Active Learning for Circular Economy Businesses, Fostering a Sustainable Mindset

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Abstract

Despite extensive literature on corporate sustainability, understanding how companies become sustainable remains elusive. Similarly, the innovative processes that lead organizations to become "green" are not well understood. Industrial symbiosis (IS) offers a new model for sustainable development, involving the exchange of waste materials between companies. This study explores how IS can be taught to students to develop sustainable entrepreneurial skills, using a business game developed for the "Circular Sustainable Business Development" course at the University of Twente. The game allows students to negotiate simulated IS agreements, helping them understand the economic and environmental implications of their decisions.
The study aims to investigate how the IS business game can enhance students' entrepreneurial skills, including negotiation abilities, holistic vision, and forward-thinking capabilities. This is crucial as entrepreneurial education must adapt to a changing economic landscape, encouraging future entrepreneurs to think sustainably. The paper addresses the need for educational models that prepare entrepreneurs to not only apply existing principles but also to pose new questions and find innovative solutions. Students complete a questionnaire right after the game to assess their knowledge and proficiency in IS and entrepreneurial thinking.
The business game is expected to significantly impact students' understanding of IS and their entrepreneurial thinking skills. It's anticipated that students will gain a deeper understanding of IS dynamics, develop sophisticated negotiation skills, and adopt a holistic view of entrepreneurial practices related to the circular economy. The study aims to highlight the transformative potential of experiential learning in shaping entrepreneurs equipped to navigate a sustainable business landscape. This research is a step towards understanding the role of innovative educational models in fostering a new generation of entrepreneurs who are prepared to tackle the challenges of a sustainable future.

Keywords: *Circular economy; soft skills; sustainable management; entrepreneurship; education*

1. Introduction

In recent years, sustainability has become a key objective to be pursued by rethinking traditional production and consumption patterns [1] and educating the population towards more responsible behaviour [2]. Education for sustainability plays a key role in this transformation. Indeed, goal number 4 of the Sustainable Development Goals aims to ensure that everyone acquires the knowledge and skills necessary to promote sustainable development; this goal is to be understood as fundamental to achieving the other 16 SDGs structured by UNESCO in 2015 and the reviewed in 2017 and 2018. Thus, modern education must provide not only students but the population at large with the competencies to achieve a sustainable future and a resilient society [3][4][5][6].

Teaching through games is emerging as an effective way to transfer knowledge on complex topics to a broad audience [7], as in the case of sustainability. Besides transferring knowledge of concepts and principles, they can also teach competencies such as decision-making and problem-solving [8][9]. This is especially useful in the case of the circular economy, where the large number of actors involved need to coordinate and make decisions that respect the goals of individuals. This research endeavors to comprehensively investigate the influence of a sustainable game, specifically the IS business game, on certain competencies recognized as pivotal for cultivating sustainable thinking. The primary objective is to gain a nuanced understanding of how engagement with this sustainable game contributes to the development and enhancement of these crucial competencies, thereby contributing to the broader discourse on sustainable education and fostering a more environmentally conscious

mindset among participants. To accomplish this objective, we will employ a meticulously calibrated questionnaire, strategically designed to systematically assess and delve into the specific competencies identified within the context of our study. This tailored instrument aims to provide a nuanced and in-depth exploration, facilitating a comprehensive analysis of the impact of the sustainable game, particularly the IS business game, on the targeted skills essential for fostering sustainable thinking.

2. Theoretical Background

The term 'competencies' describes individuals' dispositions to act and self-organise in various contexts and complex situations [10].

Competencies combine three elements: knowledge, skills, and attitudes [11][12][13].

Knowledge is composed of facts and figures, concepts, ideas and theories that are already established and provide the basis for understanding a particular field or topic; skills are understood as knowing and being able to perform processes and apply existing knowledge to obtain results; attitudes describe the disposition and mindset to act or react to ideas, people or situations [13]. These elements should not be considered independent but interconnected [12].

The European Union has identified eight key competencies that individuals must possess to live successfully in society: Literacy competence, Multilingual competence, Mathematical competence and competence in science, technology and engineering, Digital competence, Personal, social and learning-to-learn competence, Citizenship competence, Entrepreneurship competence, Cultural awareness and expression competence [13].

These competencies are developed in a lifelong learning perspective, from early childhood to adult life, through formal (e.g., through study) in the case of Mathematical competence, and informal learning (e.g., through action) in the case of cultural awareness competence [13]. Recently, sustainability competence has also been added to these competencies. If posseed by all, sustainability competencies should be agents for sustainable development in society [14].

However, more than formal or informal learning may be required for sustainability competencies. Sustainability is meant to address complex challenges, and the approach to be taken must be multi-sectoral (public, private and civil society), multi-level (from local to global), and multi-disciplinary (involving different disciplines to find a solution) [15], which is difficult to transfer through only formal study.

More significant results could be achieved by combining the two types of learning, i.e., formal and informal, because study and action are also combined with reflection and experience in its execution [16], as in the case of learning through play. Games develop knowledge, skills and the ability to understand situations. Learning through play allows also for exploration and experimentation with the guidance of a facilitator and in a safe environment. This allows participants to receive instant feedback on their actions and decisions [17] and to develop competencies quickly.

3. Methodology

3.1 Industrial Symbiosis Business Game

The IS Business game is an integral part of the CSBD class, a course in the master's degree program of Industrial Engineering and Management at UT [18]. The game serves as a practical learning tool, enabling students to experience the operational and business dynamics of Industrial Symbiosis (IS), particularly focusing on the establishment and management of Industrial Symbiosis Relationships (ISRs) over time: ISRs are formed when one company uses another's waste as a substitute for production inputs or to create new products [19].

The game involves students divided into groups, each representing a company. These companies are categorized as either waste producers or receivers. Each company produces one main output for the final market, and each waste receiver requires one production input, while each waste producer generates one waste. The amount of waste produced and inputs required are dependent on the output generated and the production technologies employed. In this context, the game poses two main challenges to the students: identifying potential partners and creating ISRs with other companies while negotiating the contractual terms, and operating these relationships in a turbulent business environment. The environmental turbulence is simulated through changes in the market demand for outputs produced by companies and changes in policy actions undertaken by the government.

The goal of each company in the game is to maximize the environmental and economic benefits created through ISRs with other companies. The performance of each company is evaluated based on two indicators: environmental performance and economic performance. At the end of the game, companies are ranked according to these two performance indicators. The game is played

continuously for several days, divided into three game periods. In each game period, companies can establish and implement as many ISRs as they want. Each relationship is ruled by a contract signed by both parties, which defines the duration of the relationship, the waste exchange rate, the amount of waste to be exchanged, the cost-sharing policy, the waste exchange price, and the penalty for prematurely ending the contract.

In this game, the diverse range of activities and extensive interactivity and interaction among the participants enable students to manifest a myriad of attitudes and competencies. These aspects will be explored through the evaluative questionnaire described below.

3.1 Literature review and questionnaire development

Following the purpose of this research, it was necessary to identify the specific sustainability competencies. A literature review was conducted by entering 'sustainab* competent*' as a keyword on Scopus. A separate search added additional articles and reports to ensure the completeness of the sources in the subject matter. The selection of articles favoured articles that identified and defined sustainability competencies as the article's central focus. In the different articles, the competencies were systematically mapped and subsequently aggregated for similarity.

In the end, eight sustainability-related competencies were identified: System thinking competencies, Strategic -thinking competencies, Futures thinking competencies, Values-thinking competencies, Interpersonal competencies, Intrapersonal competencies or self-awareness, Implementational thinking, Integrated problem solving.

1. *System thinking competencies:* Analyze problem in current state and its history [20][21][22];
2. *Strategic -thinking competencies:* Develop sustainability transition strategies [23][24][20][25][26];
3. *Futures thinking competencies:* Futures thinking competencies Craft future sustainability visions [20][26][14];
4. Values-thinking competencies: Map, specify, apply, reconcile and negotiate sustainability values [20][27][28][26];
5. Interpersonal competencies: Collaborate in each step of the problem - solving process [29][30][31];
6. Intrapersonal competencies or self-awareness: Aware of one's own emotions, desires, thoughts, behaviours, and personality, as well as to regulate, motivate, and continually improve oneself drawing on competencies related to emotional intelligence and social and emotional learning [32][33][20];
7. Implementational thinking: Act on sustainability strategies to find viable transformational solutions to sustainability problems [20][34][35][36][14];
8. Integrated problem solving: Apply different problem-solving frameworks to complex sustainability problems and develop viable solution options" in order to "meaningfully integrate problem analysis, sustainability assessment, visioning and strategy building" [14][22][23][24][20][26];

According to the analysis, a questionnaire was designed to test whether the game develops sustainability competencies. Questions for each competence were developed. The questions were formulated in the first person according to the identified definitions to test the ability, skills, and attitudes in the different situations posed by the game. Subsequently, the response criteria were defined using a 5-point Likert scale (strongly disagree, disagree, neutral, agree, strongly disagree). The questionnaire was a simple online survey using a 'Google Form'. The game was administered to 48 students attending the second year of the master's degree in management engineering at Sapienza University of Rome. The project is part of the course in environmental economics and management. The questionnaire was administered rightafter the game session. Finally, the results were analysed.

4. Results

Hereafter, the various sections of the questionnaire will be delineated, with the students' responses explicated for each individual question within every respective section. This presentation aims to provide a comprehensive overview of the collected data, shedding light on the diverse perspectives and insights offered by the participating students.

4.1 System thinking competencies

The questionnaire assessed the system thinking competencies of students, specifically their ability to analyse problems in their current state and history.

1. The question was *"I was able to understand the strengths and challenges in the game and use this information to create optimal solutions to problems":* Most students (37 out of 48) agreed (either partially or totally), 8 remains neutral, 3 partially disagree.
2. The question was *"When a problem occurred, I was able to identify the root cause":* Again, most students (35 out of 48) agreed (either partially or totally), 8 remains neutral, 5 disagree (either partially or totally).
3. The question was *"I was able to understand the severity of a problem when it occurs"*: Similar to the previous questions, most students (35 out of 48) agreed (either partially or totally), 8 remains neutral, 5 disagree (either partially or totally).
4. The question was *"I have constantly monitored budgets and deadlines to stay informed of any problems":* A majority of the students (33 out of 48) agreed (either partially or totally), 6 remains neutral, 9 partially disagree.

Overall, the results suggest that the students possess a good level of system thinking competencies. They are capable of understanding the dynamics of the game, identifying and solving problems, and managing resources effectively.

4.2 Strategic -thinking competencies

The questionnaire assessed the strategic thinking competencies of students, specifically their ability to develop sustainability transition strategies.
1. The question was *"I was able to formulate strategies and action plans to ensure the completion of objectives and goals"*: A majority of students (30 out of 48) agreed (either partially or totally), 9 remains neutral, 9 disagree (either partially or totally).
2. The question was *"I was able to develop innovative solutions to taking into account the principles of economic, social and environmental sustainability"*: Most students (31 out of 48) agreed (either partially or totally), 9 remains neutral, 8 disagree (either partially or totally).
3. The question was *"I have been able to evaluate the effectiveness of solutions and plans"*: A significant majority of students (37 out of 48) agreed (either partially or totally), 6 remains neutral, 5 partially disagree (either partially or totally).
4. The question was *"During the game, I reflected on whether the actions I took were in accordance with my personal and group goals"*: Most students (34 out of 48) agreed (either partially or totally). 9 remains neutral, 5 partially disagree.
5. The question was *"I am capable of communicating to my teammates how I would like to continue in the game"*: A majority of students (39 out of 48) agreed (either partially or totally), 6 remains neutral, 3 partially disagree.

The questionnaire results show that students possess strong strategic thinking competencies, evident in their ability to formulate strategies, devise innovative solutions, evaluate plan effectiveness, reflect on actions in alignment with goals, and communicate effectively with teammates.

4.3 Futures thinking competencies

The questionnaire assessed the futures thinking competencies of students, specifically their ability to craft future sustainability visions.
6. The question was *"I am able to anticipate the future developments of the game"*: A little majority of students (18 out of 48) agreed (either partially or totally), 15 remains neutral, 15 disagree (either partially or totally).
1. The question was *"When a problem occurred, I find a lasting solution to the problem"*: Most students (23 out of 48) agreed (either partially or totally), 17 remains neutral, 8 disagree (either partially or totally).
2. The question was *"I'm able to consider the future consequences of my actions"*: A significant majority of students (32 out of 48) agreed (either partially or totally), 6 remains neutral, 10 disagree (either partially or totally).
3. The question was *"I was able to make decisions even in situations of uncertainty, ambiguity and risk"*: Most students (30 out of 48) agreed (either partially or totally), 13 remains neutral, 5 disagree (either partially or totally).
4. The question was *"I imagined future developments of the game by linking different disciplines I studied, using creative thinking and experimenting with new methods"*: A little majority of students (21 out of 48) agreed (either partially or totally), 14 remains neutral, 14 disagree (either partially or totally).

Overall, the results indicate students have strong integrated problem-solving competencies, showcasing skills in recognizing problems, developing innovative solutions, decision-making,

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information gathering and analysis, solution implementation and evaluation, and data-driven judgments.

4.4 Values-thinking competencies

The questionnaire assessed the values-thinking competencies of students, specifically their ability to map, specify, apply, reconcile and negotiate sustainability values.

1. The question was *"I was able to create a common vision for all my teammates in the group":* A majority of students (39 out of 48) agreed (either partially or totally), 6 remains neutral, 3 disagree (either partially or totally).
2. The question was *"During the game, I reflected on whether the actions I had taken were right or still wrong":* Most students (36 out of 48) agreed (either partially or totally), 6 remains neutral, 5 disagree (either partially or totally).
3. The question was *"During the game, I reflected on whether the actions I took were in accordance with my personal and group goals":* Most students (35 out of 48) agreed (either partially or totally), 9 remains neutral, 4 partially disagree.
4. The question was *"During the game, I reevaluated actions based on experiences that had already occurred":* A majority of students (36 out of 48) agreed (either partially or totally), 7 remains neutral, 5 disagree (either partially or totally).

The results indicate that students have strong implementational thinking competencies, crucial for applying learned knowledge, conducting goal-oriented actions, considering others' needs in decision-making, and adhering to rules and constraints.

4.5 Interpersonal competencies

The questionnaire assessed the interpersonal competencies of students, specifically their ability to collaborate in each step of the problem-solving process.

1. The question was *"I was able to accept the others opinions and views":* A vast majority of students (44 out of 48) agreed (either partially or totally), 2 remains neutral, 2 partially disagree.
2. The question was *"I actively seek feedback from others":* Most students (40 out of 48) agreed (either partially or totally), 4 remains neutral, 4 partially disagree.
3. The question was *"I was able to encourage my colleagues to take responsibility":* Most students (33 out of 48) agreed (either partially or totally), 12 remains neutral, 3 partially disagree.
4. The question was *"I was able to get the members of my group to agree on the strategies to be undertaken":* Most students (36 out of 48) agreed (either partially or totally), 9 remains neutral, 3 disagree (either partially or totally).
5. The question was *"I was able to find a compromise between conflicting needs":* A vast majority of students (38 out of 48) agreed (either partially or totally), 7 remains neutral, 3 partially disagree.
6. The question was *"I was able to accept that one of my colleagues is responsible for a specific activity without intervening in decisions":* Most students (32 out of 48) agreed (either partially or totally), 13 remains neutral, 3 partially disagree.

The results suggest that students possess strong intrapersonal competencies, crucial for taking responsibility, learning from mistakes, accepting outcomes, seeking knowledge, empathizing, and understanding others' feelings.

4.6 Intrapersonal competencies or self-awareness

The questionnaire assessed the intrapersonal competencies of students, specifically their self-awareness and ability to regulate, motivate, and continually improve oneself.

1. The question was *"I take responsibility for the actions I perform":* A vast majority of students (40 out of 48) agreed (either partially or totally), 6 remains neutral, 2 partially disagree.
2. The question was *"I was able to take ownership of mistakes and learn from them":* Most students (39 out of 48) agreed (either partially or totally), 7 remains neutral, 2 disagree (either partially or totally).
3. The question was *"I was able to take responsibility for achievements, good and bad":* Most students (41 out of 48) agreed (either partially or totally), 4 remains neutral, 3 partially disagree.

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4. The question was *"If there is new information, I am very challenged to find the answer":* Most students (34 out of 48) agreed (either partially or totally), 10 remains neutral, 4 disagree (either partially or totally).

5. The question was *"I was concerned to find a solution that would suit all participants in the game, leaving aside competitiveness":* Most students (33 out of 48) agreed (either partially or totally), 10 remains neutral, 5 disagree (either partially or totally).

6. The question was *"I was able to understand the feelings of the other players":* Most students (39 out of 48) agreed (either partially or totally), 5 remains neutral, 4 disagree (either partially or totally).

The results indicate that students possess strong interpersonal competencies, essential for accepting opinions, seeking feedback, encouraging responsibility, negotiating strategies, resolving conflicts, and respecting others' roles.

4.7 Implementational thinking

The questionnaire assessed the implementational thinking competencies of students, specifically their ability to act on sustainability strategies to find viable transformational solutions to sustainability problems.

1. The question was *"I was able to implement in practice what I have studied":* Most students (29 out of 48) agreed (either partially or totally), 13 remains neutral, 6 disagree (either partially or totally).

2. The question was *"I was motivated to perform actions that are not only goal-oriented, but are respectful of others and the environment":* Most students (33 out of 48) agreed (either partially or totally), 7 remains neutral, 8 disagree (either partially or totally).

3. The question was *"When deciding which action to implement, I always choose the one that is a compromise between everyone's needs":* Most students (36 out of 48) agreed (either partially or totally), 6 remains neutral, 6 partially disagree.

4. The question was *"During the game, I implemented my actions taking into account constraints and rules given":* A majority of students (41 out of 48) agreed (either partially or totally), 5 remains neutral, 2 partially disagree.

The results indicate that students possess strong values-thinking competencies, essential for creating a common vision, reflecting on actions, aligning actions with goals, and learning from experiences.

4.8 Integrated problem solving

The questionnaire assessed the integrated problem-solving competencies of students, specifically their ability to apply different problem-solving frameworks to complex sustainability problems and develop viable solution options.

1. The question was *"I was aware of problems or issues that may affect the organization during the game":* Most students (30 out of 48) agreed (either partially or totally), 10 remains neutral, 8 partially disagree.

2. The question was *"When there was a problem I tried to develop innovative solutions to problems":* Most students (31 out of 48) agreed (either partially or totally), 11 remains neutral, 6 disagree (either partially or totally).

3. The question was *"I frequently analyze alternatives and select a course of action during the IS business game":* Most students (38 out of 48) agreed (either partially or totally), 7 remains neutral, 3 disagree (either partially or totally).

4. The question was *"I frequently collect relevant information and data to solve the occurring problems":* Most students (30 out of 48) agreed (either partially or totally), 14 remains neutral, 4 disagree (either partially or totally).

5. The question was *"I actively implemented solutions and evaluated the results":* Most students (30 out of 48) agreed (either partially or totally),15 remains neutral, 3 disagree (either partially or totally).

6. The question was *"I base my judgments upon the relevant information collected":* Most students (35 out of 48) agreed (either partially or totally), 11 remains neutral, 2 disagree (either partially or totally).

The results indicate that students possess strong futures thinking competencies, essential for anticipating future developments, effective problem-solving, considering future consequences, making decisions in uncertain situations, and thinking creatively and interdisciplinarity.

5. Conclusion

The IS business game has shown a significant impact on students' entrepreneurial skills. The game fosters a range of competencies, including strategic thinking, futures thinking, values-thinking, implementational thinking, and integrated problem-solving.

Students demonstrated the ability to formulate strategies, develop innovative solutions, evaluate the effectiveness of plans, reflect on their actions in relation to their goals, and communicate effectively with their teammates. They also showed foresight, the ability to craft future sustainability visions, and the capacity to map, specify, apply, reconcile, and negotiate sustainability values. Furthermore, students exhibited strong interpersonal competencies, demonstrating the ability to collaborate in each step of the problem-solving process. They also displayed intrapersonal competencies, showing self-awareness and the ability to regulate, motivate, and continually improve oneself. In terms of implementational thinking, students demonstrated the ability to act on sustainability strategies to find viable transformational solutions to sustainability problems. Lastly, in integrated problem-solving, students showed the ability to apply different problem-solving frameworks to complex sustainability problems and develop viable solution options.

Overall, the IS business game appears to be an effective tool for fostering these competencies, suggesting the value of experiential learning in education for sustainable development. The game prepares students for future challenges in entrepreneurship by equipping them with the necessary skills and competencies.

6. Future Reaserch

Future research could involve applying the IS business game to students without a sustainability background. This would help understand its impact on a broader student population and its potential as an introductory tool for sustainability education. Longitudinal studies could assess the game's long-term impact, and qualitative methods could provide deeper insights into students' experiences.

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