A Platform Supporting the Implementation of Collaborative Learning through Participatory Simulations

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Abstract. Student motivation is a key aspect in achieving successful collaborative learning. In the past, some techniques which help to engage the students in a motivating learning activity have been proposed. Among them, Participatory Simulation is one of the newest. In Participatory Simulations, social interaction and motivational effects are the main facilitators. In this work, we present an easy-to-use framework that facilitates the development of mobile computing applications implementing this technique. The use of this framework leads to the development of lightweight peer-to-peer applications for handheld computers with interfaces fully based on pen interaction, and designed to work with handhelds over an ad-hoc wireless network. This paper also shows the development of an application oriented toward the last-year business school undergraduate students for support in learning the concepts of reputation and trust based on the customer's experience and knowledge generated by a company's performance during a good or bad experience.

Keywords: Handhelds, gestures, sketches, collaborative learning, participatory simulation.

1 Introduction

The learning value of collaborative participatory simulations may stem from students having "rich conceptual resources for reasoning about, and thoughtfully acting in, playful and motivational spaces, and thus can more easily become highly engaged in the subject matter", [10]. Participatory simulations use the availability of a mobile computing device that gives each student the capability of simple data exchanges

among neighboring devices [17], [5]. They enable students to act as agents in simulations in which overall patterns emerge from local decisions and information exchanges. Students can then use those simulations to model and learn about several types of phenomena [5] 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 economic situations. Furthermore, the interest in participatory simulations related to experimental economics and management is part of a growing trend [3], [4], [8].

Some research groups have implemented participatory simulations with handhelds and infrared beaming [15], and it has been found that this kind of activity provides several advantages in teaching and learning: (a) it introduces an effective instructional tool and has the potential to impact student learning positively in all curricular topics and instructional activities [16], (b) it increases motivation [11], [5], and (c) it generates positive effects in engagement, self-directed learning and problem-solving. [11]. The growing acceptance of handhelds enables users to take advantage of numerous advantages in scenarios that desktop computing cannot provide, [11]. One of a handheld's most natural data-entry modes is the stylus (a.k.a. a pen-based or freehand-input-based system), which imitates the mental model of using pen and paper, thereby letting users easily rough out their ideas and/or activate different functionalities like copy, move, delete, etc. [13]. However, most currently available handheld applications adopt the PC application approach that uses widgets (buttons, menus, windows) instead of freehand-input-based paradigms (via touch screens) and/or sketching, [8].

This paper proposes a framework for implementing Participatory Simulations, having two general research goals: (a) to propose a conceptual framework for specifying (by the teacher) and developing applications in the field of participative simulations supporting motivating learning applications, and (b) to determine the feasibility of using this in an undergraduate curricular contexts, both in terms of intended and real learning outcomes, particularly in the management area. An instance of the framework is described. Its implementation is simple, lightweight and fully based on handhelds wirelessly interconnected to an ad-hoc network.

2   Participatory Simulations

A Participatory Simulation is a role-playing activity that helps explain the coherence of complex and dynamic systems. The system maps a problem of the real world in a model with a fixed number of roles and rules. Global knowledge and patterns emerge in Participatory Simulations from local interactions among users and decision-making. The impact is understood by an analysis and observation while doing and/or at the end of the activity.

An advantage of Participatory Simulations is that the activity is highly effective and motivating even in large groups. A teacher may or may not start 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 during or after the simulation help increase the understanding of the simulated reality.

Short or longer Participatory Simulations can be integrated in the lecture, where a major idea is the concept of learning by doing, [12]. Students participate in an active and motivating way, analyze information, exchange information, make decisions and see the outcome of their actions.

3   Related Work

Simulations were conducted with paper and pencil in the past, but the technological advances made a completely new type of simulation possible. The 'participatory' aspect of these simulations can be directly facilitated by the technology, which provides support to the roles and rules to be distributed among the students. Researchers are highly interested in Participatory Simulations as these simulations appear to make very difficult ideas about 'distributed systems' and 'emergent behavior' more accessible to students, [17]. Furthermore, the Participatory Simulation embeds student engagement and motivation in a playful social space [5] 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 support Participatory Simulations on various kinds of educational objectives for students of different educative levels:

- A futures trading simulation, which can be used to teach concepts of a futures/options or financial markets, is described in [2]. The futures trading is a spreadsheet program designed to minimize required input by the instructor. Student survey responses demonstrate that the simulation is a success.
- Thinking Tags, [1] small nametag-sized computers that communicate with each other. Andrews et al. (2003) built an application for kindergarten children; and [6] for high-school students in a simulation of virus propagation and asked them to determine the rules of the propagation. The tag communicates with other tags, exchanges data and visualizes similar preferences of two persons.
- Klopfer et al. [11] showed that the newer and more easily distributable version of Participatory Simulations on handhelds was as equally capable as the original Tag-based simulations in engaging students collaboratively in a complex problem-solving task. They feel that handheld 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.
- A Participatory Simulation in the form of a stock exchange 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 PDAs, [12].
- The SimCafé experiments form part of the sociological approach, aiming at validating and consolidating models, [8]. In this approach, participants are stakeholders and the witnesses of the emergence are domain experts, usually social scientists. Participatory Simulations are used as a tool to determine the condition of the emergence. As a matter of fact, this approach belongs to the experimental approach in social sciences, [4] especially experimental economics.

Based on the above-mentioned literature, 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 the main metaphor for user interaction.

4   Developing a Framework

Foundational concepts underpinning the design and use of 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.

Participatory Simulations with handhelds offer an additional perspective by 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 negotiation of objects, which takes different forms in each simulation.

We propose a conceptual framework for the specification, design and creation of mobile learning Participatory Simulations based on wirelessly interconnected handhelds (Figure 1). In order to generate, specify and implement Participatory Simulation applications, the **Teacher** must define: (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 6). **Goals** (Figure 1) need to be identified in order to let students successfully learn/construct certain knowledge. These goals may include
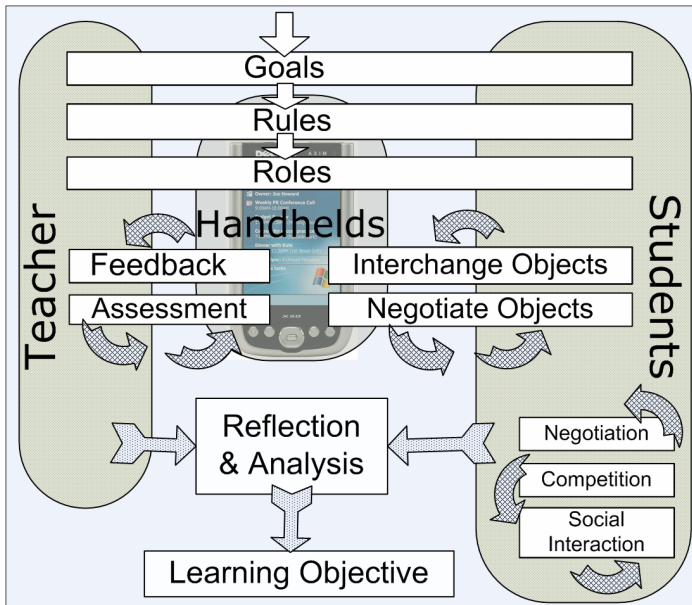

Fig. 1. Conceptual framework

meta-objectives and they are only a means to achieve an overall learning objective. **Roles** and **rules** are spread among students when the activity begins, but the teacher can interact, too. He or she can always access and modify simulation details: wireless connectivity lets the teacher alter any role or rule in the simulation in real-time, thus changing behaviors on the go. In order to configure the system for a Participatory Simulation, the **Teacher** may set up transferable objects (artifacts), their behavior parameters, rules and participant roles. Then, to begin the activity, the teacher 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 among students, (b) negotiation instances, and (c) competition to encourage an active and motivated stance as if students were playing a game, [12].

If students require assistance, our framework allows the teacher to give them wireless **feedback** and **assessment**. The teacher can (a) observe the simulation state of each participant device and (b) modify such state in order to respond to the student's inquiry.

Start-up set-up must ensure that students always play an active and dynamic role over time. This should be based on trading between students (**Negotiation** component of Students, and **Interchange Objects** in Fig. 1), or automatically among handhelds (Exchange Objects). These conditions depend on each Participatory Simulation application construction, and may involve the following aspects: (a) type of exchangeable objects, (b) exchange amounts, (c) trade conditions, (d) parameters before and after the exchange, and (e) exchangeable objects. Once the simulation concludes, the teacher must guide students' understanding about the activity. In this way, the students will construct the **learning objective** together.

5   Principles of the Interface

Pen-Based User Interface (PUI). According to [13] and [7], a handheld 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 that facilitates the sharing and exchange, thus improving efficiency.

Gestures. Essential to the functioning of PUI is the use of gestures, [14]. In [9], a survey intended to illuminate the problems and benefits users experience with gestures-PUI, it was found that the most frequent actions were deleting, selecting and moving, and that users consider these actions to be an efficient form of interaction, as well as convenient, easy to learn, utilize and remember, and potentially an added advantage for the interface.

Mobility in physical spaces and interchanging objects on the fly. Handhelds are an appropriate technology for providing high mobility and portability, and for creating ad-hoc networks through peer-to-peer connections between already incorporated WiFi components (Dell Axim X50). Such network allows deliberate information exchange

between users, as well as automatic interaction between devices (see section 7). Proximity detection is done with infrared sensors (IrDA) combined with WiFi.

6   A Scenario for Participatory Simulation

In this section, we describe an instance of the framework proposed in section 5. It is oriented toward last-year business school undergraduate students and is related to concepts like reputation and trust.

Trust is based on the customer's experience and knowledge generated by a company's performance during a good or bad experience. Repetitive interaction between a customer and a company is required to generate positive trust. This positive evaluation usually occurs when product quality is satisfactory or even when the company reacts appropriately after a client's complaint about bad products (or services).

Companies achieve a reputation when their customers trust in common transactions. With a good reputation, a company may attract new customers, even when they do not have a previous common experience: It only requires previously satisfied customers to communicate their trust and perceived reputation in the company to another consumer.

These concepts must be learned by students who should be able, during the participatory simulation, to generate, communicate and/or perceive positive trust (good products) or negative trust (bad products) generated during transactions with each company. Products acquired will have a perceptible life span directly connected to their quality. If a product lasts as long as the company offered, it will be considered a good product. Customers may claim bad products to the company. Simulation requires students to play company and customer roles where customer-students:

- are required to acquire a basket of goods, and to replace products when they expire.
- initially have no knowledge about a company's reputation, but they may query and share such information with other customers, without restrictions.
- may choose to acquire a product from any company that produces it.
- may claim a cash refund or product replacement when products fail before reaching the offered lifetime.

Company-students will:

- offer homogeneous goods, with static prices and life span defined by the teacher.
- generate new product units periodically.
- freely advertise the products' features to customers. Even when a company knows its products expected lifetime, it may advertise it with a different duration in order to manage customer expectations.
- agree or not agree to refund or replace a failing product at the customer's request.

A student ranking will be published in order to keep the simulation highly active. Such ranking will list purchase requirements and optimal cash spending for customer-students and money earned for company-students.

When the simulation finishes, students must analyze these results and conclude whether:

- There are companies with a bad reputation that may nonetheless achieve good results.
- Customers with previous knowledge have a clear advantage as compared to those who don't.

Even though it looks beneficial for a company to swindle a customer (even for the first time), in the short term, that customer will not do business again with the company and may probably convince other customers not to. In this scenario, students may recognize two cases: (a) the company reduces its earnings or (b) the company had intentions to quit its market, so it will not be affected by customers' reactions.

7   An Application Using the Framework

We have implemented a lightweight platform for the creation of participatory simulation applications based on the framework proposed in section 4. Using this platform, we have successfully implemented an application for the scenario proposed in the previous section. This application allows the teacher to assign roles to each participant. Such roles are "customer" and "vendor.." Also, the teacher can create "goods," and let "vendors" produce them or "consumers" need them. This will encourage different "vendors" and "consumers" to interact with each other in order to succeed in the goal of their role.

7.1   Simulation Management

Role assignment. Our participatory simulation system allows the teacher to assign a role to each student. Under the "activity administration" mode, unassigned students are displayed in the middle of the screen over a white area. The right area of handhelds (Fig. 2.a) has "vendors" while the left belongs to "consumers.." The teacher can drag a student icon to one side or another in order to assign the roles (Fig. 2.a). In this way, the teacher can see who has been assigned to a certain role by looking at different screen areas. The teacher can drag any participant icon from one side to another at any time in order to reassign the selected participant to the new role.
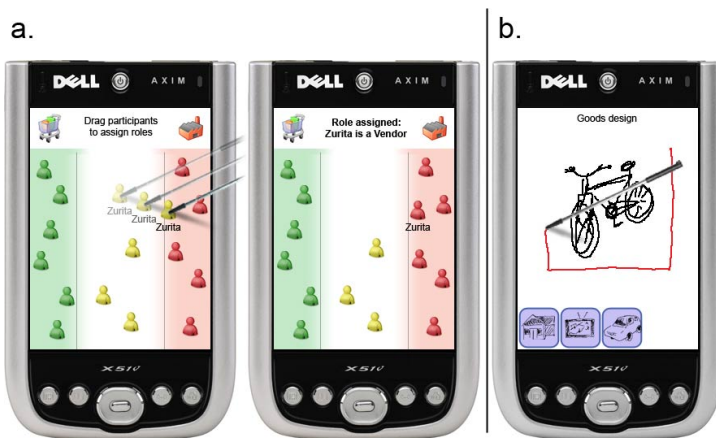

Fig. 2. a) Teacher drags a student icon into the "vendor" area to assign him a new role. b) Teacher can create new goods using free-hand drawings.

Goods design. The teacher can define different goods to be produced and required by the students. In order to do this, he or she has to work under the "Goods administration" mode. Here, the teacher can draw a sketch of a certain good and surround it by a rectangle. This will produce a "good icon,," displaying an awareness of a successful creation and a reduced icon of the original sketch in the bottom bound of the screen. Then, additional "goods icons" may be created, as seen in Fig. 2.b.

Double-clicking on a "goods icon" will bring up a screen to define default variables for such goods. Instance variables are "original price,," "production time" and "product expected life.." Each different "vendor" capable of producing these goods will assign different values to these variables, depending on a global "product variance" variable, describing how strong this difference will be among all vendors. This variable can also be manipulated in this same screen.

Goods management. Once "goods icons" have been created, they will show up in "activity administration mode" in the lower bound region of the screen. The teacher can drag these icons over vendor icons to allow them to produce this item, or over consumer icons to ask them to acquire this item. These goods assignments can be randomized in order to simplify the teacher's job and to ensure demand-supply equilibrium.

Activity status and real-time management. Anytime before or during the activity, the teacher can enter a vendor (by double clicking on its icon). By doing this, he or she can check how well this vendor has performed and modify the goods he or she can produce. The teacher can drag additional products to allow additional production or remove producible goods by sketching a cross gesture over any goods icon or double-clicking it to see and control the product's instance variables specifically for that vendor. On the other hand, the teacher can also enter a customer and check his or her performance (feedback and assessment). The teacher can drag additional required products over the participant icon, or enter and sketch a cross gesture to remove pointed items from the requirements list. On the customer screen, additional information about goals achieved (required products already acquired) and pending products can be seen.

7.2 Simulation Description

Once the activity teacher has set up the simulation, each student has its role and allowed/required goods assigned. Hence, they can start seeking their goals: (a) vendors need to sell as much as they can, (b) while customers have to acquire every item on their requirement list. Vendors will start offering by shouting about how cheap and long-lasting their products are while customers will walk around searching for the cheapest item available.

Customers may face vendors to acquire goods they sell. Vendors offer goods as if they would last for a certain period of time. After a customer acquires a product, it may last a certain period of time, shorter or longer than expected. If they last longer, they will get a good image of the vendor, and if they last less, a bad one. Once a customer faces another customer, they share information about a vendor's reputation. Customers have to decide, then, whether to look directly for vendors and save time, or to find about whose products are good or bad.

Customer's screen. This screen is divided into 5 main areas: reputation viewer, trade zone, requirements list, acquisition list and score. Reputation viewer depends on whether another customer or a vendor is being faced. Trade zone (upper bound of the
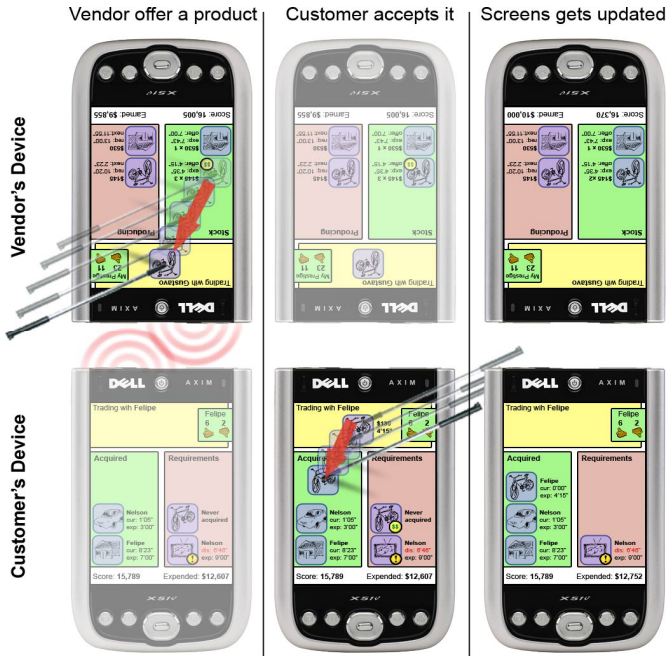
Fig. 3. Three steps in the trade process. First, the vendor offers a product; second, a customer accepts it; third, the vendor stock and customer requirements/acquired lists are updated.

screen, Fig. 3) is enabled when a consumer interacts closely with a vendor (by the IrDA sensors). The requirement list displays goods which have not been acquired or have been acquired but already expired. the acquisition list displays both enabled and expired acquired items, showing expected life span and real life span. Items expired before the expected life span was reached are specially highlighted, encouraging customers to engage the vendor for an answer. Customers may click on acquired items to display additional information about them: (a) from which vendor the item was acquired, (b) how much time the vendor offered and how much time the product lasted. Clicking on the reputation viewer will show a reputation summary of all vendors that the current customer knows or has "heard of" from another customer.

Vendor's screen. This screen is simpler than the customer's. It displays what goods the students produce and the production rate, which products have already been produced and available stock. It also displays an icon representing current prestige among all customers, and a summary of the overall score.

Students' interactions. At the beginning, vendors' reputations are unknown to customers. Every vendor starts with their product "factories" and maybe an instance of each product. Customers start with an empty acquisition list and a set of requirements. When a customer faces a vendor closely, first the reputation display shows that vendor's known reputation. If the customer has acquired a product before or if any other customer has shared its knowledge about this vendor, it can guide the user as to whether or not to trade with this vendor. A vendor can decide how much time he or she is going to offer for a product. The vendor is aware of the mean product life span, so a

different (probably shorter) life span will be offered to each customer in order to ensure that the product will last at least N years (minutes in the simulation). In order to change the offered life span, the vendor can double click on a product to enter its control screen. The system will suggest which items the vendor should offer by highlighting them. Then, the vendor has to drag an item into the trade area to offer it. As soon as this item is offered, it appears in the trade area on the customer's device screen. If the customer decides to buy the item, it has to be dragged from the trade area into the acquired items list. After a product is acquired, its life meter starts running, displaying how long the product has been enabled. The product may expire after or before the expected life span (the one offered by the vendor during the trade). As soon as it expires, a new item of the same kind is added to the customer's requirements list. In case the product has lasted the same time as, or longer than, what the vendor offered, the vendor will automatically earn a better reputation ranking. If it lasts less time, the product will be marked as failed and the customer could return to the vendor in order to trade it back by dragging it back to the trade area. The vendor may return the money to the customer, which earns him a good reputation ranking, or argue. Depending on the outcome of this negotiation, the customer may decide to rank the vendor as bad, or not to rank him or her. Customers may meet with other buyers in order to get feedback about each vendor's reputation. When two customers engage, each customer has to drag their reputation view inside the drag area to offer the information to each other. Once both have agreed to share the information, they will add to their knowledge base all the rankings gathered (experienced or traded) from the other customer. This action is completely optional and voluntary, and customers have to decide whether or not to share their information in exchange for more accurate prestige rankings.

Simulation results. During the activity, each student can check his or her current score. The teacher can see an overall summary of the activity and can also enter any student icon to see the participant score. The teacher can modify the allowed products or required items as described in previous sections. Once enough time has passed or the activity is over, the teacher can finish the simulation and an overall summary is displayed on each device.

8 Discussion and Future Work

We believe that the most significant contribution of the work reported here is to provide a conceptual framework for applications of Participatory Simulations, which is easy to adapt to many subject-matter contents and to integrate to undergraduate curricula, encouraging the adoption of learner-centered strategies. The teachers who pre-evaluated the application suggest that the same technologies and ideas could be used for many subject matter areas. The design of effective learning environments in our conceptual framework has included (a) learner-centered environment (learners construct their own meanings), (b) knowledge-centered environment (learners connect information into coherent wholes and embed information in a context), (c) assessment-centered environment (learners use formative and summative assessment strategies and feedback), and (d) community-centered environments (learners work on collaborative learning norms). The next phase of our investigation will develop and explore more subject-specific applications and learning and motivational measures at the student level.

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