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New Perspectives
in Science
Education

International Conference
**NEW PERSPECTIVES
in SCIENCE EDUCATION**



Active learning for circular economy businesses, fostering a sustainable mindset

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PAPER STRUCTURE

- 01 Introduction
- 02 Theoretical background
- 03 Methodology
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The need for sustainability competencies



European Union's recognition of sustainability competence as a **key competency for successful living in society**. They touch a nuanced spectrum of areas, from Multilingual competence to technology and engineering. (European Commission, 2018)



Sustainability competence are crucial in addressing complex global challenges and promoting sustainable development, **acting as agents for positive change in society**. (European Commission, 2018; European Commission, 2022)



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Competencies and their development



Competencies are the integration of **knowledge, skills and attitudes** (Boyatzis, 2008; Rieckmann, 2018; European Commission, 2018)



Competencies can be developed through **formal learning (e.g., study) or informal learning (e.g., action)**



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Sustainability Competencies Development



More than formal or informal learning may be required for sustainability competencies, for **better prepare individuals to address** the multifaceted **challenges of sustainability** and contribute meaningfully to sustainable development efforts. (Kurucz et al., 2017)



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Research Gap

Game based-learning can be a solution to develop these competencies because, it is characterized by **experiential and practical approaches**, complements formal education by providing opportunities for reflection, exploration, and experimentation. (Kolb, 2014; Caldana et al. 2023)



However, there is a lack of understanding as to whether learning through play contributes to developing sustainability competencies.



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Industrial Symbiosis Business Game (ISBG)



It is a practical learning tool for students to **experience** the operational and business dynamics of **Industrial Symbiosis (IS)**, focusing on the establishment and management of **IS Relationships (ISRs)**.



During the game session participant identify potential **partners**, **negotiate** contractual terms, and navigate a **turbulent business environment** simulated through market demand fluctuations and policy changes.



The final goal is to **maximize environmental and economic benefits** through ISRs and the evaluation criteria based on environmental and economic performance

Fraccascia L., Sabato A., Yazan D.M. "An industrial symbiosis simulation game: Evidence from the Circular Sustainable Business Development class". Journal of Industrial Ecology, 2021, in press.



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Research Objectives



Investigate the **impact of the IS business game on students' entrepreneurial skills and competencies**, particularly in the context of sustainability education development.



Understand if **engagement with the game contributes to the development of various competencies** crucial for fostering **sustainable thinking** among participants.



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Literature Review

The literature review process focusing on relevant articles and reports about sustainability competencies let us identify 8 relevant skills:

System thinking	Annelin and Boström, 2022; Meza et al., 2018; Wiek et al., 2011
Strategic-thinking	de Haan,2006;Wesselink et al., 2015; Annelin and; Boström, 2022; Lans et al., 2014; Savage et al., 2015
Futures thinking	Annelin and Boström, 2022; Savage et al., 2015; Pisiotis and Cabrera, 2022; European Commission, 2022
Values-thinking	Annelin and Boström, 2022; Komasinski and Ishimura, 2017; Remington-Doucette et al., 2013; Savage et al., 2015
Intrapersonal competencies	Crofton, 2000; Sterling, 1996; Kearins and Springett, 2003
Intrapersonal competencies or self-awareness	Cabral and Lochan Dhar, 2019; Faham et al., 2017; Annelin and Boström, 2022
Implementational thinking	Annelin and Boström, 2022; Ploum et al., 2018b; Brandt et al., 2019; Holdsworth et al, 2020; European Commission, 2022
Integrated problem solving	European Commission, 2022; Wiek et al., 2011; de Haan,2006;Wesselink et al., 2015; Annelin and Boström, 2022; Savage et al., 2015

Questionnaire Development

Created to understand the impact of the ISBG on the development of sustainability competencies among students:

- ? It includes **questions for each competency** were formulated in the first person.
- ? We use of a **5-point Likert scale** to assess students' responses from totally agree (5) to totally disagree (1) considering 3 as neutral.

The questionnaire was administered to **students attending the second year of the master's degree in management engineering at Sapienza University of Rome, right after the IS business game session.**



Questions to assess sustainability competencies

SYSTEM THINKING COMPETENCIES

1. I was able to understand the strengths and challenges in the game and use this information to create optimal solutions to problems
2. When a problem occurred, I was able to identify the root cause
3. I was able to understand the severity of a problem when it occurred
4. I have constantly monitored budgets and deadlines to stay informed of any problems

STRATEGIC COMPETENCIES

1. I was able to formulate strategies and action plans to ensure the completion of objectives and goals
2. I was able to develop innovative solutions to taking into account the principles of economic, social and environmental sustainability
3. I have been able to evaluate the effectiveness of solutions and plans
4. During the game, I reflected on whether the actions I took were in accordance with my personal and group goals
5. I was capable of communicating to my teammates how I would like to continue in the game

FUTURES THINKING COMPETENCIES

1. I was able to anticipate the future developments of the game
2. When a problem occurred, I found a lasting solution to the problem
3. I was able to consider the future consequences of my actions
4. I was able to make decisions even in situations of uncertainty, ambiguity and risk
5. I imagined future developments of the game by linking different disciplines I studied, using creative thinking and experimenting with new methods

VALUES THINKING COMPETENCIES

1. I was able to create a common vision for all my teammates in the group
2. During the game, I reflected on whether the actions I had taken were right or still wrong
3. During the game, I reflected on whether the actions I took were in accordance with my personal and group goals
4. During the game, I reevaluated actions based on experiences that had already occurred

INTERPERSONAL COMPETENCIES

1. I was able to accept the others opinions and views
2. I actively sought feedback from others
3. I was able to encourage my colleagues to take responsibility
4. I was able to get the members of my group to agree on the strategies to be undertaken
5. I was able to find a compromise between conflicting needs
6. I was able to accept that one of my colleagues is responsible for a specific activity without intervening in decisions

IMPLEMENTATIONAL THINKING COMPETENCIES

1. I was able to implement in practice what I have studied
2. I was motivated to perform actions that were not only goal-oriented, but also respectful of others and the environment.
3. When deciding which action to implement, I always chose the one that was a compromise between everyone's needs
4. During the game, I implemented my actions taking into account constraints and rules given

INTEGRATED COMPETENCIES

PROBLEM

SOLVING

1. I was aware of problems or issues that may affect the organization during the game
2. When there was a problem I tried to develop innovative solutions to problems
3. I frequently analyzed alternatives and select a course of action during the IS business game
4. I frequently collected relevant information and data to solve the occurring problems
5. I actively implemented solutions and evaluated the results
6. I based my judgments upon the relevant information collected



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Questionnaire Results (1/2)

System Thinking

The ability to analyze problems in their current state and history

Average Likert scale score assessed by the 48 considered students: 3,92 ($\sigma = 0,13$)

Strategic Thinking

The ability to develop sustainability transition strategies

Average Likert scale score assessed by the 48 considered students: 3,88 ($\sigma = 0,19$)

Futures Thinking

The ability to craft future sustainability visions

Average Likert scale score assessed by the 48 considered students: 3,46 ($\sigma = 0,28$)

Values-Thinking

The ability to map, specify and apply, sustainability values

Average Likert scale score assessed by the 48 considered students: 3,99 ($\sigma = 0,09$)

Questionnaire Results (2/2)

Interpersonal Competencies

The ability to collaborate in each step of the problem-solving process

Average Likert scale score assessed by the 48 considered students: 4,06 ($\sigma = 0,15$)

Intrapersonal Competencies

The ability to regulate, motivate, and continually improve oneself

Average Likert scale score assessed by the 48 considered students: 4,07 ($\sigma = 0,14$)

Implementational Thinking

The ability to act on sustainability strategies to find viable solutions

Average Likert scale score assessed by the 48 considered students: 3,89 ($\sigma = 0,18$)

Integrated Problem Solving

The ability to find viable solution to complex sustainability problems.

Average Likert scale score assessed by the 48 considered students: 3,87 ($\sigma = 0,16$)

Final Consideration



The **ISBG emerges as an effective tool** for developing a wide range of competencies essential for entrepreneurship and sustainability.



This experience **highlights the value of experiential learning in education for sustainable development**, emphasizing practical, hands-on approaches in preparing students for future challenges.

Future research: recommendations include exploring the game's impact on students without a sustainability background and conducting longitudinal studies to assess its long-term effects.



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