“Remote Earthquakes”: Getting Serious about Authenticity in CSCL

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Abstract: The discovery or re-construction of scientific explanations and understanding based on experience is a complex process, for which school learning often uses shortcuts. Based on the example of analyzing real seismic measurements, we propose a computer-facilitated collaborative learning scenario, which meets many of the requirements for authentic learning. The implementation of the learning environment is based on a general platform for supporting collaborative modeling activities.

Keywords: authentic activities, computer-supported collaborative learning,

Introduction

Vygotsky’s sociocultural theory (Vygotsky, 1978) promotes the importance of social interaction and the use of artifacts for knowledge acquisition. Bellamy (1996) proposes three principles for the design of educational environments derived from Vygotsky’s works. First, the notion of authentic activities proposes the modeling of activities and tools derived from professional practices. Second, “construction” refers to learners creating and sharing artifacts within their community. Third, educational environments should be designed to involve a close collaboration between learners and their peers as well as between students and experts.

However, activity-theoretic approaches (e.g., Bertelsen & Bodker, 2003) usually remain rather general when it comes down to specific implications for the design of tasks and artifacts. Especially the notion of authenticity widely spread in the current literature on learning remains a blurry demand rather than a well-defined or even measurable concept.

Reviewing educational theory and research on authentic activities and online learning, Reeves, Herrington, and Oliver (2002) propose ten characteristics of authentic activities. Authentic activities are supposed to have real world relevance and create valuable products. The learning process is seamlessly integrated with assessment. They involve ill-defined, complex tasks to be examined from different perspectives, using a variety of resources and allow a diversity of outcomes. They provide opportunities for collaboration and reflection of students’ values and can be applied across different subject areas.

Rather than a final and universal definition their additive listing of characteristics alludes to the need to define what is meant by authenticity and what requirements for learning can be derived from each definition. In the end every activity can be considered authentic and learning from authentic activities implies moving beyond the original learning situation one has to ask in relation to what learning activities should be “authentic”. Following activity theory in starting from a problem-space motivating activities in the context of this paper we specify authenticity with respect to real-world problems, tasks and collaboration. Instead of claiming vague authenticity, we propose to design learning environments for the accomplishment of goals and tasks, derived from real-world problems necessitating collaboration.

Real-world or practical problems and goals in this sense exist independently and prior to designing the specific learning setting, therefore also calling for professional solutions that student activities may become part of. The conceptual gap between learner and work (Quintana, Carra, Krajcik & Soloway, 2001), typical for learner centered design, is being addressed in this way. This notion also supports the demands of problem-based approaches to learning (Mandl & Reinmann-Rothmeier, 1999). To enable students to relate to them and find a basic common ground for joint activities the problems should be sensible/noticeable part of the students’ world linking individual and culture – enabling self-reflection in contexts that matter.

For Edelson (1995), authenticity refers to a learning context reflecting the context of use. With respect this notion of authenticity he characterizes science practice with its attitudes of uncertainty and commitment, discipline-specific tools and techniques and social interaction. Uncertainty refers to the continual reexamination of techniques and results in the pursuit of unanswered questions. Commitment indicates that to pursue has meaningful ramifications within the value system of scientists – or students. The use of historically refined tools and techniques also provides a shared context facilitating communication. And social interaction stresses that scientific work exceeds investigation by including sharing results, concerns and questions among a community of scientists. "A vision of learning that integrates these features of scientific practice has students investigating open questions about which they are genuinely concerned, using methods that parallel those of scientists. Throughout the process, they are engaged in active interchange with others who share their interest." (Edelson, 1994).

Regarding collaboration it is important that the need for collaboration is not artificially imposed on the community of learners by the system but grounded in the nature of the task. Only if collaboration is needed to accomplish the task learners will appreciate the value of and seriously engage in collaborative activities such as sharing information, discussing partial research results and come with shared decisions and synthetic solutions. Therefore it is also important to clearly differentiate between a task to be accomplished alone and that requiring or noticeably profiting from collaboration with peers and experts. Understanding and appreciating the need for collaboration may be a significant part of the learning process.

Distributed seismography

Within the field of remote experimentation a valuable application domain to meet these pedagogical requirements and provide value to students and society is work on distributed seismography. The real-world problem starts with the natural (and feared) phenomenon of earthquakes experienced by most students in the Chilean context. Inhabitants of the region are usually subjected to without being able to actively relate to. Results from seismographic research are used to analyze seismic processes, to evaluate and avoid risks for specific locations and regions and somehow to understand the uncontrollable behavior of nature. Born out of these needs are not only professional tools for remote measurement and analysis and professional practices but also the need for applying mathematics and physical operations. Collaborative effort is needed to integrate temporal-spatial measures into shared computations and the creation of seismic maps. Besides, persisting complexities and fuzziness in the nature and instruments of measurement as well as dispute on theoretic approaches afford participants to specify and argue about their sometimes conflicting research decisions and conclusions.

Affordances of the field yield to potential learning goals of students moving from peripheral participation to the epicenter of the activity. The environment we are presenting in this work consists of a seismograph network, a computer network that allows the sharing of the data generated and, most important, the tools that enables students and teacher to process this information. This environment allows the students learn about geophysics by engaging in seismographic research contents, methods and tools, develop and apply basic concepts and methods of mathematics and physics, discover the potentials of collaboration, reflect upon the impact of scientific research and the limits of human nature. To support these learning goals and provide a computation-augmented environment for collaborative learning about real-world problems, tasks and solutions the following design principles were applied:

- Orientation on expert workflow, activity structures and tools.
- Visualization supports concept understanding and the (re-)creation of common grounds. Particularly scientific visualization for data analysis allows comparably easy access to and direct investigation of else wise complex domains. From a learners point of view it also provides a means for active, open-ended exploration of scientific questions and demonstration of research results, a basis for collaborative exchange and discussion and a common ground with scientists (Edelson, 1997).
- Integration of online and offline, individual and collaborative, in-class and distributed activities.
- Flexibility to adapt the environment to the local conditions (students' background and capabilities and/or teacher's preferred teaching style).

Related Works

The CoVis Project (Edelson, 1997; Edelson, Pea & Gomez, 1995) focuses on science "Learning through Collaborative Visualization" that resembles authentic practices of science. It provides a variety of collaboration and communication tools and tries to embed the use of technology in the development of new curricula and pedagogical approaches. It focuses on a project-enhanced science learning pedagogy, scientific visualization tools for open ended inquiry and networked environments for communication and collaboration.

Bellamy (1996) introduces two systems, which are based on authentic activity theories and theories of mediation and its basis in social interaction. The first one, Dinosaur Canyon, designed for teaching earth sciences to middle school students, is a simulation of a canyon, petrology and a paleontology lab. It provides a simulated context for students to engage in the activities of interpretation of rock and fossils. Students work in small groups, each group studyinng a portion of geological sequence through the canyon. They select a 10-meter by 10-meter sqare in their area and proceed to collect fossils and rocks and analyze them in the lab. The second one, Media Fusion, allows students to construct digital video messages that can contain embedded pointers to data analysis application. It focuses on allowing students to explore issues concerning global warming. It contains seed video and text messages created by experts on global warming and actual global warming data that the students can explore.
Van Joolingen (2000) has recently suggested a synthesis between discovery learning in science and collaborative learning, both supported by computational tools. Indeed, there are a variety of different collaborative activities in discovery learning and collaborative modeling. Bollen et al. (2002) have identified following aspects of computer support in collaborative modeling:

- Several students can share a running model by synchronizing their simulation environments.
- The actual model building process can be shared activity using a modeling language and annotations in shared workspaces.
- Simulations are analyzed to generate hypotheses about the global behavior of systems. To do this in the form of group work, free-hand sketches as well as argumentation graphs and mathematical tools (function plots, tables, etc.) are useful tools.
- Data can be collected in a distributed working mode with different parameters. Shared workspaces allow for gathering data from different groups.
- Group work can be supervised by sharing the environment with a distant tutor.

These are supported by the “CoolModes” platform (Pinkwart, Hoppe & Gaßner 2001). It provides a uniform shared workspace environment which allows for constructing and running models with different formal representations (Petri nets, System Dynamics, mathematical graphs etc.). It also supports semi-formal argumentation graphs and hand-written annotations. The work reported in this paper has been strongly inspired by these developments. The SeismoFreestyler (Hoppe & Gaßner, 2002) tool we present is an extension of “CoolModes”.

The sensors network

In Santiago, Chile, a set of 8 seismographic sensors was installed in different high schools and attached to computers (see Figure 1, dark triangles). There is also an additional sensor network installed for scientific research in the region (gray triangles). A group of students interested in learning about geophysics and seismic phenomena is responsible for maintaining and taking care of the sensor and the computer at each school. When seismic activity occurs, the sensors produce data about the intensity of the earthquake at a rate of 50 times per second. This data is sent to the computer and stored in files. Three data-sets recording the intensity of the movement for a three axis Cartesian coordinate system are generated: one for the intensity according to the north-south axis, one for the east-west axis and one for the z axis. The structure of the generated file for one earthquake includes three sections where these values are displayed separately. It also includes additional information about date, time, and location of the sensor and duration of the earthquake.

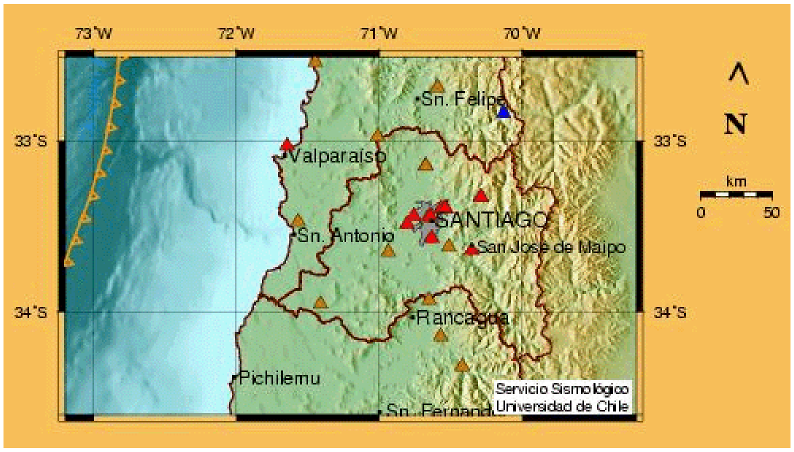


Figure 1: The network of seismic sensors

Learning by calculating the epicenter

An important goal for students is to calculate the epicenter of the earthquake by applying knowledge about wave's propagation and geometry. This is possible because the longitudinal and transversal components of the earthquake wave propagate at different speeds (see Figure 2). This will produce two impacts on a sensor: one resulting from the longitudinal and another one from the transversal component of the wave.

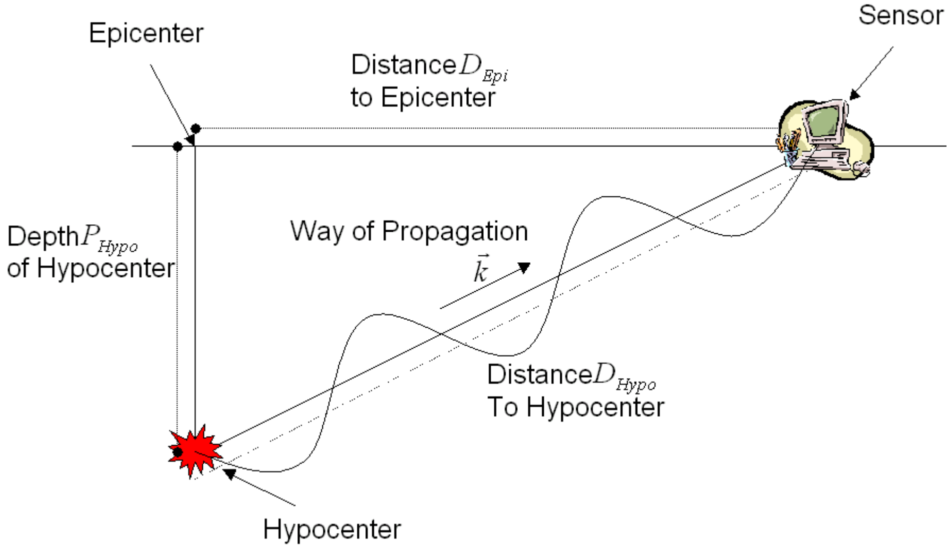
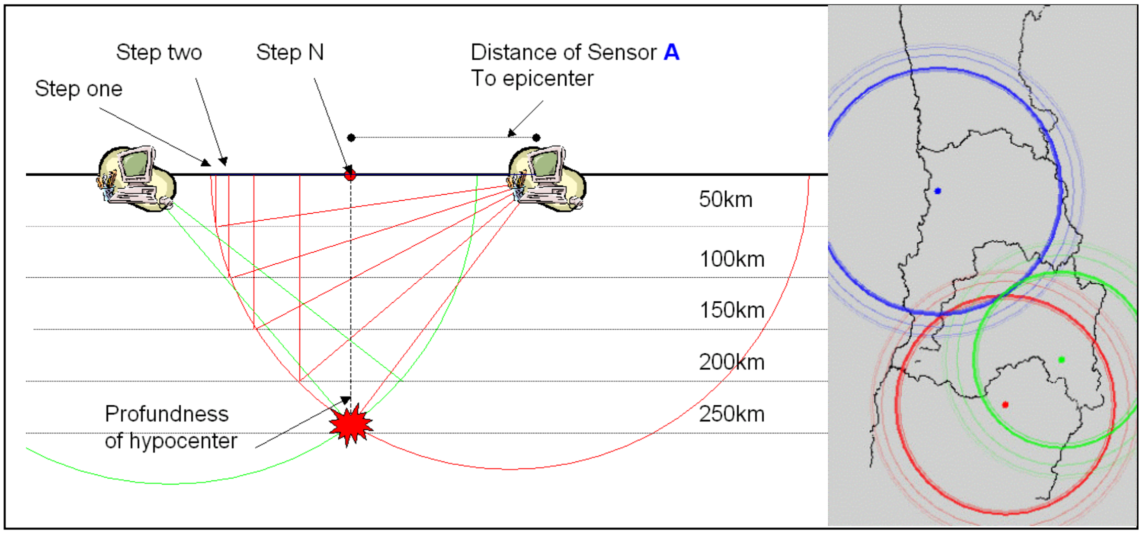


Figure 2: Propagation of a seismic wave

Longitudinal wave travels faster in the ground, so it will reach the sensor first. Both velocities are known, therefore by using simple path-time law it is possible to compute the distance at which the earthquake originated. This is the distance to the hypocenter, which is the point under the earth surface where the earthquake was generated. It may be located several kilometers beneath the ground surface and it is still not known in which direction is this point located. This distance defines a radius of a hemisphere beneath the ground surface with the location of the specific sensor as its center. By using the computations of at least 3 radiuses defining a hemisphere with a censor in its center the location of the hypocenter and then the epicenter can be determined with some degree of accuracy. The intersection of all these hemispheres defined by the data recorded at each sensor marks the volume in which the hypocenter is located. Performing iterative calculations varying the depth at which the hypocenter may be located does this. This is depicted for a two-sensor case in the figure 3. The epicenter is the projection of the hypocenter on the ground surface and marks the point where the earthquake had its largest intensity as captured by human beings.

Figure 3: The intersection of the hemispheres defines the location of the earthquake's epicenter



The students need a framework to calculate the distance to the epicenter. They should also be able to share the data with all other groups also hit by the earthquake. Finally, they must be able to share and discuss the results with the remote groups in order to learn collaboratively. The need to collaborate follows from the procedure to find the epicenter, as explained in Section 3.

For supporting these activities, a system was developed which consists of three different programs: a central server, a client, and a data processing module. The first one, central server implements the communication and data exchange functions between the groups. It allows each group to upload the local data generated by their seismograph, and the downloading of the data generated by the seismographs located remotely. It also provides a framework for the exchange of messages, news and data between the different groups, thus allowing the interaction and discussion.

The second one, the client program is the counterpart of the central server program, which runs locally in every computer attached to a seismograph. It may also run in computers of groups, which have no seismograph, for example, in schools in another region or even another country, but in this case the seismograph's data uploading functionality will not be used.

The third one, known as SeismoFreeStyler, which is and extension of FreeStyler (Hoppe & Gaßner 2002) is the program which allows the students to process the data of the different seismographs for calculating the epicenter's location. FreeStyler is a parallel development to “CoolModes” with the following specific features: It combines “Concept Mapping”-tools with archiving and retrieval functions. These allow to build and access a group- or “Corporate Memory”. Beside the retrieval aspects the system supports the structuring and representation of different kinds of knowledge. A palette of different object types and relationships (as well as annotations and free handwriting) provides a visual language in the form of semantic networks.

The system provides a working area, which is meant to support the workflow of the students’ activities. A workflow is represented as a network of different types of nodes, each one implementing a step further towards the calculation of the epicenter. The nodes have different functionalities and appearance (see Figure 4). Students can create and place nodes in the working area by "drag-and-drop" from a palette of different node types. Adding an edge between two nodes they may transfer output values of one node into input values for the successor, wherever this operation makes sense.

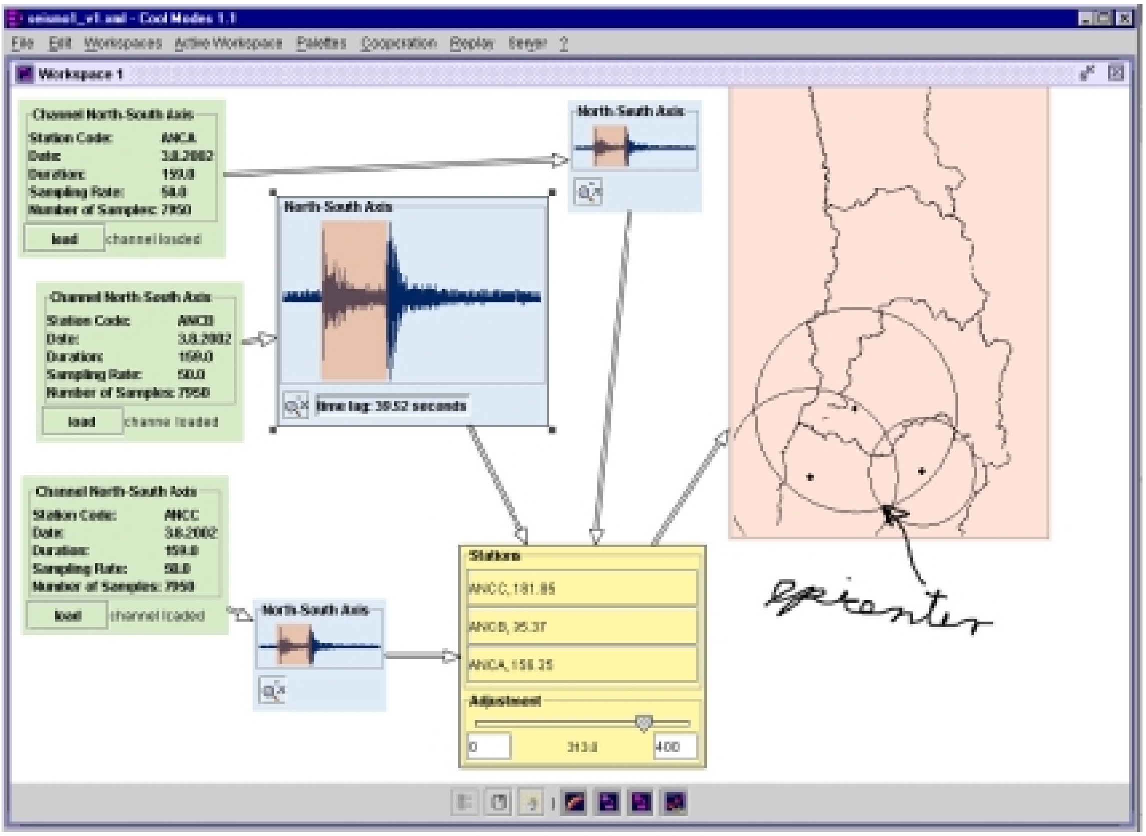


Figure 4: The workspace with different kinds of nodes dragged into

The first type of nodes (at the very left side of Figure 4, representing values from three different seismographs) is able to read and store the data of a file generated by a seismic sensor. It also displays some useful information like date and duration of the event. The second type of node (in the top middle of Figure 4) is able to graphically display this information, if the students connect them with an arrow. Here the students can easily determine the time lag between the primary and secondary wave, just by marking this space in the graphic node. Also the student can zoom in and zoom out, scroll or mark relevant data points. The determined time lag is the basis for further calculations as mentioned above. The third or "calculation node" uses this value to compute the distance depending on the time lag and the chosen depth (at the bottom of Figure 4, summarizing the values for three seismographs). When students establish a connection with the last or "Map Node" the system displays the map of the specific region e.g. Santiago, Chile, and shows the computed distances. On the right-hand side of the Figure 4 the palette for choosing the different nodes is displayed. Using this two-dimensional top view the minimum intersection area can easily be found. In this way, this nodes network offers a workflow to exchange results and/or intermediate data.

Learning by Collaborating

According to Bellamy (1996), three principles for the design of educational environments have been derived from Vygotsky's work:

- Authentic activities: Children should have access to, and participate in, similar cultural activities to those of adults and should be using age-appropriate tools and artifacts modeled on those used by adults. The system creates the environment for authentic activities because it gives the possibility for the students to mimic the activities professional people do while monitoring and recording earthquakes, as well as calculating some characteristics of them. The system gives the appropriate scaffolding for doing transformation of data and calculating complicated formulas.
- Construction: Children should be constructing artifacts and sharing them with their community. FreeStyler documents enable the collaborative construction of the workflow for calculating the characteristics of the

earthquake, which they can share, with the rest of the community. In the next chapter we will see how students can construct physical artifacts to model the earthquake.

- Collaboration: Educational environments should involve collaboration between experts and students and between individual learners and fellow learners. Our setting allows different kinds of collaborative learning activities:

Collaboration inside one group: the group trying to compute the distance to the hypocenter, based on local data. The tool supports asynchronous collaboration by annotating and recording the work of each participant. Creating coupled sessions supports synchronous distributed collaboration.

Collaboration among groups in the same earthquake region: exchanging data produced by the seismograph is the first step towards collaboration. Calculation of the distance from a seismograph to the hypocenter is based on visually determining the time difference between the arrivals of both waves. Since calculating the distance to the hypocenter is based on a visual procedure. This will necessarily mean, the results of the different groups will not be exactly the same. The system gives the necessary platform for the groups to engage in a discussion, trying to find the most probable area where the hypocenter was located, contrasting all the results.

Collaboration among groups in different regions: because the system is working over the Internet, it gives student groups located in remote areas the possibility to use the same data, ask about the consequences of the earthquake and try to “reproduce” it in the virtual laboratory.

Visualizing Results

The visualization of outputs is very important in our approach. It helps students to really understand the involved physical phenomena. It also provides opportunities for new learning activities. The visualization implementation is under way at the time of writing this paper. Therefore, only the design is presented.

The first way of providing access to results is through animated waves. Students will be able to see the waves from the hypocenter or the projected waves on the Earth surface (see Figure 5). Also provided will be the visualization of the propagation of the earthquake, depicting the hypocenter and the waves reducing their size as they get far from the hypocenter.

A second visualization feature to be provided is the illustration of the intersecting (virtual) hemispheres. This will allow students to visually understand the theoretical computation of the hypocenter location. It may also motivate students to care about people living at a short distance of the epicenter. Understanding the effect of earthquakes will be obtained by accessing recorded 3D animations of buildings subject to various degrees of earthquake strength. These animations will be complemented with the corresponding sounds. Finally, a real-object understanding of the effect of earthquakes on buildings is being designed with the help of Lego Mindstorms models (Papert). Students having access to models of this type can have a touching feeling of the seismic movements. Moreover, students can try to build Lego towers resistant to strong earthquakes.

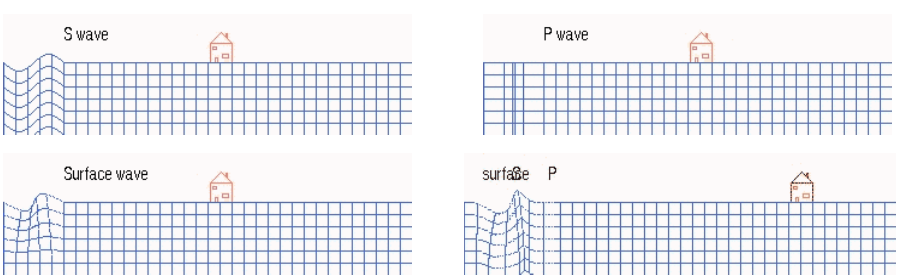


Figure 5: Visualization of seismic waves

Conclusions

Since the sensor network is connected to the WWW, students of any part of the world may be able to do the calculations and learn from an earthquake. The idea of installing sensors in schools is not new: there are some similar initiatives in USA, France and Japan. The novel idea is to use them for collaboration at various levels.

The main contribution of this work is to present a platform supporting cooperative learning. This work is part of a larger project named Coldex (2003), which deals with the problem of achieving true learning through remote collaborative monitoring or experimentation. One of these Coldex experiences we are doing is to set up a system, which allow students to remote control a telescope and capture images from the sky. In our opinion, this is only the first part of the work, which should be done in order to achieve meaningful learning through remote or distributed collaborative experimentation. There must also be a system supporting the learning process through concrete learning activities. The Coldex telescope experience considers the development of a supporting system, which will allow the students to simulate the scientific work and procedures professional astronomers do.

The work described in this paper allows various types of collaborative learning, since the results of others are needed for own work, and vice-versa. The collaborative opportunities provided by the setting occur naturally. This is perhaps the main difference with other collaborative learning experiments in which the collaboration is artificially induced.

Following our approach to collaborative learning, students from different cultural backgrounds but sharing the fact of living in seismic active areas (e.g., Japan, Chile and Italy) can work together. It is also possible to integrate students not subject to earthquakes but who are willing to learn and share others' problems.

For students living in seismic areas, this is an opportunity to understand the phenomena and be prepared for earthquakes. It is a way of reducing fear and anxiety. More importantly, this process of personal growing is done cooperatively with other students.

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