A Platform for Motivating Collaborative Learning Using Participatory Simulation Applications

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Abstract. Several research efforts suggest that collaborative participatory simulations improve teaching and learning, increasing motivation inside the classroom. Currently, it has been mainly applied with students of primary and secondary educational levels, leaving higher level students aside. This paper presents a platform for implementing participatory simulations, where social interactions and motivational effects are the main facilitators. An instance of this platform was implemented for medicine school undergraduate students. Its implementation is simple, lightweight, fully based on pen-based interaction, and designed to work with handhelds and tablet-PC over an ad-hoc wireless network. The platform is able to support any kind of application implementing participatory simulation based on the exchange of artifacts among the learners.

Keywords: Techniques, methods and tools for CSCW in design. Other Keywords: Handhelds. Collaborative Learning. Participatory Simulation. Learning Motivation. Gestures. Sketches. Freehand-input based.

1 Introduction

Some research groups have implemented collaborative learning participatory simulations with handhelds, tablet-PCs and infrared beaming [15], and it has been found that this kind of activities provide various advantages for teaching and learning: a) they introduce an effective instructional tool and have the potential to impact student learning positively across different curricular topics and instructional activities [18], (b) they increase motivation [8], [2], (c) they improve engagement, self-directed learning and problem-solving [8], and (d) they may stem from students having "rich conceptual resources for reasoning abut and thoughtfully acting in playful and motivational spaces, and thus can more easily become highly engaged in the subject matter" [7].

Collaborative learning trough participatory simulations use the availability of mobile computing devices having the capability of simple data exchanges among neighboring devices [19], [5]. They enable students to act as agents in simulations in which overall patterns emerge from local decisions and information exchanges. Such simulations allow students to model and learn about several types of phenomena [3], in order to improve their knowledge about human behaviors, to help them in solving conflicts, to shape interaction protocols between humans, and to learn some aspects of collective management, games and experimental economics situations. Due to the nature of participatory simulations, it can be used to support the learning and teaching of any kind of systems for which its general behavior emerges from the interaction of its agents.

As stated in [13], new pedagogical practices for the whole classroom are required in order to take the most advantage of new Technologies: it not enough to provide each classroom with handhelds or tablet-PCs but the way how technology meets education in a synergic way should be reinvented [14]. Computers have been already used since long time to support learning, but traditionally, most efforts have been directed to support individual learning [1]. This approach, tough very effective for some scenarios, fails to take advantage of what a collaborative learning can contribute to the whole learning process. On the other hand, the growing acceptance of handhelds and tablet-PCs enable users to take advantage of numerous advantages in scenarios that desktop computing cannot provide [8]. Handheld's and tablet-PC most natural data-entry mode is the stylus (pen-based or freehand-input-based system), which imitates the mental model of using pen and paper, thereby enabling users to easily rough out their ideas and/or activating different functionalities like copy, move, delete, etc.[10]. However, most currently available handheld applications adopt the PC application approach that uses widgets instead of freehand-input-based paradigms (via touch screens) and/or sketching, [4].

This paper, presents a collaborative learning experience based on participatory simulations, having two general research goals: (a) to propose a conceptual platform for specifying participatory simulations using handhelds and tablet-PCs, (b) implementation of this platform to be managed by the teacher for developing applications to the whole classroom of participative simulations supporting motivating learning objectives, and (c) to determine the feasibility of using this in undergraduate curricular contexts of the simulation activities both in terms of intended and actualized learning outcomes; particularly in the medicine area. An instance of the platform is described. Its implementation is simple, lightweight and fully based on wirelessly interconnected handhelds with an ad-hoc network.

2 Handheld and tablet-PC in whole-classroom participatory simulations

Handheld and tablet-PC computers provide advantages, which make this an especially attractive platform for developing participatory simulations for a whole class activity [12]. In order to fully take advantage of this hardware, we should harness common features of handhelds and tablet-PCS including: (a) portability – students can move around within a classroom with their computing devices, (b) social interactivity – they can exchange data and collaborate with other people face-to-face, (c) context sensitivity– mobile devices can gather data unique to the current location, environment, and time, including both real and simulated data, (d) connectivity – it is possible to connect handhelds and tablet-PCs to data collection devices, other handhelds and tablet-PCs (ad-hoc network) that creates a true shared environment, (e) individuality – mobile devices can provide unique scaffolding that is customized to the individual's path of investigation. Our research project is to develop and examine a new participatory simulation platform that is designed from the ground up for handheld computers (used by students) and tablet-PC (used by the teacher) and draws on the unique affordances of these mobile technologies. Implicit to our research is the belief that a powerful handheld learning environment might capitalize on the portability, social interactivity, context sensitivity, connectivity, and individuality of ubiquitous devices to bridge real and virtual worlds. The handhelds and tablet-PC then provides a window into the virtual context that is sensitive to information being supplied to it by the real world.

A learning participatory simulation is a role-playing activity that helps to explain the coherence of complex and dynamic systems. The system maps a problem of the real world to a model with a fixed number of roles and rules. Global knowledge and patterns emerge in participatory simulations from local interactions among users and making decisions to understand the impact by an analysis and observation while doing and/or at the end of the activity. Foundational concepts underpinning the design and use of collaborative learning participatory simulations include (a) immersion of students in simulations of complex phenomena; (b) development of inquiry and research design skills by the reflections and analysis of the simulation; (c) negotiation, coordination and alignment of individual local behavior in order to foster group-level systems understanding.

An advantage of learning participatory simulations is the fact that the activity is highly effective and motivating even in large groups (a whole class). A teacher could starts or not with an introduction where he or she explains the relevant theoretical parts of the complex problem. At least the roles and rules need to be clearly specified. The students should understand the possible activities and consequences, which are available in the simulation at the end. The exchange of experiences and a discussion in small groups within or after the simulation help to increase the understanding of the simulated reality. A whole class activity of participatory simulations can be integrated in the lecture [12], where a major idea is the concept of learning through doing [9]. Students participate in an active and motivating way, analyze information, interchange information among them, make decisions and see the outcome of their actions.

2.1 Principles of the handheld and tablet-PC interface

According to [10], [4] a handheld (and tablet-PC) application interface must imitate the pen-and-paper metaphor so users can interact naturally with the computer in varied situations, especially when they are or need to be in movement, thus freeing them to concentrate on the tasks at hand instead of worrying about the interface (interaction with keys, menus, widgets, etc.). A pen-based system offers a more natural and intuitive interface enabling the sharing and exchange of design information so as to improve efficiency.

Essential to the functioning of pen-based user interface is the use of gestures [11]. In [5], a survey intended to illuminate the problems and benefits users experience with gestures, it was found that the most frequent actions were deleting, selecting and moving, and that users consider these actions to be efficient as a form of interaction, as well as convenient, easy to learn, utilize and remember, and potentially an added advantage for the interface

Finally, handhelds are an appropriate technology for providing high mobility and portability in physical spaces like a classroom, and for creating ad-hoc networks through peer-to-peer connections between already incorporated WiFi components (Dell Axim X50) jointly with a tablet-PC. Such network allows deliberate information exchange between users, as well as to automatically interaction between devices (sees section 5). Proximity detection is done with infrared sensors (IrDA) combined with WiFi

3 Developing a platform

Collaborative learning trough participatory simulations with handhelds offer an additional perspective providing off-screen, first person experience and insight into the dynamics and emergent behavior, as students become agents in a complex system. Information and conceptual knowledge circulates through peer-to-peer interaction by the interchange and negotiations of objects, which takes different forms in each simulation. We propose a platform for the specification, design and creation of mobile learning participatory simulations based on handhelds wirelessly interconnected.

In order to generate, specify and implement applications of collaborative learning participatory simulation, the teacher defines on the tablet-PC): (a) learning goals of the reality simulated, (b) artifacts to be interchanged, b) behavior variables and parameters, and (c) rules and roles for playing the simulation (see section 4). Goals need to be identified in order to let students successfully learn/construct certain knowledge. These goals may include meta-objectives and they are only a mean to achieve an overall learning objective. Roles and rules are spread among students when the activity begins, but the teacher can also interact too.

In order to configure the system for a collaborative learning participatory simulation, the Teacher may setup transferable objects (artifacts), their behavior parameters, rules and participant roles using his/her tablet-PC. Then, to begin the activity, the professor explains the goal of the activity to the students, also describing objects, rules and roles, and how these concepts are represented in their handhelds. Rules, roles and goals should be designed to achieve (a) a high social interaction between students, (b) negotiation instances, and (c) competition to encourage an active and motivated stance as if students where playing a game [9]. If students require assistance, our platform allows the teacher to wirelessly give them feedback and assessment. The teacher can (a) observe the simulation state of each participant device and (b) modify such state in order to solve the student inquiry.

Start-up setup must ensure students play always an active and dynamic role through time. This should be based on trading between students (Negotiation component of Students, and Interchange Objects), or automatically among handhelds (Exchange Objects). These conditions depend on each learning participatory simulation application build, and may involve the following aspects: (a) type of exchange objects, (b) exchange amounts, (c) trade conditions, (d) parameters before and after the exchange, and (e) exchange objects.

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4 A scenario for collaborative learning participatory simulation

In this section we describe an instance of the platform proposed in section 3. It is oriented to support undergraduate students of medicine schools to learn aspects related to the identification of illnesses trough their symptoms and the corresponding medication. Students normally reinforce their knowledge about these aspects with a lot of real practice accompanying physicians. They have to develop skills on associating a certain set symptoms to the correct disease, since one symptom may be present in many diseases. Also medication can be different even for the same disease according to the intensity of the symptoms. We propose a scenario where a whole medicine course simulates this process in order to determine the illness and the corresponding medication based on a set of symptoms distributed to the handhelds of the students. Initially, the teacher configures a set of diseases, symptoms and prescriptions delimiting the tolerance range and possibilities they can present. This information is distributed among the 20-30 medicine students of the whole class, so each student has at least one disease and various medical prescriptions and symptoms which may not all correspond to the illness. The students have to establish face-to-face encounters in order to exchange symptoms and medical prescriptions they may have in case they want to do so. This exchange of information and the discussion between the students involved should reinforce or refute their knowledge about the corresponding disease in a highly participating and motivating atmosphere. Handhelds in their turn act proactively informing students who put their devices close together if they have symptoms or prescriptions which they can exchange (according to the configuration established by the teacher at the beginning). Handhelds will only inform of this opportunity. Students should identify and decide if they exchange these elements.

The teacher can monitor the process of each student using the tablet-pc. The teacher can also change the association parameters between symptoms, diseases and medical prescription during the experience. A correct solution by a student establishing the right association between a disease, it symptoms and the right medication can be automatically determined comparing the student's solution with the configuration given by the teacher. Small deviations are allowed. It is also possible that cases unexpected by the teacher may arise during the experience. These can be assessed in real time by the teacher giving the corresponding feedback to the students.

5 An application using the Platform

We have implemented a lightweight application for the creation of participatory simulation applications based on the platform proposed in section 3. Using this platform we have successfully implemented an application for the scenario proposed on previous section. This application allows the teacher to organize and administrate the simulation using a Tablet. The teacher can create "Medical Conditions", “Treatments” and “Symptoms”, and let students organize and link them finding out the optimum configuration. This will encourage different students to interact with each other in order to trade their items (treatments and symptoms) in order to describe in the best way his or her assigned medical conditions.

5.1 Simulation Management

Items design. The teacher can define different items, which may represent medical conditions, treatments and symptoms. In order to do this, he or she has to work under the “Define activity" mode. Here, the teacher can draw a sketch, type or hand-write the name of certain item and surround it within a rectangular shape. This will produce an "item icon", displaying an awareness of successful creation and displaying a reduced version of the original scratch. Then, additional "goods icons" may be created, as seen in Figure 2.a. Selecting a created item will display contextual options for choosing item type: "Medical

Conditions", “Treatments” and “Symptoms” (Figure 2.b). Clicking such options will change the item’s type. Items of each type are displayed with different colors.

Items linking. Once items of different types have been created, the teacher can relate “symptoms” and “treatments” to certain “medical conditions”. This is done drawing a line that starts from one item and ends in another. When the stylus is released, an arrow symbolizing a link between both items will replace such sketched line. Internally, the system will store the relation between these two items. When students reproduce this link they will get appropriate bonus.

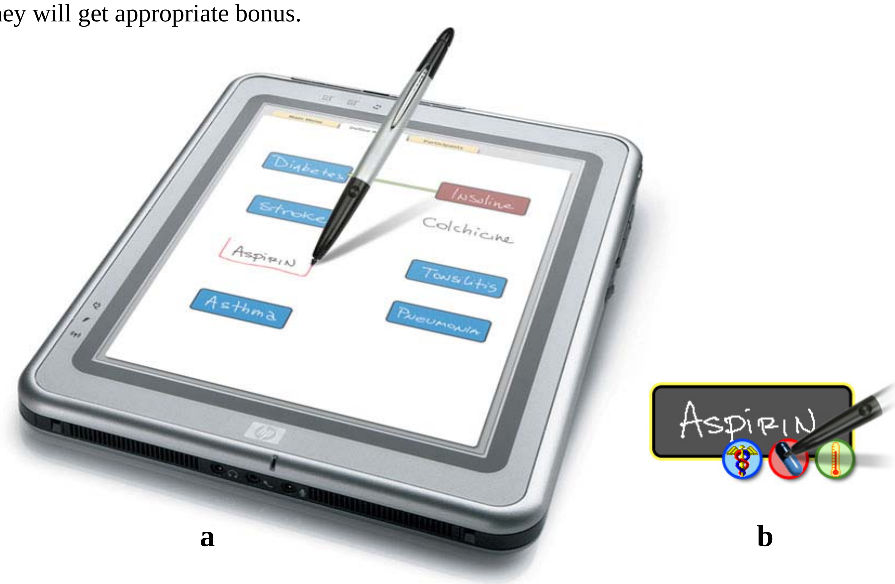

Fig. 2. a) Teacher can create items by handwriting their names on the tablet-PC. Surrounding some sketches with a rectangle shape will define a new item. b) Selecting an item will show contextual options, which allow the teacher to choose selected item’s type.

Activity status and real time management. Anytime before or during the simulation, the teacher can enter the “Define activity” mode and create new items, or alter their previous relationship. For instance, he or she could introduce a new treatment for an old medical condition, encouraging the students to keep searching for alternatives to their current individual configuration in their handhelds. Another mode is the “Activity overview”, which presents metrics about the activity status, overall students’ assessment, how many students are performing correctly, how many need help, and how much are students interacting with each other.

Detailed watching and teacher-student interaction. Entering the “Participants” mode will display all students’ current screens in a matrix, allowing the teacher to watch exactly what students are doing, which score they have, and who are interacting – and what are they exchanging. Figure 3 shows an example participant's screens summary. All students’ handhelds screens are reproduced scaled in order to fit them in the teacher screen. Students' current action is also being displayed: in the image, first three students are linking their concepts, while Felipe and Pedro are exchanging items. The teacher can double click a student's screen in order to access a full scale mode where he or she can interact with the participant's configuration, both altering and assessing the student's actions.

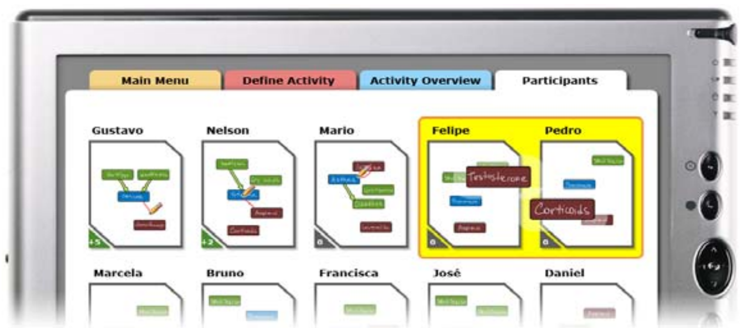

Fig. 3. On “Participants” the teacher has a quick summary of every student's screen. In this example, some students are drawing links while others (Felipe and Pedro) are exchanging items in order to achieve better individual configurations. Exchanged items appear bigger, highlighting them.

5.2. Simulation description

When the activity teacher has setup the simulation, each student has randomly assigned “medical conditions”, “treatments” and “symptoms”. Originally assigned items will not correspond to each other, so students will have to start seeking for adequate “treatments” and “symptoms” for their assigned “condition”. Once they exchange their items for the corresponding ones, they'll have to establish links between them.

Fig. 4. Students screen displays items like the teacher's screen. Drawing a link between two items will generate a link. Repeating such action will remove a previously generated link.

Sudents' screen and items linking. Assigned and exchanged items appear in the student's handheld screen, just as they would look in the teacher's tablet-PC, showing customs colors depending on the item's type. Students may establish different linking configurations trying to find the optimal relationship. In this process, each student may define and remove links between concepts, until the system highlights link as “optimal”.

Student may define links in the same way the teacher does so, by drawing a line from one item to the other (Figure 4).

Item exchange between students. When two students engage in a face-to-face encounter, automatically their handhelds display the exchange mode. In this screen, the lower area shows items currently owned by the student, while the upper area of the screen there are two negotiation spots: one where offered items may be dragged, and other where engaged student's offered items are shown. Dragging an item from the owned area into the offered area (Figure 5) will include such item into the exchange. On the other hand, when the trade is done and both students agree, dragging any of the items offered by the other switches current student's trade state to “accept”. When both accept, the exchange is done, transferring items between both students.

Fig. 5. Two students exchange items through a face-to-face encounter using their handhelds. Dragging an item from the owned area (“My items”) into the offer zone will put such item on trade.

6. Implementation

The System was implemented over a platform we developed previously which supports the development of distributed applications for mobile devices over different platforms: Java and .NET. The middleware we developed consists of a set of classes implementing an API the programmer can use in order to write distributed applications easily. These classes are available in Java and C# and implement the necessary mechanisms for converting data objects from their internal representations into an XML representation, transmit them across platforms and convert the XML representation into the corresponding internal one. They also provide and start the necessary services for discovering partners present in the ad-hoc network and establish the necessary connections among the different applications in order to synchronize shared data.

6.1 Discovering partners and establishing the connections

Every application programmed wit our platform starts a service which will send multicast messages at regular intervals to the group in order to inform other participants of the presence of a new one. It will also start consuming multicast messages from other partners present in the ad-hoc network. This allows the application to maintain a list of active participants updated. Every time a multicast message of a new participant is received, its ID and IP number are stored in the list and a TCP/IP connection is established with that application through which data will be shared. If a certain amount of time has passed without receiving a multicast message from a member of the list of active participants, its entry is deleted and the connection to that application closed. The Figure 6 shows the structure of the communication node present in all applications developed with the platform. It has a module which manages threads for sending and receiving multicast packages used to maintain an active partners list. This list is used by another module which is responsible for creating TCP/IP connections with the active partners and destroying them for those partners which left the group and transmit synchronization data.

6.2 Sharing objects

The data sharing mechanism is based on a "shared objects" principle. A shared object is an abstract class which should be extended in order to create an object class whose state will be transmitted to all active participants when the object changes its state, this is when one or more variables change their value. The programmer implements a shared object by extending the SharedObject abstract class. The synchronization of the shared objects is achieved by transmitting a copy of it to all partners every time their state is changed. For this, methods for sending and receiving objects were designed and implemented. At the beginning these methods were private to the middleware, but very soon we discovered that many small yet powerful applications could be implemented very easily based on those methods without having to use the SharedObject class. Therefore we made these methods public to the API. In order to transmit an object across platforms we need a way to represent objects common to both platforms: this is XML. When the application must update the state of an object it is passed to a serializer which produces an XML representation. This description is then sent to the communication node of the other application. The receiving node uses its own de-serializer for transforming the XML representation in the corresponding internal one.

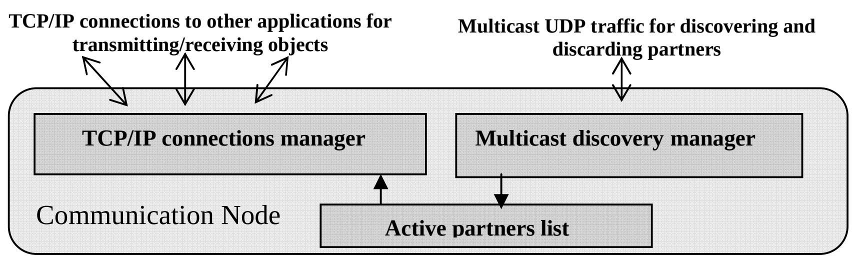

Fig. 6: The structure of the communication node.

6.3 Group management

The face-to-face edutainment scenario was the first situation that motivated us to for developing this middleware because of the need to have applications implemented and running in different platforms to share data. In this scenario, we also recognized the need to have the possibility of defining subgroups of partners inside the whole group of active participants. For example, the teacher may want to propose a task which should be accomplished by small groups which do interact among them, but she wants to keep the possibility of looking what the different groups are doing. For this we developed the necessary mechanisms inside the middleware in order to have applications join and leave certain groups. This information is stored in the communication node and is used when the copy of an updated object has to be distributed among participants. Accordingly, we developed the methods which will send objects only to applications belonging to a certain group. An application can join more than one group, so it can receive updates coming from different groups. We also implemented methods for remotely force an application to join and/or leave a group. This was necessary because in many cases, the teacher or the moderator of a group was supposed to form smaller working groups. The teacher or moderator can then join the various in order to “see” what was happening on all of them.

7 Related Work and Discussion

Throughout much of the fifty-year history of participatory simulations, computational technologies have played a central role. Nowadays, the ‘participatory’ aspect of these simulations can be enhanced by available technology, which gives support for the roles and rules to be distributed among the students. Researchers are highly interested in collaborative learning participatory simulations due to these simulations appear to make very difficult ideas around ‘distributed systems’ and ‘emergent behavior’ more accessible to students [19]. Furthermore the participatory simulation embeds student engagement and motivation in a playful social space [2] where they have rich conceptual resources for reasoning about and thoughtfully acting in playful spaces, and thus can more easily become highly engaged in the subject matter. Different hardware devices were used to implement participatory simulations.

Colella et al. [3] developed wearable computational badges (or "thinking tags") that allow users to move freely while communicating information between badges. Colella, researched about student learning with one of the first instances of a participatory simulation supported by a thin layer of computing technology. Disease propagation models are natural candidates for this kind of participatory simulation and have been implemented by a number of researchers and curriculum developers [16].

Klopfer et al. [6] describes a prototype about “Environmental Detectives,” which is a participatory simulation experience where groups of students participate in a real-time simulation based on a local watershed. The real-world watershed includes streams, trees, and other natural elements. This real-world situation is then augmented by a simulation of an environmental disaster; in this case the river being polluted. Handheld computers implement a simulation where students can take air and water readings, interview people and get geographical information.

Tomlinson [17] presented a novel interaction paradigm for multi-user participatory simulations which involves desktop PC screens that serve as virtual islands populated by autonomous 3D animated creatures, and mobile devices, such as tablet PCs, that serve as virtual rafts that participants may use to carry creatures between the islands. This paper described how this “Island/Raft” paradigm may serve as an interactive platform for education in several different content domains, and presented a functional implementation of the paradigm. The system is able to present content in ways that are of interest to learners and growing effectiveness as educational tools.

HubNet [19] is an architecture designed to give students the experience of participating as elements in a simulation of a complex dynamic system. HubNet is an open client-server architecture, which enables many users at the "Nodes" to control the behavior of individual objects or agents and to view the aggregated results on a central computer known as the "Hub". This network of nodes is integrated with a powerful suite of modeling, analysis and display tools that, together, give the capacity to "fly" the system in intuitive mode, to reflect on the emergent result of the simulation and to encode student strategies as rules which the system can then run independently. The network layer implements flexible communication protocols that include the ability to upload and download data sets, upload and download program, monitor key-presses at the handheld computer level, support real-time interaction as in network computer games, and form collaborative groups of various sizes: peer to peer, small groups, and whole class modes.

Klopfer et al. [12] showed that the newer and more easily distributable version of Participatory Simulations on handhelds was equally as capable as the original Tag-based simulations in engaging students collaboratively in a complex problem-solving task. They feel that handhelds technology holds great promise for promoting collaborative learning as teachers struggle to find authentic ways to integrate technology into the classroom in addition to engaging and motivating students to learn science. The fact that handhelds can display results in a more attractive way suggests that they might be a more motivating platform for implementing participatory simulations.

A collaborative learning participatory simulation implementing a stock exchange scenario was designed for master’s students in financial theory, using architectures based on a server and clients running on desktop PCs or laptops as well as on handhelds, [13].

Based on the literature above mentioned, we have identified that no system has yet been proposed or implemented for handhelds in a wireless ad-hoc network using a pen-based interface as main metaphor for user interaction. We believe that the most significant contribution of the work reported here is to provide a conceptual platform for applications of collaborative learning participatory simulations, which is easy to adapt to many subject-matter content knowledge and undergraduate curricular integration and encouraging the adoption of learner-centered strategies. The teachers, who pre-evaluate the application, suggest that the same technologies and ideas could be used across many subject matter areas. The design of effective learning environments of our conceptual platform have included (a) learner centered environment (learners construct their own meanings), (b) knowledge-centered environment (learners connect information into coherent wholes and embedding information in a context), (c) assessment-centered environment (learner use formative and summative assessment strategies and feedback), and (d) community-centered environments (learner work in collaborative learning norms). The next phase of our investigations will develop and explore more subject-specific applications and learning and motivational measures at the student level. In fact, another application was already developed with the goal of learning the building of confidence between buyers and sellers [20]. The first results of the testing of our prototypes indicate that the developed platform is the right approach to support the implementation of participatory simulations and that they can play a positive role supporting the learning of various systems in a motivating way.

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