Référence complète de la publication :

Type : Acte de colloque international avec comité de lecture

Colloque : Advances in Computer, Information, and Systems Sciences, and Engineering (CISSE) 2005, International Conference on Engineering Education, Instructional Technology, Assessment, and E-learning, on-line.

MICHELIN Y. & DÉPIGNY S., 2006. Can a game put engineering students in an active learning mode ? A first experiment in sustainable agriculture teaching. *In* "Advances in Computer, Information, and Systems Sciences, and Engineering", Proceedings of IETA 2005, TeNe 2005 and EIAE 2005, ELLEITHY K., SOBH T., MAHMOOD A., ISKANDER M. & KARIM M. (Eds.), Springer Netherlands, pp. 343-350.

Can a game put engineering students in an active learning mode? A first experiment in sustainable agriculture teaching

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***Abstract*- An experiment using educational games has been conducted in France with first year engineering students to develop their understanding of what sustainable farming is. We have devised a game that models the impact of grazing practices on landscape dynamics and compared a board version and a virtual one. The game appears to be more efficient in developing the desire to learn more and stimulating players' imagination than in teaching precise scientific knowledge. The game does not take the place of the classical courses. It introduces them. Finally, there is not any competition between the board game and the computerized one ; the board game is more relevant to start the educational process, the second allows more possibilities to experiment different ways of management.**

I. Introduction

After the Second World War, agronomists had to propose technical solutions to develop food production at the lowest price in order to feed an increasing population arriving in large cities. In Europe, they got very good results but with negative consequences on either the environment or the landscape quality. Nowadays, the society asks them to imagine new farming systems, more sustainable, at the same time profitable for farmers and able to take care of either the environment or the landscape.

A good example : the landscape management in French uplands areas

The evolution of the landscape's demand in the French Massif central provides a good illustration of the gap increasing between what people expect and what farmers do to maintain their activity, a gap that new agronomists will have to bridge.

A large part of the traditional summer grazing pastures of these mountains covered with grass and heath have disappeared from the end of the nineteenth century till the end of the twentieth century [13]. Most of them have been converted into woodlands (spruce and pine plantations, beech colonization, etc).

As a response of this evolution, the direct landscaping policies in the nineties aimed at stopping closing of the landscape. They generated few results. In fact, this major change, which was badly felt by the inhabitants, was not a voluntary landscape change but the result of five main factors, a demographic decrease in the population (landowners moved away and prefered to plant their land rather than rent it), a consequence of the national reforestation subsidy policy initiated in 1946, the disappearance of the common grazing system (Fig. 1), which was the best adapted way to give better value to these relatively poor pastures, a technical and economic improvement of agricultural systems, with a decrease in flocks that led to an abandonment of bad pastures which were not useful in these new farming systems and an ecological phenomenon of broom expansion furthered by a low stocking rate.

Fig. 1. Old shepherd and the common flock, Chaîne des Puys, 1980.

That is why it was so difficult to explain to local representatives or visitors that the best method for keeping these landscapes open was to have an economic policy that was favorable to livestock farmers. When this explanation was understood by the locals, the regional support of common flocks through the regional park action maintained enough animals to stem the expansion of broom [14].

Regarding this example, our hypothesis is that the misunderstandings between landscape producers (farmers, foresters, etc) and landscape users (inhabitants, tourists, etc) is mainly due to a lack of intelligibility.

Our students meet with the same difficulties. During the first three semesters, the courses are shared into different topics with very few links. Another difficulty comes from the academic way of teaching that starts with theoretical courses. Even if all the students in agronomy have a practical period on a farm after a one month course, they have difficulties to apply this theoretical knowledge in describing and analyzing actual situations. In front of the complexity, a simple explanation is not sufficient. Students have to "touch" the process, to see it in their mind. Later, when a systemic approach combining different kinds of information occurs, the students understand at least why we asked them to learn so many things but they have lost a part of their time and sometimes they have forgotten what they have learned before. That is why we devised starting the first semester by an explanation based on a demonstrative situation that put them in an active learning mode. For Bonwell and Eison [3], in active leraning, "*students are doing things and thinking about what they are doing*". In 1987, Stice [20] demonstrates that when learners remember only 50 % of what they see and hear, they remember 90 % of what they say as they do something. Regarding to this results, Stalheim-Smith [19] proposes the concept of meaningful learning, by putting students in small groups top create through cooperation with peers an active learning environment. But the concept of learning by doing is difficult to apply to agronomic studies because of the time needed to assess the consequences of what have been done. As the use of models allows the possibility of testing scenarios, Bareteau et al. [2] consider that it is possible to learn by simulating as well as by doing. With the same point of view, we thought that an educational game could involve the students in the educational process in an active way while giving them a clear meaning and a lively dimension of what they will have to learn before being able to apply it on actual situations.

II. Interests of a gaming process

The educational potential of the game has been known for many centuries [12]. However, this point of view was only studied and formalized in the early twentieth century. In 1958, Caillois proposed a theoretical classification based on four aims (competition, chance, mimicry and vertigo) and two attitudes (eccentric and ruled) which remain relevant to this day [4]. At the same period, Piaget [17] considered that the game theory could facilitate the teaching of social sciences, in a multidisciplinary way. More pragmatically, geography and history teachers [9] have devised many games using emulation and simulation. They have demonstrated that these attitudes offer strong possibilities on motivating pupils and students to become more active in the learning process. Similarly, these teachers consider games as useful teaching aids for helping students visualize the consequences of events decided or suffered by them during play. Simulation exercises and educational games are widely used as teaching resources in the USA and Canada [7]. However, very few techniques and methods have been developed in France especially for students of public schools [9]. One possible explanation for French teachers' mistrust is the confusion between educational and instructive games. Instructive games which are based on competition between players, are often unattractive and leave very few possibilities for involving players. On the other hand, educational games combine emulation and mimicry attitudes and create an illusion that puts players in an active mode and develops their will to learn [10].
Moreover, simulation games have been used by social workers to help poor people to express their problems and imagine solutions [8]. Today, different studies in easier social conditions are using simulation gaming. In the context of agricultural systems, Daily et al. [5] uses a software (GRASSGRO) to help students developing an appreciation of the interrelationships between soil, pasture growth and animal production. However, it is more a decision support program than a game. Except the MEJAN JEU, used in landscape planning to generate a discussion between farmers and stakeholders about the best way of managing the landscape of the Causse Méjan [6], very few techniques of gaming are used with students. Etienne *et al* consider the computerized version of the game as a very efficient tool for involving local actors. However, as it removes a material part of the representations, the same result may not be reproduced elsewhere. Thus, we preferred to start our experimentation using a concrete game with a board and 3D checkers, the SHRUB BATTLE before computerizing it (the GENIX software presented below).

III. Description of the shrub battle game

A. Principles

The major educational goal of this game is to better understand the making of the landscape. Its gaming objective is the competition for land cover. We built the SHRUB BATTLE like a model by adapting the results of studies carried out by our colleagues describing the vegetation development as the consequence of livestock farming practices [15, 16]. We also took advantage of our own experience in farming system management [14] to identify socioeconomic events that could influence farmers' decisions. This represents a very complex system, combining different space-related factors (plant station, agricultural field, landscape point of view, etc) with different time-related factors (immediate decision and action, the farming year, ecological processes, etc). We decided to make a semi-realistic model and we defined simple, understandable and clear rules, less complex than in the actual world. On the other hand, we included recreational aspects into the model to make the game funny. Thus, we imagined an original situation: the plants can directly interfere in the decision process!

B. Concepts

The game is based on three main concepts that are linked in a global system (Fig. 2) :

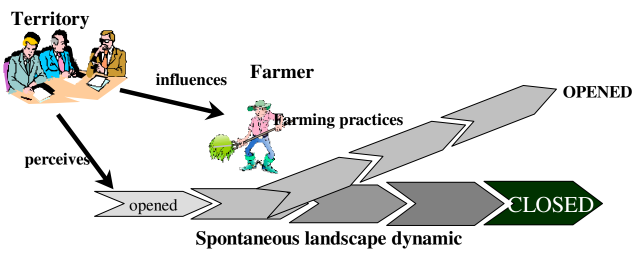


Fig. 2. The three scale levels of the game

- ***Natural vegetation expansion*** is determined by ecological rules.

Each species has a specific power of invasion that depends on their reproduction system (sexual or vegetative), their way of colonizing new areas (by spreading moving or heavy seeds, by producing rhizomes…), the time they need before being mature. We chose three representative plants of the Massif central uplands areas. In the game, each species has its own type of spreading and a specific color:

- *Rubus caesius* or Blackberry bramble expands by vegetative reproduction: it needs at least one full-grown plant to create a progressively larger patch. We chose this plant because it is highly resistant to farmers' practices.
- *Cytisus scoparius* or Broom often appears on abandoned plots due to significant seed supply in the soil. It expands by random and abundant germination: it can appear anywhere without a full-grown plant, and can quickly create landscape patterns. We chose this plant in relation to several questions asked to both farmers and researchers. Broom has got a short lifespan (about 15 years before natural degeneration) but its very high seed supply gives it significant germination capacities as soon as agricultural fields are left unused [16].
- *Pinus sylvestris* or Pine tree represents the woody stratum, the last stage of vegetation development. It produces seeds around itself, with a distribution proportional to distance [18]. Like blackberry it needs full-grown plant to colonize land.

- ***the farmers' practices*** modify the vegetation growth by limiting the shrub and trees expansion. Farmers have three different types of management: grazing practices that eliminate young plants and permit animals to increase their weight. Their landscape impact is seen only several years later, depending on the agricultural management system (under-stocking grazing, field intensification, etc…). Clearing practices (burning or crushing undesirable plants) and agronomic investments (fences and fertilizers) have an immediate impact on the landscape.

- ***natural and socio-economic events*** interfere with the farmers' decisions and the vegetation growth with favorable or unfavorable consequences for each player. The game offers two kinds of events. The socio-economical events can be compulsory (a law), inciting (subsidies, price levels) or negotiated (agro-environmental agreement). Natural events are unpredictable: climatic events can modify the vegetation dynamics, pest or disease attacks on herds can lead farmers to change their farming management system, etc.

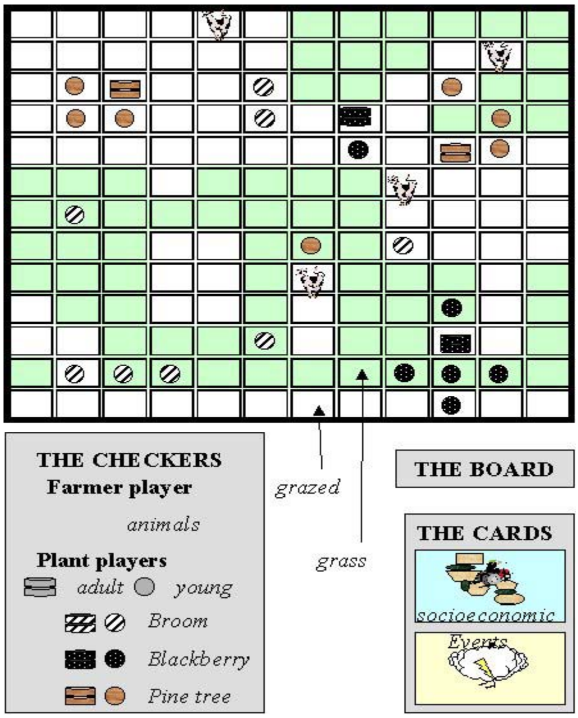
C. Game structure and components

The SHRUB BATTLE is a board game shown by Fig. 3.

The playing board represents a small part of an agricultural field patterns. It is split into 144 small plots, representing decision units for farmers or plants. Each plot's status is characterized by a color (grass, fertilized grass, grazed grass, protected area, moorland area or woodland area). Small wooden checkers on the playing board mark the players' position. Each player has particular tools, which always combine three important components:

- Determinist behavior model, extracted from research studies.
- Unpredictable events, generated by a dice or draw cards.
- Player strategy: Each plant player can colonize the board with the combination of a toss of the dice (when the dice gives from 1 to 4) and a rules table, which represent spread types and germination capacities. For example, blackberry cannot spread itself without one adult plant, which can produce new plantlets while broom can appear anywhere. An originality of the SHRUB BATTLE game is that the plant

Fig. 3. A view of the play board, the pawns and the players



players have human decision-making potential. This property provided a way to represent ecological trusts, which try to protect the interests of Nature against human pressure. The fourth player represents a livestock farmer. The player is alone against nature, its main objective being to protect its grass field against plants invasion particularly from broom. The player does it by combining two activities : i) earning money from production practices: where their small herd (four or five animals) can graze and produce beef, and ii) spending money via clearing practices such as the slash-and-burn technique, fertilization, enclosure and clearing.

The last components of the game are cards. These cards represent two types of possible events. The first type lists several events that are dependent on the socioeconomic context (compulsory policies, the wishes of trusts, markets laws, etc.). The second type lists several unpredictable events (frost, drought, pests and diseases, etc.). When the dice gives a 5, the player takes an EVENT card and has to apply it, even if the result is bad for him. If the dice gives a 6, the player can choose to apply a socioeconomic event. If he prefers, he plays as if the dice gave a 4.

A game covers a six-year period. One year is finished when each player has played six times. Players have to record many parameters through a game: numbers of plants, events, farmers practices, etc. These data are used to build graphs, which can be used to compare the results from one game to another to show the different methods of livestock farming management or land management.

D. First results

After about ten experiments with various people, agronomy students[1] (250), countryside planning students[2] (300), agricultural researchers and technical experts (20) and farmers (2), we noticed a very good sensitive involvement. Each player was strongly involved in the game. Players quickly picked up an identification with a plant or an animal, and lived through the making of the landscape. This may have been partly due to the fact that the 'virtual' situation presents no risk for the player who can experience many possibilities and evaluate the results in a short time. A large majority of players were enthusiastic about the game, especially younger people untrained in agronomic principles. During one presentation with 94 students playing in 20 groups, we conducted a short survey to evaluate the impact of the game on their level of knowledge and comprehension of agri-environmental landscape management. We asked the same questions before and after the game. We did observe a better understanding of the impact of grazing management on protected plants. Before gaming, 70% of students thought that forbidding grazing on dry pasture could eliminate the orchids, compared to 83% after gaming. The best progression results were recorded for people who came from towns and urban areas. However, farmers' children did not change their opinion. The last question concerned the impact of fencing on vegetation dynamics. 25% changed their opinion during the game, but only 30% proposed a correct answer. Two factors can explain this moderate result. First, the question was too complicated to be well understood. Second, several groups did not use fences during the game, and so could not appreciate the result.

This short overview shows that SHRUB BATTLE can be considered as an attractive game for players. Despite the many simplifications, it produces a result that is not too far from reality. We think that this good result is due to an homogenous level of simplification and to the care taken to define the events and the relationships between factors. Only a few engineering students considered that the game was not serious enough for a course. Another slightly negative point came from certain agronomists or agricultural technicians who were well-trained in grazing management. They considered the game as too simplistic and took time to discuss the rules despite taking part in the game. However, if the game is funny to play, it has some educational limits. One is due to the fuzzy rules, specially those concerning the plants, because the randomization is difficult to obtain by hand. Another limit is a consequence of the time needed to register the different data during the play. In a three-hours period, it is only possible to play one time and many events don't occur and a part of the understanding of the processes is missed.

That is why we decided to computerize it. Both games have advantages and inconvenient that will be discussed in the last part.

IV. DESCRIPTION OF THE GENIX GAME

The principle of the GENIX game is a bit different from the board game's. Even if the rules are globally the same, it is not presented the same way.

Indeed, there is only one human player, the farmer, fighting against the plants, simulated by the computer. One can consider the GENIX game as a landscape maker simulator.

A. Technical aspects

From a technical aspect, there are two points to consider : the global structure and the execution progress.

To determine the best structure of the game, we had to identify all its components, their behaviours and actions, and the link they have with the others. Once the components identified, with their own role and actions, it was possible to fix the structure, that is an object one. We used the UML language to show as precisely as possible the objet structure of the game. In the state diagram (Fig. 4), classes have been

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[1] Students of ENITA of Clermont-Ferrand. It is an Engineering National College of Higher Education Specialized in agricultural techniques. We use SHRUB BATTLE to introduce all the concepts, which can be tackled during the three years of the agronomic learning process.

[2] Students of ENGEES of Strasbourg. It is an Engineering National College of Higher Education Specialized in water and environment management. We use SHRUB BATTLE to show negotiation process and to explain agricultural points of view in rural area management.

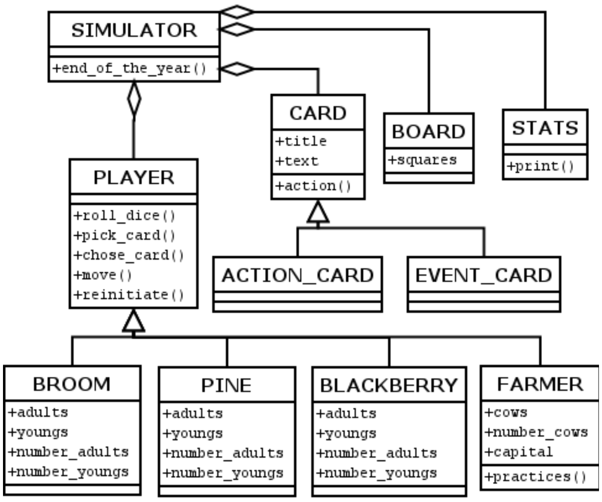

Fig. 4. State diagram of GENIX

created to represent the game, the players and the elements that make up the game, like the board or the cards. Each player can do the same kind of action like tossing the dice, picking a card, moving animals ... that is why there is a mother class that gathers all these actions. As each player has his own way to do these actions, each class reimplements them.

The simulator manages the game progress on the whole. It allows each player to play. It proposes choices to the farmer (practices or pasture). It reinitiates the board at the end of the year. It manages the statistics.
This game is a sequential, not an evenemential one. Each player plays one after the other. The simulator only stops when it waits for the farmer's action. From a dynamic point of view, the game progress is simple. It consists in two loops, one including the other. The first one, managing the years, embraces the months loop and the processing at the end of the year. The second loop, the months one, manages each player turn.

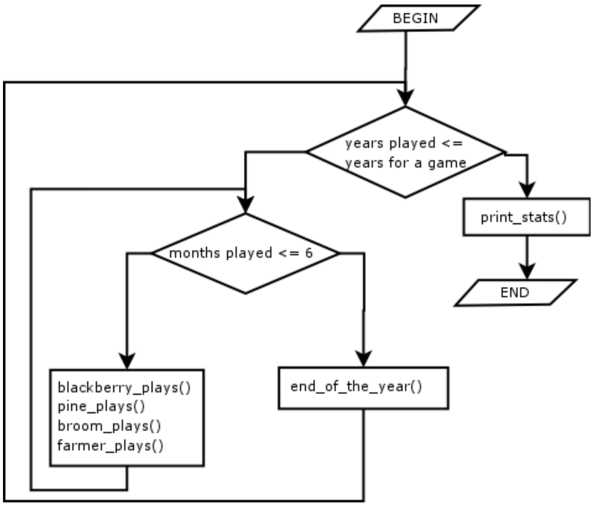

Fig. 5. Game process algorithm

The main difficulty lies in the fact that there are a lot of events that can happen and cumulate. For instance, a small plot can have different states and occupants. A square can be grassy, empty, fertilized, burnt or crushed. But at the same time, a plant, young or adult, a cow or a cow and a plant can be present on it. Moreover, the square can have a caps or a flower on it. So when an event appears, like fire, pasture ... all these aspects have to be taken into account to decide how the state and the occupants of the square will be modified.

B. Physical aspects

To obtain a user-friendly game, we decided to limit the resort to the keyboard. Indeed, the mouse is easier to use than the keyboard. Moreover, we wanted the graphical interface to be attractive, simple to play and understandable, and efficient too. Thus, the game window has been divided in two parts. The first one is the board, with all the 144 squares which compose it. It looks like the board game with more beautiful pictures. The second part of the window recapitulates the main information about the game : which year and month it is, the level of the farmer's capital, etc. It also shows the information about the present month and the available choices.

We developed this game with Linux and the development tools provided with this system, like GCC. As very few persons are using Linux, we decided to integrate this game to a live-CD saving players from installing anything. The environment is loaded in memory, so the game can be used everywhere, if the computer has enough memory.
This live-CD was elaborated from a Knoppix distribution, lightened in order to reduce the loading time. We added the game, with a script to launch it after the boot, and also 'openoffice' and a macro to generate the statistics at the end of the game. All these elements allow the game to work independently from the computer. One play simulating a six-years grazing period takes around half an hour.

Fig. 6. GENIX game

The first version of the GENIX software is not yet customized. We have preferred to work on the simulator before spending time to make it more pleasant. However, we recently started a test with several students who have played SHRUB BATTLE, to better know which game they prefer and why. The first players consider that GENIX is as efficient as the SHRUB BATTLE to enlighten the relationship between farmers' practices and landscape evolution. They find the software version easy to use and quicker. They proposed several improvements (on line documentation, sounds and music, short presentation when the game starts, another window indicating which events are active…).

V. Discussion

Without mentioning about the lack of user-friendliness, we noticed some problems with the GENIX game. As it is a one-player game, it is difficult to use it with large groups. A part of the originality of the game (100 students playing at the same time in the same place) is lost. Another limit is due to the disappearance of concrete elements like pawns or small animals. The last problem comes from the speed of the game. A great deal of information arrive at the same time without any explanation and discussion, and the player could be lost at the beginning. In fact, this game is perceived by students a bit less funny and less original than SHRUB BATTLE. We think it is possible to solve these problems by developing a nice environment with more realistic pictures and by adding sounds, commentaries, or short videos.

However, the computerized game offers new opportunities. First, while the SHRUB BATTLE play-board needed a large table for each board and was difficult to transport, the GENIX software is an 'autorun CD', easy to transport and to duplicate. It is well adapted to small groups and to students who want to take time to play at their own speed. It takes less time to play and, as the data are automatically registered and converted into graphs, it allows new possibilities of analysis.

Secondly, during the computing process, we discovered some inaccuracies in the rules and some situations we had not considered before, so we had to modify the organization of the play. The passage from the board game to the computerized one helped us to think back of the processes that we wanted to explain by gaming. As a result, it has strengthened our understanding of the system modeled by the game.

Thirdly, the attitude of the students is rather different in front of the board than in front of the screen. When they play together with large groups, with pawns and small cows, they change their attitude. They become more active and then start to think differently. However, they do not gain a precise agronomic knowledge. They only discover that the different topics they will have to learn could be linked and crossed to answer practical questions. Alone or in small groups in front of a screen, they quickly start to experiment different grazing management systems. They still remain in an active learning mode but they go deeper in the process, they ask questions and try to imagine solutions. Of course, this attitude is only possible if they have first played the SHRUB BATTLE.

It is a great paradox to consider that while the game has become less concrete in its appearance, it is closer to the reality and explain it better. What the game has lost in gaming value was won in educational power. That is why we consider the board game as a tool for stimulating the curiosity of students early in their studies. The computerized game does not replace the board game, it extends it by allowing the player to experiment different systems of management that conciliate environmental dimensions and landscape projects with a satisfactory level of cattle production.

CONCLUSION

This short overview shows that a game can be used with engineering students who starts their studies. However, the game is sometimes felt as too childish so we had to give a scientific course before starting the play. This introduction, carried out in an academic way, presented a survey of the theoretical background and established a link with our research activity. This fact demonstrates that the game does not produce an educational result if it is not combined with a presentation of the context and the rules before gaming and a debriefing session after. The educational ability of the game manager is one of the most important keys to the success of the game, since explanations given while recording analyses may help to overcome misunderstandings. The game appears to be more efficient in developing the desire to learn more and stimulating players' imagination than in teaching precise scientific knowledge. We think that the game does not take the place of the classical courses. It introduces them in a constructivist way of teaching [1]. It could also be used to help students develop a more holistic, systemic vision than the basic education taught in secondary schools. Finally, there is not any competition between the board game and the computerized one. The concrete game is the first step of the educational process. It "opens the eyes". The virtual one allows students to access a second level : the experimentation of different landscape and grazing management systems. The third step is to go deeper into the subject during the courses. At this moment, a more realistic tool is needed, in order to maintain users interest, as it has been noticed by Hyltander with surgeon students, learning laparoscopy technique with a simulator [11]. At least, the practical period in a farm gives the students the opportunity to use the concrete situation of the farm where they stay to combine what they learn to better understand the farming system and its impact on the environment.

We propose two perspectives for future development. Firstly, assessment tools inquiries should be developed using short surveys to provide insight into what these games actually teach or not. A second way is to customize the computer version in order to propose a more attractive framework for this game.

ACKNOWLEDGMENT

The authors thank Jacques Verdier and Jacques Virmont for their help and the ENITA students Julien Coquillou, David Liautard, Mathieu Orth, Antoine Reulier for the time they spent to test the GENIX ver1.1.

REFERENCES

[1] Barker, S. (2002). Virtual learning environments for constructivist teaching in Biosciences to promote sustainable development in higher education, CAL-laborate, volume 8, june 2002, <http://science.uniserve.edu.au/pubs/callab/vol8/barker.html>

[2] Barreteau, O., LePage, C., D'Aquino, P. (2003). Role-playing games, Models and Negociation Processes, *Journal of Artificial Societies and Social Simulation*, vol. 6, No. 2, <HTTP://jasss.soc.surrey.uk/6/2/10.html>

[3] Bonwell, C., Eison, J.A., (1991). *Active learning : Creating excitement in the classroom*, ASHE-ERIC Higher Educaton Report No. 1., Washington, D.C.: The George Washington University, center for Faculty Evaluation and Developement.

[4] Callois, R., (1967). Les jeux et les hommes. Paris, Gallimard.

[5] Daily, H.G., Hinch, G.N., Scott, J.M., Nolan, J.V. (2000). The use of decision support program to facilitate the teaching of biological principles in the context of agricultural systems, TEDI conferences: Effective teaching and learning at university, Brisbane, the University of Queensland.

[6] Etienne, M., Le Page, C., Cohen, M., (2003). A step-by-step Approach to Building Land Management Scenarios Based on Multiple Viewpoints on Multi-agent System Simulations, . *Journal of Artificial Societies and Social Simulation*, vol. 6, No. 2, <HTTP://jasss.soc.surrey.uk/6/2/2.html>.

[7] François, P., (2001). La nature dans les jeux pédagogiques. *Géographes associés*, n°25.

[8] Freire, P., (1972). Pedagogy of the Oppressed. London, Penguin.

[9] Glemarec, R., Hochet, Y., Joffrion, Y., Sestier, D., (2004). Petite classification des jeux. Ludus network. [*online*] URL :http://www.discip.crdp.ac-cen.fr/histgeo/ludus/classification.html

[10] Grataloup, C., (1994). L'espace de la transition. Essai de géohistoire chorématique. Le laboratoire des jeux. Livre III, Thèse inédite.

[11] Hyltander, A., (2003). Simulation as a teaching alternative : Utopia or reality ?, CAL-laborate, volume 10, june 2003, <http://science.uniserve.edu.au/pubs/callab/vol10/hyltand.html>

[12] Mauriras-Bousquet, M., (1984). Théorie et pratique ludiques. Economica.

[13] Michelin, Y., (1995). Les jardins de Vulcain. Paysages d'hier, d'aujourd'hui et de demain dans la chaîne des Puys. Maison des Sciences de l'Homme.

[14] Michelin, Y., (1997). Gestion concertée du domaine pastoral: l'exemple des parcs régionaux auvergnats. Les parcs naturels, un concept de développement territorialisé et environnemental à l'épreuve du temps. Bulletin de la société languedocienne de géographie, 123-139.

[15] Orth, D., Chevillot, B., Teuma, M., Dulphy, J. P., Carrere, P., Michelin, Y., (2002). Combining multiple land use with shrub invasion management. *European Grassland Federation*, vol. 7, 1062-1063.

[16] Orth, D., Picon-Cochard, C., Prévosto, B., (2003). Dynamique d'invasion par des petits ligneux de prairies sous-exploitées de moyenne montagne du Massif Central : le cas du genêt à balai. Rapport final, Enitac Inra Cemagref.

[17] Piaget J., (1970). Psychologie et Epistémologie, Paris, Denoël

[18] Prevosto, B., Hill, D. R. C., Coquillard P., (2003). Individual-based modelling of Pinus sylvestris invasion after grazing abandonment in French Massif Central. *Plant Ecology*, vol. 168, 121-137.

[19] Stalheim-Smith, A., (1998). Focusing on active, meaningful learning, IDEA paper, No. 34, IDEA center, Kansas State University

[20] Stice, J.E. (1987). Using Kolb's learning cycle to improve student learning, *Engineering Education*, 77(5), 291-296.