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## **Learning agroecology through the serious game SEGAE in an online lesson: unveiling its impact on knowledge articulation**

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### ***Abstract***

*Facing global challenges, the current dominating agricultural system has shown its limitation. Therefore, agroecology appears as an attractive alternative. Its implementation has been shown to benefit the environment, while harboring economic potential. For a transition towards more agroecology, this new paradigm needs to be taught to students and professionals in the agricultural sector. However, traditional learning methods are not fully adapted to teach these concepts because of the poor interactivity and/or lack of interdisciplinarity.*

*To help teach agroecology, the “SErious Game for AgroEcology” (SEGAE) was developed. SEGAE is a simulated mixed crop–livestock farm complex models in which players can learn by doing.*

*To access SEGAE pedagogical interest, university students, coming from four specializations (Agronomy; Chemistry; Environment and Forest) participated to a theoretical class which was paired to a play session of the game. The students then answered a knowledge survey on agroecology and a feedback survey based on flow theory. Results showed that students significantly increased their knowledge of agroecology. Students performed better when answering open-ended questions, which required them to articulate knowledge. Moreover, a large majority of students enjoyed the game (83%) and thought playing this game increased their knowledge (91%).*

***Keywords:*** *serious game; agroecology; interdisciplinarity; farming system*

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## **1. Introduction**

Acknowledging the documented impacts of agriculture (Campbell et al., 2017), the transition towards more sustainable agro-food systems is urgently needed (IPES-FOOD, 2018). One tricky equation in this will be to strike a good balance between warranting sufficient production of food for a growing population and remaining within planetary boundaries (Gerten et al., 2020). Associated with the concept of food sovereignty, agroecology is increasingly advocated as a promising alternative (Wezel et al., 2014). More specifically, agroecology-led initiatives are designed to meet the triple challenge of proposing a food system that is at the same time more sustainable, efficient and socially fair (Gliessman, 2014; Godfray et al., 2010).

Agroecology is commonly defined as “the ecology of sustainable food systems” (Gliessman, 2014). Agroecology is defined in this article as “the study of the interactions between plants, animals, humans, and the environment within agricultural systems” (Dalgaard et al., 2003, p. 42).

However, even if the advantages of agroecology have already been demonstrated in numerous studies (van der Ploeg et al., 2019; Wezel et al., 2014), it remains a topic which raises many questions in terms of learning, in academic institutions. When it comes to food-related and agronomic purposes, students are indeed still mostly trained to be specialized in particular fields, such as biotechnology, economics and soil sciences. However, agroecology is a notion that brings together a complex of components in interaction, such as environmental, social and economic sciences (Francis et al., 2011). Agroecology requires being taught in a different way, in order to give a more systemic view of its various components (Francis et al., 2008). As judiciously pointed to in David & Bell (2018, p. 615), the teaching of agroecology “is not only about content, it is also about process”.

Serious games are a way to satisfy the teaching requirements of agroecology because digital tools allow the simulation of complex models which allow players to develop their understanding of systems approaches (Wu & Lee, 2015). They are referred to as being entertaining tools with an education purpose. They improve the implication, the engagement and the immersion of the players, while having a fun aspect. New skills are acquired by participants who receive immediate feedback based on the choices and strategies adopted.

Accordingly, the serious game SEGAE (SErious Game for AgroEcology learning) has been developed to facilitate the teaching of agroecology, accounting for the need to convey both a systemic, as well as, an inter(trans)disciplinary perspective (De Graeuwe et al., 2020). Within the realm of the present study, the objective is to explore the relevance of using this game in short lessons of 4 hours, with a single teacher. More particularly, we make the assumption that serious games, and more precisely SEGAE, are an effective learning tool, adapted to a short lesson, for improving the agroecological knowledge of university-level students. This acquisition of knowledge should be more manifest in open-ended questions which require

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having acquired a systemic vision. A related and complementary hypothesis is that SEGAE positively contributes to knowledge acquisition through providing fun during the game session.

To determine the performance of SEGAE with respect to the education of agroecology, two types of surveys have been conducted. Firstly, to measure the acquisition of agroecological skills, a knowledge survey was proposed before and after the lesson. Secondly, to assess the student's perception of the serious game, flow theory has been mobilized (Fu et al., 2009) and used as a feedback survey. Both surveys are the replica of those used in De Graeuwe et al. (2020).

## **2. Materials and method**

The study was carried out in Belgium during March 2021. Due to the Covid-19 pandemic, all activities took place online. Students from the 3rd bachelor year, following an agricultural engineering education in four specializations (Agronomy; Chemistry; Environment and Forest) followed this lesson. In a period of 4 hours, several activities were organized (1) a theoretical class, (2) a serious game class and (3) two survey's times.

### ***2.1 Theoretical class***

Once the pre-survey was completed, a 2-hour lesson was given to introduce the theoretical notions of agroecology. This introduction contains three distinct modules which are "Soil-Plant-Ecology", "Animal" and "Socio-economic". The goal of this introduction was to give students basic knowledge of agroecology and its effects, introduce a system approach to evaluate a combination of practices on the production system and also to study different options to solve a given problem with limited resources.

### ***2.2 Serious game class***

After the theoretical class, another 2-hour lesson was given to the students. This time is dedicated to the handling of the serious game. The whole group was divided into several subgroups from 20 to 30 students, randomly mixing the different specializations. During this class, three scenarios were proposed to them, starting with a "sandbox", followed by a "system approach" and ending with an "indicator oriented" (for more information, *see De Graeuwe et al. (2020, p. 6)*). After that, a discussion about the results and limits of the serious game with the teacher followed.

### ***2.3 Survey's times***

Before starting classes, students were asked to fill a pre-survey which was divided in two sections. The first one was about the respondent's profile questions such as age, nationality and specialization of study were asked. The second one contained 15 multiple choice and 6 open-ended questions about agroecology knowledge.

In order to be able to measure the acquisition of competence, the same knowledge questions, as in the pre-survey were asked in the post-survey. Moreover, a feedback section was added to assess whether the SEGAE game was stimulating as a learning tool. It included 4 open-ended questions and 45 statements. The eight factor of EgameFlow were used to characterize the state of flow that students experienced : (1) concentration, (2) clear goal, (3) feedback, (4) challenge, (5) autonomy, (6) immersion, (7) social interaction and (8) knowledge acquisition (for more details, *see* De Graeuwe et al. (2020, p. 7)). Each flow factor was assessed with 2-5 statements. Students ranked each statement on a 4 Likert scale.

### **2.3 Analysis of survey results**

All the questionnaires were anonymized. The study included 68 students for the pre-survey and 72 for the post-survey. After data cleaning, 50 students were retained for the analysis of knowledge questions (17 from Agronomy; 6 from Chemistry; 10 from Environment; and 17 from Forest). Aberrant data was removed from the database. Students who did not answer all the open-ended questions in both surveys (even if it was required) were discarded for the knowledge section. For the flow assessment, the 72 students of the post-survey were all retained. All statistical data analyses were performed using R software v.4.2.2 (R Core Team, 2022) and a  $\alpha = 0,05$  for significance level.

Each student's pre- and post-scores were calculated and registered. For the multiple-choice questions, students received a score of 1 when they had a correct answer, 0 when they did not answer, -1 if the answer was not correct. For open-ended questions, students are given a score between 0 and 3 depending on the number of correct answers given, compared to those expected. They are given a score of -1 for each incorrect answer. The result of each question is added up to calculate the total score. The maximum score that could be reached is 39, which were converted into percentages. Final scores were used to calculate descriptive statistics (e.g. average and median). Then, a paired t-test was performed with the null hypothesis of absence of increase of the scores between the before/after the 4-hour lesson. Subsequently, the scores of each specialization were calculated and the same statistical analysis as previously described was performed.

The score for the feedback questions is calculated by converting all answers to each of the 45 statements with a scale from 1 to 4 (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree). Each flow factor score was calculated by adding up the results of all statements corresponding and divided by the number of statements included in the flow factor itself. Final flow scores were used to calculate descriptive statistics. Mean scores were calculated for the group of all students and by specialization.

### 3. Results

#### 3.1 Results of knowledge acquisition

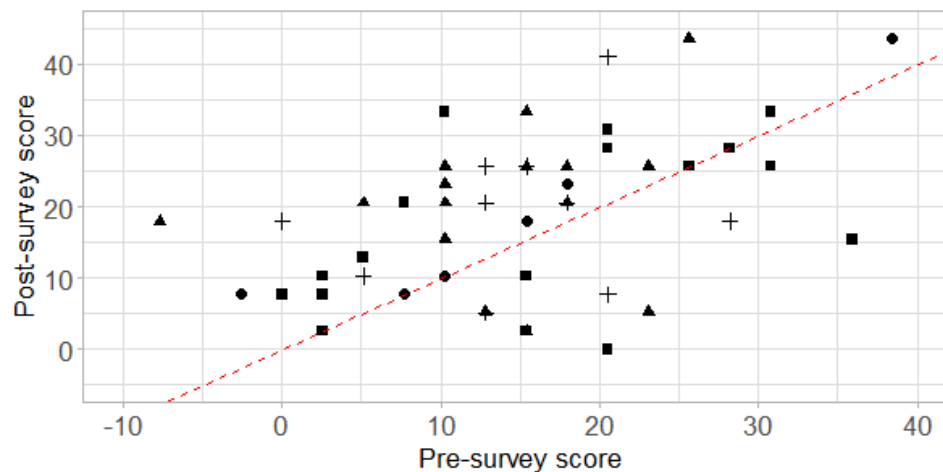
On the knowledge pre-survey, the student's general mean was 14.7 % of correct answers (Table 1). The scores differ significantly among the type of questions: Open-ended questions reached the highest scores (21.3%), while close-ended questions recorded the lowest (9%). The scores did not differ significantly among the specializations. On the knowledge post-survey, the students' general mean was significantly ( $p < 0.05$ ) higher: 18.5%. Their progression was very highly significant for open-ended questions ( $p < 0.001$ ).

**Table 1. Mean of students' scores (% of correct answers) on the knowledge survey during the pre-survey and post-survey, and the increase after the 4-hour lesson (percentage points).**

<i>Grouping of Data (and number of students)</i>	<i>Pre-Survey</i>	<i>Post-Survey</i>	<i>Increase</i>
All students	14.7	18.5	3.8*
<i>By specialization</i>			
Chemistry (6)	14.5	18.4	3.9
Forest (17)	13.4	19.1	5.7
Agronomy (17)	16.1	17.3	1.2
Environment (10)	14.6	19.2	4.6
<i>By type of questions</i>			
Close-ended questions	9	9.5	0.5
Open-ended questions	21.3	28.8	7.5***

Legend: \*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ ; no symbol  $p > 0.05$

Overall, 31 of 50 students increased their scores, 5 had the same scores, and 14 decreased their scores slightly (Figure 1).



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Figure 1. Comparison of students' mean scores on the knowledge pre- and post-surveys, by their specialization: Agronomy ■, Chemistry ●, Environmental + and Forest ▲.

### 3.2 Perception of SEGAE and its evaluation through flow

In the feedback post-survey, 83% of the students “agreed” or “strongly agreed” with the question “I enjoyed the game without feeling bored or anxious”. Therefore, the SEGAE game is globally appreciated by the students. Moreover, 91% of students “agreed” or “strongly agreed” with “The game increased my knowledge”. The eight factors have an average of 2.93 points (i.e.,  $\approx$  “agree”) out of 4 (Figure 2). The factors “social interaction” and “feedback” are rated particularly low compared to the others. For each specialization, the flow average was carried out and compared to the general mean. Only chemistry students have a slight difference with an average of around 3.25 points out of 4 (Figure 2).

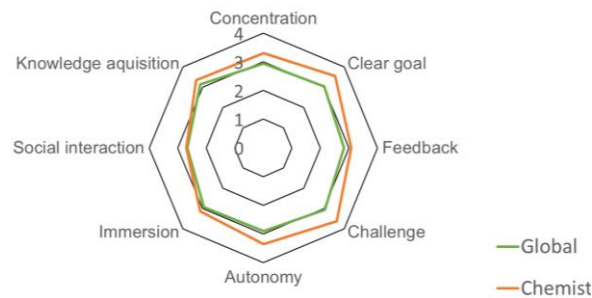


Figure 2. Radar chart on chemist mean scores for the eight flow factors compare to global mean score

## 4. Discussion and conclusion

Students significantly increased their knowledge in agroecology using the game. This result corresponds to 60% of the mean increase previously recorded for a 5-day workshop in a similar curriculum (6.4 percentage points for “multidisciplinary” *see* De Graeuwe et al. (2020, p. 13)). More particularly, students increased their performance with respect to answering open-ended questions, those which required them to analyze problems in their global context and as parts of an interconnected whole. The game thus appears to improve the ability of students to articulate their existing and newly acquired knowledge. The game makes it easier to link different knowledge by mobilizing it simultaneously. However, the metacognitive involvement of each student depends upon their profound enjoyment and concentration (i.e. a good level of ‘flow’). The results show that SEGAE provides such a context for metacognitive learning. The knowledge increase recorded in open-ended questions is assumed to reflect the increase in the meta-knowledge of students. Accordingly, following a 4-hour lesson with a single teacher seems promising in terms of learning.

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Every specialization increased their mean. The agronomy specialization has the lowest increase. Agronomy students already had knowledge about agroecology and breeding systems. Therefore, it is important to note that their scores were already higher in the pre-survey, thus reducing their possible progression in the post-survey. To the contrary, the other student groups, only had limited knowledge on the fundamentals of agroecology. Therefore, it could be argued that this limited knowledge opened the space for a greater progression, than students specialized in agronomy. Overall, the means pre- and post- surveys are extremely low; particularly for close-ended questions. Two explanations can be highlighted to explain those results.

First, the unplanned digitalization of this lesson due to covid-19 period involved poorer interactions between the students and the teacher. This is reflected in low reported level of flow factors: “social interaction” and “feedback”. Moreover, surveys were done online without any supervision, which caused problems to receive answers of these surveys on time. For further study, the response time to complete the survey could be analyzed to identify aberrant data. Also, a replica could be performed with a larger number of students to validate results found.

Secondly, low knowledge results and low levels of surveys’ submissions can be explained by the language used for the surveys. They were in English, with most of the students being francophones. As such, this may have created difficulties with comprehension of the questions and thus slowing down the progression rate in the surveys. For further study, 4 steps are recommended: (1) translate surveys in French; (2) select a 5 to 10 % of final sample size; (3) administer the questionnaire to the selected percentage and (4) assess understanding of these students about each question (Roopa & Rani, 2012, p. 276).

Concerning the feedback survey, the height factors of flow showed that students assessed the game positively. A large majority (>80%) of them reported that they enjoyed the game and felt that they increased their knowledge thanks to it. These results reinforce the use of serious games and particularly SEGAE to learn agroecology. Indeed, this game allows students to learn through an active posture which helps to overcome the knowledge-action gap. Especially as this knowledge-action gap has been demonstrated as a critical competence in learning agroecology (Østergaard et al., 2010) .

To conclude, this study confirms that the format of the game SEGAE in a 4-hour lesson with a single teacher is a relevant tool in learning agroecology. Students appreciate learning using this game. Therefore, the development of serious games is an alternative for the future of agroecology learning. As the activities took place online rather than face-to-face (as initially planned), the acquisition of agroecology knowledge might have been impacted. The same study carried out in a non-covid period would allow to determine the influence of online lesson.

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