<td>Developing a strong civil society</td>
<td>Strengthening the role of the civil society in social and economic development</td>
<td>Social Capital</td>
<td>Social cohesion, community engagement, and democratic participation</td>
<td>Participatory planning, community development, and social innovation</td>
<td>Empirical evidence</td>
<td>Sustainability</td>
<td>Information society, technological change, and sustainable development</td>
<td>Critical thinking and analytical skills, computational thinking, and creativity</td>
<td>Reflective assessment</td>
<td>Diverse participation and equitable outcomes</td>
</tr>
<tr>
<td>3</td>
<td>Fostering an enabling environment for innovation</td>
<td>Creating an environment that fosters innovation and entrepreneurship</td>
<td>Entrepreneurship and Innovation</td>
<td>Innovation, creativity, and risk-taking</td>
<td>Open-ended, problem-based learning, and collaborative inquiry</td>
<td>Empirical evidence</td>
<td>Innovation</td>
<td>Information society, technological change, and sustainable development</td>
<td>Critical thinking and analytical skills, computational thinking, and creativity</td>
<td>Reflective assessment</td>
<td>Diverse participation and equitable outcomes</td>
</tr>
<tr>
<td>4</td>
<td>Building a resilient and inclusive society</td>
<td>Building a society that is resilient to shocks and inclusive of all its members</td>
<td>Resilience</td>
<td>Adaptability, flexibility, and resilience</td>
<td>Open-ended, problem-based learning, and collaborative inquiry</td>
<td>Empirical evidence</td>
<td>Innovation</td>
<td>Information society, technological change, and sustainable development</td>
<td>Critical thinking and analytical skills, computational thinking, and creativity</td>
<td>Reflective assessment</td>
<td>Diverse participation and equitable outcomes</td>
</tr>
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</table>

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.
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.

**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 # 1001-IF0001-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.

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