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ORIGINAL ARTICLE

FARMTASIA: an online game-based learning environment based on the VISOLE pedagogy

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Abstract Virtual interactive student-oriented learning environment (VISOLE) is a game-based constructivist pedagogical approach that encompasses the creation of an online interactive world modeled upon a set of interdisciplinary domains, in which students participate as "citizens" to take part cooperatively and competitively in shaping the development of the virtual world as a means to construct their knowledge and skills. FARMTASIA is the first online game designed using the VISOLE philosophy, encompassing the subject areas of biology, government, economics, technology, production system and natural environment. The "virtual world" deployed is a farming system covering the domains of cultivation, horticulture and pasturage, situated in a competitive economy governed by good public policies. The design and implementation of FARMTASIA pursue three vital principles. The first one is to make the game as realistic as possible so that students can learn in a near-real life environment; the second one is to inject motivational elements so that students can sustain to learn and acquire various knowledge and skills with the game; and the third one is to make easy for teachers to conduct various VISOLE facilitation tasks. According to our exploratory educational study, we show evidentially that positive perceptions and an advancement of subject-specific and interdisciplinary knowledge appeared among the students who participated in VISOLE learning with FARMTASIA.

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1 Introduction

Since the widespread of the Internet and world wide web (WWW) in the early 90s, "learning online" has been commonly viewed as a mechanism for empowering improved learning outcomes, increased flexibility of aligning learners' needs, and better quality of educational interactions. While the full availability of WWW technology and online "educational" resources are in place, educators have to be very cautious in interpreting this as a corresponding increase in ability to enable an educational paradigm shift to take place as those approaches and resources may just continue to perpetuate the teacher-centred paradigm, rather than the student-centred paradigm.

Lee and Lee (2001) delineate the deficiencies of most existing online learning approaches in exploiting the full potential of the pervasive Internet technology. Most existing online learning systems have just been used as a repository of "digitized" educational materials, without taking the versatile advantages of the immense power of WWW. They propose virtual interactive student-oriented learning environment (VISOLE), an online game-based constructivist pedagogy, and, together with their research team, have been conducting various research and development work in this area (Chiu et al. 2005; Jong et al. 2006a, b; Luk et al. 2006; Shang et al. 2005).

Briefly speaking, the VISOLE approach encompasses the creation of an online interactive world modeled upon a set of interdisciplinary domains, in which students participate as "citizens" to take part in shaping the development of this virtual world. With teachers' facilitation *(scaffolding and*

debriefing) and a sophisticated multi-learner game-play simulation context, the students are empowered to cooperatively and competitively learn from their near real-life experiences in the virtual world (the game), and finally construct knowledge and skills by their own. With a working group composed of pedagogical, subject-domain, instructional-design and technological experts, and under a 3-year-long design and implementation stage, FARMTASIA (http://www.farmtasia.com) is the first VISOLE online game-based enviroment that has been developed. It involves the subject domains of biology, government, economics, technology, production system and natural environment, while the "virtual world" deployed is a farming system. Distinguished features of FARMTASIA include realistic simulation models developed with the help of subject domain experts, mini-games, interaction among players, virtual synchronization of asynchronous game play, and full logging of user behavior to facilitate case studies and analyses sessions. This paper aims to describe the design and implementation of FARMTASIA, and present the learning outcomes and perceptions of a group of secondary school students who have learnt with this game.

The rest of the paper is organized as follows. In Sect. 2, we give an overview of the VISOLE approach to online learning. Sect. 3 describes the designed features of FARMTASIA based on the VISOLE principles, followed by an exposition of the implementation technologies employed for the game in Sec. 4. In Sect. 5, we report on an exploratory study of the deployment of FARMTASIA. Sect. 6 concludes our contributions and shed light on future directions of research.

2 A closer look on VISOLE

VISOLE is a three-phase pedagogical approach with a combination of ***Multi-disciplinary Scaffolding*** *(Phase 1)*, ***Online Game-based Learning*** *(Phase 2)* and ***Just-in-time and Summative Debriefing*** *(Phase 3).* A diagrammatic illustration of the full VISOLE process is shown in Fig. 1.

Phase 1 is for VISOLE teacher(s) to act as cognitive coaches in a conventional classroom setting to activate

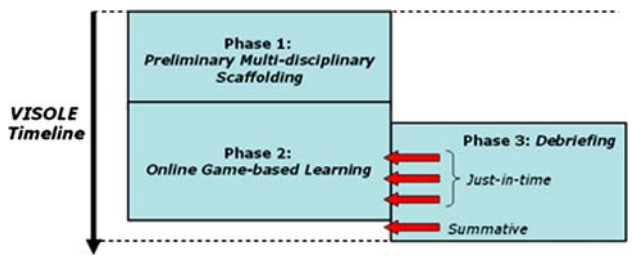


Fig. 1 The VISOLE process

VISOLE students' learning motive and scaffold (Graesser et al. 1997; Lepper et al. 1997; Roehler and Cantlon 1997) them with high-level knowledge of the multi-disciplinary subject areas. Students are given general knowledge without reference to the subject matters and also pointers to possible information sources, just enough so that the students are able to further pursue the knowledge on their own. The main goal of this phase is to encourage and guide student participants to become independent learners who can benefit from the rich repertoire of information in the Internet. The scaffolding stage prepares the students for the upcoming learning phases.

Phase 2 deploys an online multi-player interactive game portraying a virtual world. The scenarios therein become the dominant motivator driving students to go on to explore the interrelated nature of the multi-disciplinary understandings encountered in Phase 1. It encompasses the creation of a virtual interactive world in which the students are divided into groups to participate as "citizens" who take part in shaping the development of this world for a period of time. All tasks therein are generative and open-ended with neither prescribed strategy nor solution. Since every single action can affect the whole virtual world, students have to take into account the overall effects associated with their strategies and decisions to others. Therefore, it is expected that the students not only can learn the subject-specific knowledge in an interdisciplinary fashion, but also the skills of problem analysis, strategy composition and decision making etc. The purpose of Phase 2 is to allow (interdisciplinary) knowledge assimilate and to prompt needs for further learning using online materials from various sources, including the Internet. This is also a form of training of global views and visions. Competitive elements in the game design can usually enhance the playability of the game and reinforce immersive participation.

Part of Phase 3 interleaves with activities in Phase 2. In this phase, the teacher(s) closely monitor the progress of the students' development of the virtual world in the backend, and look for and try to act on "debriefable" moments to "lift" the students out of particular situations in the game and empower them to reflect and generalize their gained knowledge and skills, that is, to transform their game-play experiences into learning experiences. Respectively during and at the end of this phase, the teacher(s) extract problematic and critical scenarios arisen in the virtual world, and then conduct just-in-time and summative case studies with the students by arranging some face-to-face class meetings, namely, debriefing sessions. At the end of each gaming session in Phase 2, students are also required to work on worksheets and write a reflection journal to internalize their learning experience. This is a means to keep track of student progress and for evaluation.

VISOLE supplements but does *not* replace classroom teaching. It supports multi- and interdisciplinary learning. A well-implemented computer gaming environment should be fully automated to support realistic simulations and case studies with complex user-interactions. In this sense, a VISOLE online game is a virtual reality environment, providing student players a first hand *immersion* experience in a near-real virtual world. Teachers do not deliver knowledge directly and play more of a facilitator role. Students learn through the gaming activities, self-exploration of knowledge from various information sources, and the debriefing sessions and the reflection activities. The VISOLE pedagogy enhances training of high order skills, and global views and visions.

Fig. 2 The game-play interface of FARMTASIA (*A*) Cropland (*B*) Orchard (*C*) Rangeland (*D*) Wise Genie

3 The first VISOLE game: FARMTASIA

FARMTASIA is the first online game, which is strictly followed the pedagogical philosophy of VISOLE. It involves the subject areas of biology, government, economics, technology, production system and natural environment, while the "virtual world" deployed is a farming system covering the domains of cultivation, horticulture and pasturage. In this game, every student (*hereafter interchangeable with the term "player"*) acts as a "farm manager" to individually run a farm, which is composed of a cropland, an orchard as well as a rangeland. Each of them competes for financial gain and reputation with other three "farm managers" (players) who are also at the same time running their own farm somewhere nearby in the virtual world. Throughout the game-play period (around 2 weeks), the players have to formulate various investment and operational strategies to output both high quality and quantity farm products to the market in order to make money. Nevertheless, the richest may not be the final winner, as the final reputation of the players in the virtual world, governed by good public policies, is also a vital and critical judging criterion, which is determined upon their practices on sustainable development and environmental protection.

As in real-life, the players can easily fall into dilemmas in this virtual world, for examples, buying machineries will increase the operational cost of the farm but may boost the quantity of the farm outputs, or keeping more livestock will increase the daily cost of the farm but livestock's excrement can be used as a sort of organic fertilizer for nurturing the cropland and the orchard that achieves the goal of sustainable development. On the other hand, they have to always keep an eye on the context (temperature and rainfall etc.) in the virtual world in order to make just-in-time actions, such as cultivate and reap crops at suitable time, and schedule tasks for the farm workers to conduct fertilization, irrigation and grazing etc. Nevertheless, hard work does not guarantee rewards, and sagacity may not come along with fortune. Catastrophes from the nature and disasters caused by other players can ruin one's achievement in a single day. Fortunately, "Wise Genie", one of the game characters who will occasionally appear in the virtual world to give some advice or hints to the players in some critical moments. Figure 2 shows the game-play interface of FARMTASIA.

The design of FARMTASIA follows three vital principles. The first one is to make the game as realistic as possible so that players can learn in a near-real life environment that enables situated learning (Lave and Wenger 1991) to occur. The second one is to inject challenge, curiosity, control, fantasy, competition, cooperation and recognition elements to arouse the players' intrinsic motivation (Malone 1980) so that they will go on to constructively learn and acquire various knowledge and skills with the game. The third one is to make easy for teacher(s) to conduct various VISOLE facilitation tasks.

3.1 Special game-play design and features in FARMTASIA

3.1.1 Scientific models

All of the game contexts are based on real data simulation articulating with sophisticated scientific models developed with the help of domain experts. The geographical model is in charge of four-seasoned climate, which alternates temperature, rainfall, wind-speed and humidity against a year in the virtual world (see Fig. 3).

On the other hand, both botanical and biological models are adopted in simulating how the crops and livestock evolve in the game. Therefore, in the virtual

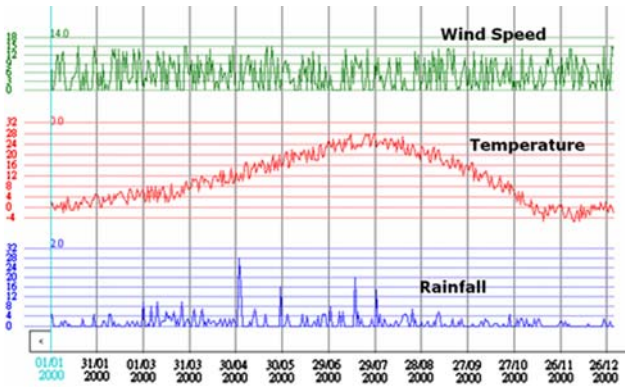


Fig. 3 Wind-speed, temperature and rainfall against 12 Months

world the players will experience how their crops sprout, flourish and languish, and witness how their livestock grow and propagate their offsprings, etc. Figure 4 shows some crops' sowing-harvest relationship in terms of time. Last but not least, an economic model is also adopted to deal with the exchange of toils, farm products and revenues in the game.

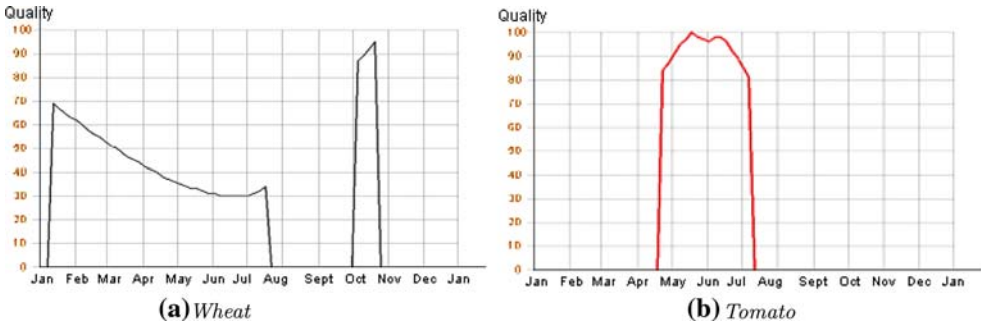
3.1.2 Events

In order to offer more chances for the players to sharpen their skills on dealing with contingency and emergency, sudden events will randomly happen in the virtual world, and they can be categorized into three genres (some examples are shown in Fig. 5):

Farm events These events only happen in respective farms and they will not cause any interfarm consequential effect within the virtual world, for instances, fire accidents, workers' strikes, and invitations of debiting bank loan, etc.

Market events These events happen either in the local or global markets and they will cause consequential effects on all farms in the virtual world, for instances, market-price fluctuations on farm products, and outbreaks of bovine spongiform encephalopathy (mad-cow disease) etc.

Mass-decision events These events involve cooperation and collaboration among all players and they will cause interactive effects on the virtual world, for instances, raising funds to build a dam, and accusing an entrepreneur



(a) *Wheat* **(b)** *Tomato*

Fig. 4 Sowing-harvest relationship against 12 Months. **a** Wheat. **b** Tomato

(a) *Do you need money for investing your farm?* **(b)** *Market-price fluctuation on farm products*

Fig. 5 Sudden events in FARMTASIA. **a** Do you need money for investing your farm? **b** Market-price fluctuation on farm products

Fig. 6 Examples of mini-games. **a** Driving out intruding wolfs. **b** Scare-crowing birds. **c** Cropping corrupted apples

(a) *Driving out intruding wolfs* **(b)** *Scare-crowing bird* **(c)** *Cropping corrupted apples*

of a plastic industry whose factories pollute the water sources, etc.

3.1.3 Mini-games

Besides the main game, players will be assigned to play selected stand-alone mini-games. The theme of the mini-game series is according to the routine but vital activities that have to be conducted in a real-life farm (see Fig. 6 for some examples).

The mini-games serve for two main purposes. The first one is to make FARMTASIA to be more fun, pleasurable and challenging; the second one is that the players' performance in the mini-games will contribute to how well the relevant activities are carried out in their own farm. In other words, players who perform well in the mini-games will be credited with better overall managerial and financial abilities in the virtual world.

Mini-games are competitive in nature, in which players compete for better scores. After each mini-game competition, an interactive event affecting all players will be generated. Examples can be the scenario that one player will have dumped some toxic wastes into the river stream so that all other players suffer from such pollution. Of course, the offending player will lose reputation because of the unethical act. When such an event is generated, details of the event, such as who the respective "unethical" player is and the amount of pollution, are determined by the results of the mini-game competition. This feature injects some randomness and reality into the gaming environment.

In fact, it is unrealistic to make every player access FARMTASIA and play exactly at the same time on the Internet. We create an illusion of real-time multi-player competitions by allowing asynchronous game-play. Each player can play the mini-games on their own, which are usually tests of speeds and accuracy. The game server logs the details of the players' actions and results of game-play for every player. The next time a user logs on to the system, the user will be shown a replay of all users' game-plays on the same console (see Fig. 7).

Fig. 7 Mini-game competition in a "synchronous" manner

3.1.4 Game-play control

Simplicity is the guiding principle in the game control design of FARMTASIA. We adopt the method used in most real-time strategic war game by allowing the players to control more than one character (e.g., farm workers and cows etc.) in a select-and-go manner.

To move one or more characters, the players have to select the character(s) first. This can be done by either clicking on one targeted character, or by dragging a region around the group of targeted characters. After selection, another mouse-click can command the selected characters to perform specific actions, like asking the farm workers to conduct fertilization, irrigation and grazing etc.

The mini-games' control conserves the same principle. All mini-games require only one mouse button or no more than three keyboard buttons, allowing the players to enjoy the games with intuitive and simple control.

3.2 Teacher console in FARMTASIA

As stressed in Sect. 2, teacher(s) play a vital role in the VISOLE process. In FARMTASIA, a specifically designed teacher console is implemented to empower the teacher(s) to conduct various VISOLE facilitation tasks.

While the students (players) proceed to run their farm in FARMTASIA, the game server logs every single action of the players. Afterwards, the VISOLE teacher can view the proceedings of each student in the virtual world by making use of the teacher console which re-transforms the game-play logging stored in the game server into students' game-play histories and presents them in Gantt chart format, see Fig. 8a. By clicking on the "blocks" appeared in the Gantt chart, the teacher can entirely replay all students' actions in the game even in the form of "video" playback, see Fig. 8b. This feature enables teachers to conduct debriefing sessions in which he/she can extract complex, problematic and critical scenarios arisen in FARMTASIA for case studies, and discuss the constructive and destructive occurrences and corresponding enhancement and corrective actions with the students with VCR-like playback functions. In particular, it is extremely useful to perform what-if analysis to help them understand the different possible outcomes.

Besides the "Sudden Events" (mentioned in Sect. 3.1), through the teacher console, the teacher(s) can also inject "artificial" catastrophes (such as twister and tsunami, see Fig. 9) into the virtual world so as to test the students' capability in dealing with contingency and emergency.

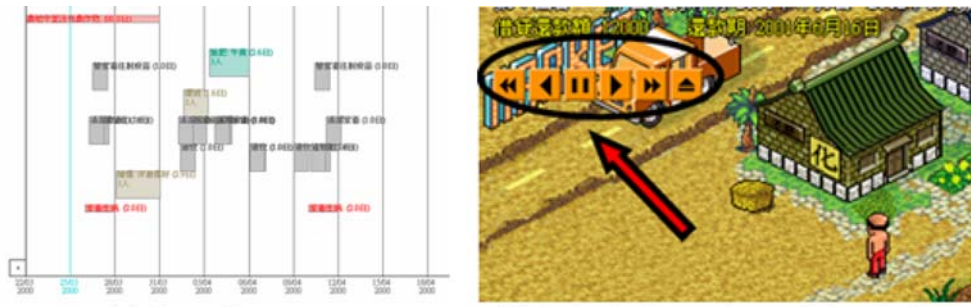
4 Implementation

FARMTASIA is built upon the Java technology (Sun Microsystems and Inc. 2006). With a java virtual machine (JVM) enabled browser (which is very common nowadays), players can get anytime-anywhere access to the game, without any extra installation. On top of that, various implementation strategies are adopted to develop the game.

4.1 Game characters

Characters are definitely important elements in any computer games. Good design of game characters can certainly help the success of that game. Figure 10 shows some FARMTASIA characters.

In FARMTASIA, each game character is represented by an object, and different forms (i.e., the actions that an object is taken) are referred as states. A state pattern (Gamma et al. 1995) is used to represent an object's behavior at a certain state. This is enabled by using polymorphism (Alexander 2003) so that we can have two different objects performing in the same way, or the same object performing differently in different situations.



(a) *Gantt Chart* **(b)** *Student's Game-play as Video Playback*

Fig. 8 Review on student's game-play history with teacher console. **a** Gantt Chart. **b** Student's Game-play as Video Playback

(a) *Twister* **(b)** *Tsunami*

Fig. 9 Catastrophes injected by teacher(s). **a** Twister. **b** Tsunami

Fig. 10 Some characters in FARMTASIA

Polymorphism is a method, which allows a generic interface to be specified by a superclass, leaving its subclasses to implement the method as needed. In FARMTASIA, a superclass called "Character" is defined, which provides a framework and patterns for its child classes, such as "Worker" and "Sheep". In fact, the inheritance structure between superclasses and subclasses saves a lot of development effort. The superclass describes generally what actions need to be done, and a subclass inherits the structure and gives a concrete implementation of the actions.

4.2 Three-tier network structure

With the consideration of scalability, flexibility and security, we adopt a three-tier (client-server-database) network model to implement FARMTASIA, as diagrammatically shown in Fig. 11.

4.2.1 Client tier

It interacts with the players directly and is responsible for presenting the game interface.

4.2.2 Server tier

It protects the data from direct access by the clients and is also responsible for managing the player accounts and globally simulating the game contexts.

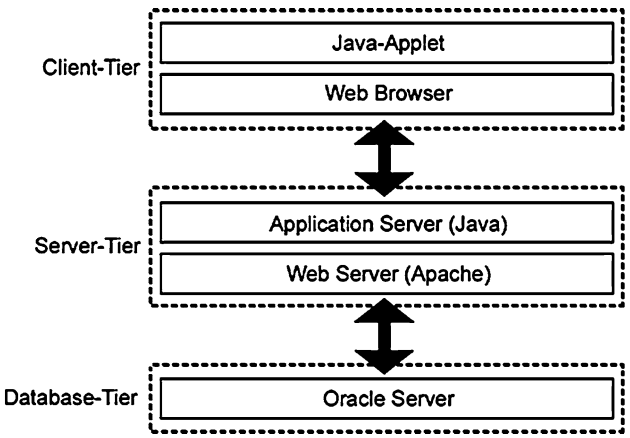


Fig. 11 Three-tier network model

4.2.3 Database tier

It is responsible for data storage. When the players access the game at the client-side, they can only connect to the server, but not the database. In fact, no direct access is allowed from the client side to the database (which makes the data more secure). Therefore, storing the players' actions and game contexts into the database should be done by the server.

Each midnight, the server iterates new game contexts by doing a global simulation of what the players have done during the daytime. In the simulation, events such as pollution, prosecution and workers' strike, will be generated and propagated to all players for their next round of game-play.

4.3 Speed

The adoption of Java applets in our implementation allows anytime-anywhere access and cross-platform compatibility; however, the tradeoff is the speed. Typically, Java programs are not directly executed by computer hardware; instead, it is interpreted by the JVM line by line. The JVM consumes both processor time and memory while managing a Java program execution, and generates a significant amount of overhead. We tackle this problem by using *Frame Skipping* and *Partial Redraw*.

4.3.1 Frame skipping

In order to keep FARMTASIA running at full speed on slow computers, its rendering frame rate will be automatically adjusted, that is, the slower the computer, the lower the rendering frame rate. Nevertheless, the actual frame rate of the game will not be affected during the adjustment, and it can have a constant game-play speed on different computers.

4.3.2 Partial redraw

During the redraw pass, the screen objects with their position or frame changed will be marked as dirty. Only screen region with dirty objects will be updated and refreshed. The partial redraw not only increases efficiency of the interface but also speeds up the game on slow computers.

5 An exploratory study on FARMTASIA

An exploratory study has been conducted in March 2006 to investigate the learning outcomes and perceptions of 16

Table 1 Results of pre- and post-test

	Descriptive statistics				
	N	Minimum	Maximum	Mean	SD
Pre-test	16	30	74	56.38	10.51
Post-test	16	50	80	67.00	7.87
Valid N (listwise)	16				

Hong Kong Secondary-four (comparably equivalent to K-10) students who participated in VISOLE learning with FARMTASIA.

5.1 Students' subject-specific and interdisciplinary knowledge

A pre- and post-test research design was adopted to investigate the advancement of students' subject specific and interdisciplinary knowledge with FARMTASIA. The level of difficulty of the pre-test and post-test was the same, and the full mark of both tests was 100. The result (see Table 1) shows that the average mark of the post-test was 10.62 points higher than the average mark of the pre-test (P-value < 0.001, see Table 2). This demonstrates that useful learning takes place.

5.2 Students' perceptions

The perceptional questionnaire is composed of 42 five-point-scale (1 Very Dissatisfied–5 Very Satisfied) questions to gather students' perceptions of FARMTASIA. The summative result appears in Table 3. It shows that the students were generally positive towards this game.

6 Conclusion

Many educators and game designers argue that the computer game world is a totally "learner-centered" environment as gamers always constructively learn in computer games on their own. Therefore, computer game-play would effect learning spontaneously. Regrettably, there have not been too many success stories of computer game-based learning to date. In fact, we believe educational games themselves may not easily facilitate effective learning unless they are designed with pedagogy and augmented with sound learning activities. The result is the VISOLE pedagogy, which encompasses scaffolding, online game-play, and teacher-facilitated debriefing and reflection.

FARMTASIA is the first VISOLE instance that we have developed. In a nutshell, FARMTASIA is a multi-player online game providing players a first hand immersive experience to interact and to shape the development of a realistic virtual world. At the design level, we employ various scientific models to make the whole game as realistic as possible. Besides the main game, we also create various mini-games to make the whole VISOLE process more pleasurable and challenging. Sudden events provide opportunities to sharpen students' skills on dealing with contingency and emergency, while the teacher console helps VISOLE teacher(s) conduct various VIOSLE facilitation task more easily. On the other hand, at the implementation level, in order to make the game more secure, flexible and scalable, we adopt a three-tier network model and various strategies to improve the game-play speed.

The exploratory research, which we present in this paper, shows positive perceptions and an advancement of subject-specific and interdisciplinary knowledge appeared

Table 2 *T* test against pre- and post-test

	Paired differences					*t*	Df	Sig. (two-tailed)
	Mean	SD	SE Mean	95% confidence interval of the difference				
				Lower	Upper			
Pair 1 Pre test–post test	−10.63	6.92	1.73	−14.31	−6.94	−6.14	15	0.000

Table 3 Students' perceptions of FARMTASIA

Perceptions (summative)	Very satisfied (%)	Satisfied (%)	Neutral (%)	Dissatisfied (%)	Very dissatisfied (%)	Mean	SD
Overall satisfaction	18.8	68.8	12.5	0	0	4.06	0.57
Overall experience	12.5	62.5	25.0	0	0	3.88	0.62
Overall gain	25.0	50.0	25.0	0	0	4.00	0.73

among the students who participated in VISOLE learning with FARMTASIA. Further large-scale study is necessary to assert the educational effectiveness and efficiency of the VISOLE approach and FARMTASIA in particular.

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