Quantifying agroecology learning with the SErious Game for AgroEcology (SEGAE) in a 4-hour lesson.

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Abstract:

The current agricultural system fails to meet global challenges, leading to the rise of agroecology as a relevant alternative. Agroecology delivers ecosystem services, develops social relationships, and holds economic potential. Incorporating this new paradigm into agricultural education is a step toward the transition. However, its complex, interdisciplinary nature poses learning challenges. Conventional teaching methods lack effectiveness in cultivating interdisciplinary skills.

To assist in the teaching of agroecology, the "SErious Game for AgroEcology" (SEGAE) was developed (*see* www.segae.org). It simulates a mixed crop-livestock farm in which players can modify agricultural practices to improve sustainability. This paper aims to evaluate the effectiveness and efficiency of this game within a brief lesson period (4 hours). Our approach is based on the evaluation of three parameters: (1) knowledge acquisition in agroecology, (2) the level of 'flow' (a concept used to measure engagement in a task), and (3) the potential additional benefits of different lesson formats (online versus face-to-face)."

Results indicate a significant improvement in agroecology knowledge after the game. Lesson type did not significantly impact knowledge gain, but the online session negatively affected the "flow" level. Most students enjoyed SEGAE and believed it enhanced their agroecology knowledge.

Keywords: serious game; agroecology teaching; interdisciplinarity; knowledge; bioengineering

1. Purpose

European agriculture faces numerous challenges, prompting an urgent call for a transition (IPES-FOOD, 2018). Negative impacts such as forest loss, freshwater depletion, and greenhouse gas emissions highlight the need to balance food production within ecological limits (Gerten et al., 2020). Agroecology, aligned with food sovereignty principles, offers a promising alternative by promoting sustainability, efficiency, and social equity (Gliessman, 2014).

Despite the demonstrated benefits, transitioning to agroecology requires overcoming scientific and educational barriers (Vanloqueren and Baret, 2009). Agroecology encompasses a complex array of interacting components, such as environmental, social, and economic sciences (Francis et al., 2011). Traditional teaching approaches compartmentalize content by discipline, which fails to foster a systemic approach. Hence, Agroecology should be taught in a manner that offers a more holistic perspective on its diverse elements (Francis et al., 2008). Efficient learning involves engaging in active, hands-on, problem-solving methods, complemented by prompt feedback (Al Hakim et al., 2022; Boyle et al., 2011; Kiili, 2005).

Serious games address these considerations by offering immersive, interactive educational experiences (Wu and Lee, 2015). The SErious Game for AgroEcology learning (SEGAE) simulates a crop-livestock farm, allowing players to implement agroecological practices aimed at enhancing the

farm sustainability indicator (Jouan et al., 2021). In practice, players can select from strategic dimensions such as (1) soil, (2) crops, (3) landscape, (4) land use, (5) cows, (6) fertilization (7) strategic decisions (8) heifer and fattening cattle, and (9) feeding system. They have access to the related practices and can make changes accordingly (a maximum of 5 changes per year, and the simulation can be run for up to 10 years). Previous research highlighted SEGAE's effectiveness in enhancing agroecological knowledge and facilitating systemic and interdisciplinary learning in a 5-day international workshop setting (De Graeuwe et al., 2020).

This study aims to assess SEGAE's suitability for a short 4-hour lesson led by a single teacher, offering a more feasible educational format for university courses. We hypothesize that SEGAE enhances agroecological knowledge and enjoyment during the session. We will analyze three lessons to evaluate knowledge acquisition and flow levels (a notion aimed at gauging the degree of engagement in a task), considering the impact of lesson delivery mode (face-to-face vs. online). Additionally, we will explore the relationship between knowledge performance and flow experience. This research contributes to understanding the effectiveness of serious games in agroecology education.

2. Design

The research draws on an analysis of three 4-hour lessons using the serious game SEGAE. One lesson took place entirely online in March 2021 due to the COVID-19 pandemic, while the other two were face-to-face, held in March 2023 (in France) and May 2023 (in Belgium). These lessons were attended by university students in their 2nd and 3rd undergraduate years, enrolled in agricultural engineering programs across four specializations: Agronomy, Forest, International Development, and Others.

Each pedagogical process included various activities: (1) a pre-survey, (2) a theoretical session, (3) a serious game session, and (4) a post-survey. The theoretical session aimed to introduce agroecological concepts, encompassing three modules: "Soil-Plant-Ecology," "Animal," and "Socio-economic". Interactions of agricultural practices are also introduced in the session. Following this, the serious game session provided hands-on experience with SEGAE, involving scenarios such as "sandbox," "system approach," and "sustainability-oriented" (for more information, *see* De Graeuwe et al. (2020, p. 6)). Debriefing sessions followed each scenario to discuss outcomes and limitations.

Additionally, an evaluation based on the use of pre- and post-tests was mobilized. It is a widely utilized methodology for examining the impacts of innovative educational techniques (Dugad and Todman, 1995). The knowledge assessment was composed of 21 questions, either multiple-choice or open-ended, including 10 focused on crop production, 4 on animal production, and 7 that were general. That allowed the research team to analyze knowledge acquisition. The pre-survey also included questions about some control variables, such as number of ECTS credits completed in agroecology, study specialization, and childhood living environment. In the post-survey, an added section gathered feedback on the SEGAE game (which includes flow assessment). For more information on the surveys, see the supplementary materials of De Graeuwe et al. (2020).

Data analysis involved cleaning the datasets, removing outliers, and managing incomplete responses. The sample sizes for each section of the surveys are presented in Table 1.

Table 1: Samples of the 3 lessons (*numbers of students*)

	Knowledge section	**Feedback section**
First lesson (March 2021)	48	74
Second lesson (March 2023)	20	20
Third lesson (May 2023)	42	49

Student scores were calculated for the knowledge section. For the multiple-choice questions and open-ended questions, students received a score of 1 when they had a correct answer, 0 when they

did not answer, and -1 if the answer was not correct. The result of each question was added up to calculate the total score and was converted into percentages. In the feedback section, we resort to general pedagogical aspects and the 8 factors of the EgameFlow scale described in Fu et al. (2009), yielding an overall score. The feedback scores were computed based on students' responses to statements, scaling from 1 to 4 (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree). Each flow factor was assessed with 2-5 statements.

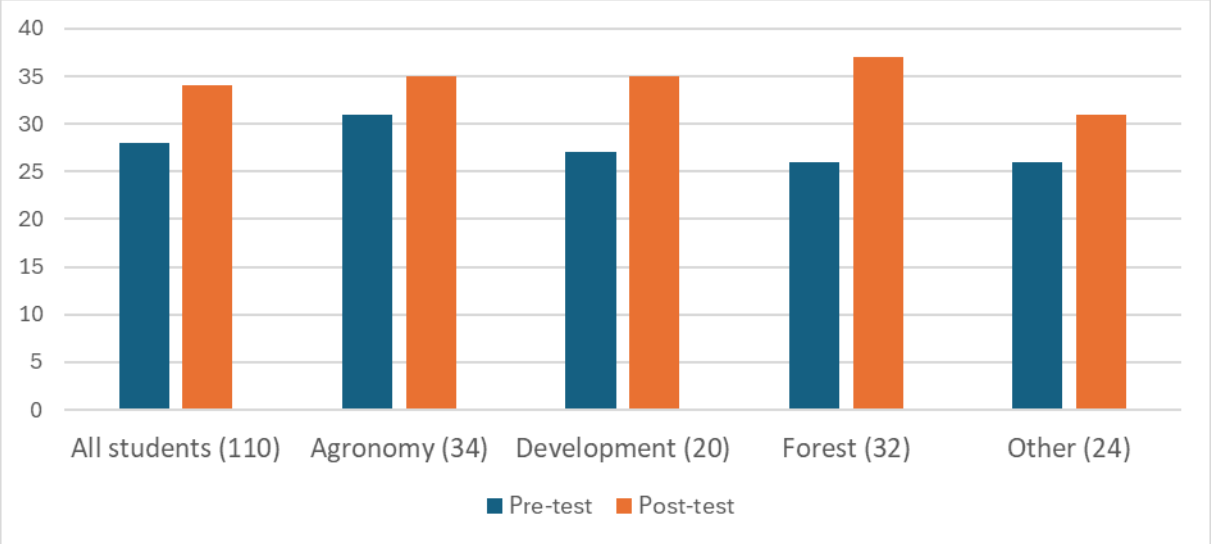
Descriptive statistics, paired t-tests, and multiple regressions were employed to analyze knowledge acquisition, specialization-wise and overall. Two-factor ANOVA and Tukey tests were used to compare flow scores among lessons and specializations. Furthermore, principal component analysis (PCA) was conducted to confirm results and explore the relationship between flow experience, knowledge change, and lesson type. This involved analyzing mean values of flow factors, absolute knowledge change, and lesson type for each student.

3. Findings

Seventy percent of the students experienced an increase in their scores, while 4% maintained the same scores, and 26% experienced slight decreases.

In the pre-test of knowledge, the overall average score stands at 28% (Figure 1). Each specialization ranges from 26% to 31%. In the post-test, there is a notable increase in the students' overall mean score ($p<0.001$), reaching 34%. The forest specialization exhibits the most substantial improvement, with an increase of 11 percentage points.

Figure 1. Mean of students' scores (in percentage) on the knowledge survey



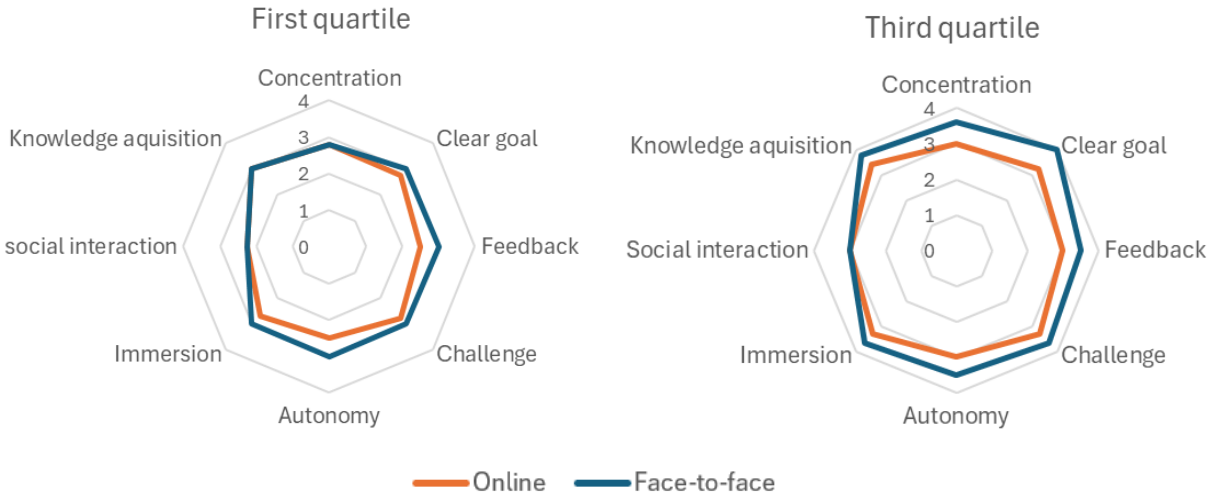
Control variables such as ECTS ((European Credit Transfer and Accumulation System) in agroecology, study specialization, and childhood living environment do not significantly influence pre-test scores (p-values>0.05). The number of books or articles read about agroecology is the only highly significant variable ($p<0.001$).

Additionally, the type of lesson (online or face-to-face) does not significantly affect post-test scores. The significant predictor is the score on the initial knowledge test ($p<0.0001$, $R^2=0.34$), with each point increase correlating with a 0.6% rise in correct answers.

In the feedback post-survey, 91% of students recommend the SEGAE game to peers. Additionally, 87% agree or strongly agree that the game was easy to play and complementary to theoretical

lessons. Overall, SEGAE is well-received, with a median score of 2.99 for the overall flow, indicating a degree of immersion. However, the "social interaction" factor scores the lowest (median: 2.75). Students display higher levels of flow factors for the face-to-face lesson than for the online lesson, *see* the first and third quartiles in Figure 2. Except for the social interaction factor being similarly ranked between both types of lessons. The difference is highly noticeable for the factors of "autonomy" and "feedback".

Figure 2. Comparison with a radar chart on flow factors



To analyze the potential link between knowledge and flow, a principal component analysis (PCA) has been carried out. In essence, the PCA reveals (1) an inverse relationship between flow factors and online modality, and (2) a link between social interaction, feedback, and absolute knowledge acquisition.

4. Implications

As the findings show, a game-based teaching approach significantly enhanced agroecological knowledge among the students surveyed. That supports findings from prior researches that suggest educational games can advance agroecological transition, as noted by Meunier et al (2022). While the increase in knowledge is evident, it is essential to consider that the average scores on both the pre- and post-surveys were comparatively low. Conducting the post-survey outside the lesson times may have negatively affected student post-scores, with 30% of students showing no improvement or a decrease. The respective time taken by each student to fill out the questionnaire was checked, but it turned out to be insignificant in explaining the results. This corroborates the findings of Bolsinova et al. (2017) which highlighted strong differences in the way individuals process responses to a questionnaire.

More crucially, it should be emphasized that the educational framework employed enabled students to realize a change in knowledge acquisition comparable to the one achieved through a 5-day workshop[1], despite the latter requiring significantly more organizational resources and thus being more demanding in terms of time and energy. Additionally, this 4-hour method also yielded comparable levels of student satisfaction and immersion. Therefore, a concise lesson conducted by a single instructor presents itself as an effective and efficient method for agroecology education.

[1] *see* 6.4 for "multidisciplinary curriculum" (similar student profile) in Table A1 of De Graeuwe et al. (2020)

Additionally, the research highlights a significant impact of pre-existing knowledge on scores observed in post-tests, reinforcing the outcomes reported in earlier studies, such as, by Zumbach et al.(2020). Intriguingly, even erroneous pre-existing knowledge detrimentally influences final scores, suggesting a complex interplay between prior knowledge and performance results. These observations support Lipson's (1982) findings, underscoring the importance of strategic interventions aimed at correcting misconceptions and enhancing fundamental comprehension.

Amidst the ongoing digital transformation of educational landscapes, our analysis contextualizes the systematic integration of online courses. Specifically, it highlights the necessity for deliberate consideration of instructional design principles and their alignment with pedagogical objectives (Caliskan et al., 2020). While online education offers unparalleled flexibility and accessibility, its efficacy in promoting crucial aspects of learning, such as feedback (Anderson et al., 2010) and social interaction (Azmat and Ahmad, 2022), remains uncertain. The current study indeed underscores the potential added value of traditional face-to-face instruction in facilitating prompt peer and teacher feedback, emphasizing the multifaceted nature of effective knowledge acquisition.

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