Learning about Earthquakes:
Getting Serious about Authenticity in Computer-supported Learning

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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, knowledge construction and collaboration. The implementation of the learning environment called SeisModes is based on a general platform for supporting collaborative modeling activities. SeisModes provides a tool to allow students collaboratively learn about earthquakes and thus reduce the fears they might have concerning them. First formal evaluations showed the approach motivates students.

Keywords: Collaborative Learning, Authentic activities, Earthquakes Preparedness, Science Education, Knowledge Modeling.

1. Introduction

Vygotsky's (1978) socio-cultural theory promotes the importance of social interaction and the use of artifacts for knowledge acquisition. Bellamy (1996) proposed three principles for the design of educational environments based on 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 among learners and their peers as well as among students and experts.

However, activity-theoretic approaches (e.g., Bertelsen and Bodker, 2003) usually remain general when applied to the design of tasks and artifacts. Especially the notion of authenticity widely spread in the current literature on e-learning remains a blurry demand rather than a well-defined concept. This paper presents a concrete implementation of the activity-theoretic approach and it specifies the requirements for a digital artifact supporting this approach. The subject to be learned is the earthquake phenomenon and the developed system implements an environment where students can retrieve real data from seismographs and compute interesting statistics.

Reviewing educational theory and research on authentic activities and online learning, Reeves et al. (2002) extracted ten characteristics from authentic activities. Some of these features are: authentic activities are supposed to have real world relevance and create valuable products. The activities involve ill-defined, complex tasks to be examined from various perspectives, using a variety of resources and allowing a diversity of outcomes. They provide opportunities for collaboration and reflection and they can be applied across several subject areas.

Reeves et al.'s list of characteristics is not a final and universal definition of authenticity. Reeves et al. rather referred to the need to define what is meant by authenticity and which requirements for learning can be derived from each definition. We take into account activity theory by starting from a problem-space that motivates activities. In particular, we specify/substitute authenticity by real-world problems, tasks and collaboration. Thus, instead of claiming vague authenticity, we propose to design learning environments for the accomplishment of goals and tasks, derived from real-world problems requiring collaboration.

These real-world or practical problems and goals exist independently and before designing the specific learning setting. Therefore, there are solutions used by professionals which can provide a frame for the students' learning activities. The conceptual gap between learning and professional worlds (Quintana et al., 2001) may be filled in this way. This is also consistent with the problem-based approach to learning (Reinmann-Rothmeier & Mandl, 2001). Being coherent with Vygotsky's works, practitioners should ideally provide scaffolding support to learners' proximal development. On their side, students should be motivated to participate in communities of practice in order to eventually contribute valuable input and proposals for solutions. A seamless integration of learning activities with assessment resembles real-world processes and prevents the setting from imposing a purely artificial activity structure.

It must be emphasized that the need for collaboration should not be unnaturally forced on the community of learners by the system but grounded in the nature of the task. The learners will appreciate the value of collaboration only if it is clearly needed to accomplish the task or achieve better results than alone: they will seriously engage in collaborative activities such as sharing information, discussing partial research results and produce shared decisions and synthetic solutions. Understanding and appreciating the need for collaboration may be a significant part of the learning process.

The rest of the paper is organized as follows: Section 2 presents the general domain of application in which the learning strategy will be implemented. Section 3 includes a bibliographic review of the subject. The specific scenario of experimentation is described in Section 4. Section 5 describes the educational approach for this scenario. Section 6 discusses how this approach fits Bellamy's authenticity principles. Section 7 presents some experimental data and Section 8 concludes the paper.

2. Distributed seismography

A real-world problem deals with the natural phenomenon of earthquakes experienced by students in several parts of the world. Inhabitants of those regions are suddenly subject to the shaking of the earth's surface without being able to actively relate to it. On the other hand, results from seismographic research are used to analyze seismic processes, to evaluate and avoid risks for specific regions and locations and somehow to understand the uncontrollable behavior of nature.

The gap between scientific research of earthquakes and the experience of people having just had an earthquake is an opportunity to create a collaborative learning activity. Students may use specially adapted versions of professional tools and practices for remote measurement and analysis. Such tools and practices will also allow applying and developing mathematics and physical operations. A 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 theoretical approaches afford participants to specify and argue about their sometimes conflicting research decisions and conclusions. Students move from a peripheral participation to the epicenter of the activity by facing the challenges of real practitioners.

The environment we are presenting in this work consists of a seismograph network, a computer network that allows the sharing of the generated data and the tools enabling students and teacher to process this information. The main student activities we want to support are:

- Learning by engaging in seismographic research contents, methods and tools.

- Developing and applying concepts and methods of mathematics and physics.
- Discovering the potential of collaboration.
- Reflecting upon the impact of scientific research on human lives.

The following paradigms and design principles were applied to support these learning goals. They also provide a computation-augmented environment for collaborative learning about real-world problems, tasks and solutions:

- Orientation on expert workflow, activity structures and tools.
- Visualization that supports concept understanding and the (re-)creation of common grounds. In particular, scientific visualization for data analysis allows comparably easy access to and direct investigation of otherwise 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 et al., 1999).
- 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 skills).

3. Related work

A review is made below of previous research on authentic activities and the use of seismographs in schools. Although there are several initiatives aimed at providing students with hands-on experience with seismographic data, they differ from our approach in the way students process the data in order to achieve significant learning.

3.1 Implementation of Authentic Activities

The CoVis Project (Edelson, 1998) focusing on science - "Learning through Collaborative Visualization"- resembles authentic practices of science. It provides a variety of collaboration and communication tools and it 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.

For Edelson, authenticity refers to a learning situation reflecting the context of use. He thus characterizes science practice with its attitudes of uncertainty and commitment, discipline-specific tools and techniques and social interaction. Uncertainty refers to the continual re-examination of techniques and results in the pursuit of unanswered questions. Commitment indicates that the inquiry has meaningful ramifications within the scientists' value system– or the students' one. The use of historically refined tools and techniques also provides a shared context easing communication. 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, 1998).

Van Joolingen (2000) has suggested a synthesis between discovery learning in science and collaborative learning, both supported by computational tools. Indeed, there are several collaborative activities in discovery learning and collaborative modeling. Bollen et al. (2002) have identified the 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 a collaborative activity using a modeling language and annotations in shared workspaces.
- Simulations are analyzed to generate hypotheses about the global behavior of systems. Free-hand sketches as well as argumentation graphs and mathematical tools are useful to do this analysis in group work.
- Data can be collected in a distributed working mode with various parameters. Shared workspaces allow for gathering data from different groups.
- Group work can be supervised by sharing the environment with a distant tutor.

The “CoolModes” platform (Pinkwart et al., 2001) developed by the COLLIDE group (COLLIDE, 2008) supports these activities by providing a uniform shared workspace environment which allows for constructing and running models with various formal representations (Petri nets, mathematical graphs, etc.). It also supports semi-formal argumentation graphs and hand-written annotations. The work reported in this paper has been inspired by these developments. In fact, the CoolModes platform was extended in order to allow modeling of the workflow needed to analyze the data generated by the sysmographs, as it will be explained in detail in section 5.

3.2 Seismographs at schools

Acknowledging the motivation that a seismograph can produce in schoolchildren, many initiatives have been established to provide seismographs to schools for supporting earthquakes learning. The Boston College Educational Seismology Project first installed a seismograph at the Garfield School for fourth- and fifth-grade schoolchildren where they can monitor and see the seismogram generated by earthquakes all over the world. They report an increased students’motivation to understand and learn about these phenomena (BostonCollege, 2008).

As part of the Seismographs in Schools Program, the Incorporated Research Institutions for Seismology organization (IRIS, 2008) provides educational seismographs and related materials to selected teachers for use in the classroom. The seismographs are used in the laboratory to teach about seismic waves, earthquakes, how a seismograph works, and data collection principles. They claim the use of the seismograph by teachers and students and recording actual data from local and significant events from around the world can stimulate interest and motivation to further learning on seismology and Earth science. Also in the USA, the Educational Seismology Network (USESN, 2008) promotes the use of seismographs and seismic data for science education. In Germany, a workshop about constructing and using home-made seismographs was organized by motivated students at the Monschau St.-Michael High School. Similar initiatives have been reported from other schools in Germany (Philipsburg, Aachen, Staufen), Italy (Napoli), Norway, and Portugal.

These projects, at least formally, do not claim to promote and put in practice a certain educational methodology. They seem to concentrate more on the installation of seismographs, distribution of software for visualizing the waves and complementary learning material for motivating the study rather than proposing a novel didactic process grounded in the learning sciences. An interesting exception to this is Roomquake (Moher, 2005) which is based on a principle its authors call Embedded Phenomena. In this project, children simulate an earthquake occurring in the classroom. Handheld computers simulate the waves recorded by a sensor for a certain earthquake whose epicenter is somewhere inside the classroom. Student teams read and interpret the seismogram waveforms and determine the roomquake magnitude and distance of the epicenter of the quake from each of the stations. They do this with the help of a dry-line (calibrated reel of twine) anchored at each of the seismographic stations. Pulling out the corresponding length of twine, students sweep out arcs until they literally collide with one another, physically enacting a mathematical triangulation of the epicenter.

By contrast, the approach presented in this paper starts from and it is deeply rooted in learning theories and methodologies. At the same time, it re-creates the real professionals' actual working environment, hiding the advanced details which are irrelevant to learn the intuitive concepts.

4. A Sensors Network for Chilean Schools

Chile is a seismic country: several large earthquakes happened in this country during the last century (notably, in 1906, 1939, and 1960). It is, therefore, a suitable scenario for distributed seismography, as introduced in Section 2.

A set of eight seismographic sensors were installed in some Santiago high schools and attached to computers (Fig. 1, dark colored triangles). Students interested in learning about geophysics and seismic phenomena are responsible for maintaining and taking care of the sensor and the computer at each school.

Figure 1. The network of seismic sensors

It is possible to compute interesting characteristics of an earthquake using the data gathered by the sensors, e.g., the location of its epicenter and its magnitude. This requires the application of knowledge about how waves propagate in the ground and some knowledge about geometry. In particular, computation of the epicenter is based on the different propagation speeds of the primary and secondary waves. The computation is based on intuitive principles. However, the actual computing is a tedious and time consuming procedure, especially if we want to obtain accurate results. There is highly sophisticated software developed for professionals, e.g., SEISAN (2008), which allow with just a few mouse clicks to quickly obtain accurate results for the computations. They are designed for the expert geophysicists and they do not stress the awareness of the background necessary for the calculations, encapsulating, and thus hiding the principles in which they are based, which are supposed to be known by the user.

Although the presence of a seismograph was shown to be a very motivating element for students in order to enhance their interest for studying earthquake phenomena, the geographical distribution of them was not good enough to have data for making the triangulation needed to calculate epicenter and magnitude. Consequently, we arranged that the students could also get access to data sets generated by seismographs belonging to the Chilean National Seismological Service, which runs a large network of them, conveniently distributed in order to obtain quality data for computing the parameters of an earthquake (Fig. 1, light colored triangles). We obtained access to the data of eleven seismographs located in central Chile. The data produced by each of these seismographs is stored in a dedicated server whenever a tremor occurs which surpasses a certain threshold, in order to avoid recording noise produced by events other than real earthquakes. There is an average of 4 to 6 of such events in normal days in this area. Although 90% of them are not perceived by people, 30% of the recorded events produce data of enough quality for doing the calculations. A server for the project was set up to provide the following functionalities:

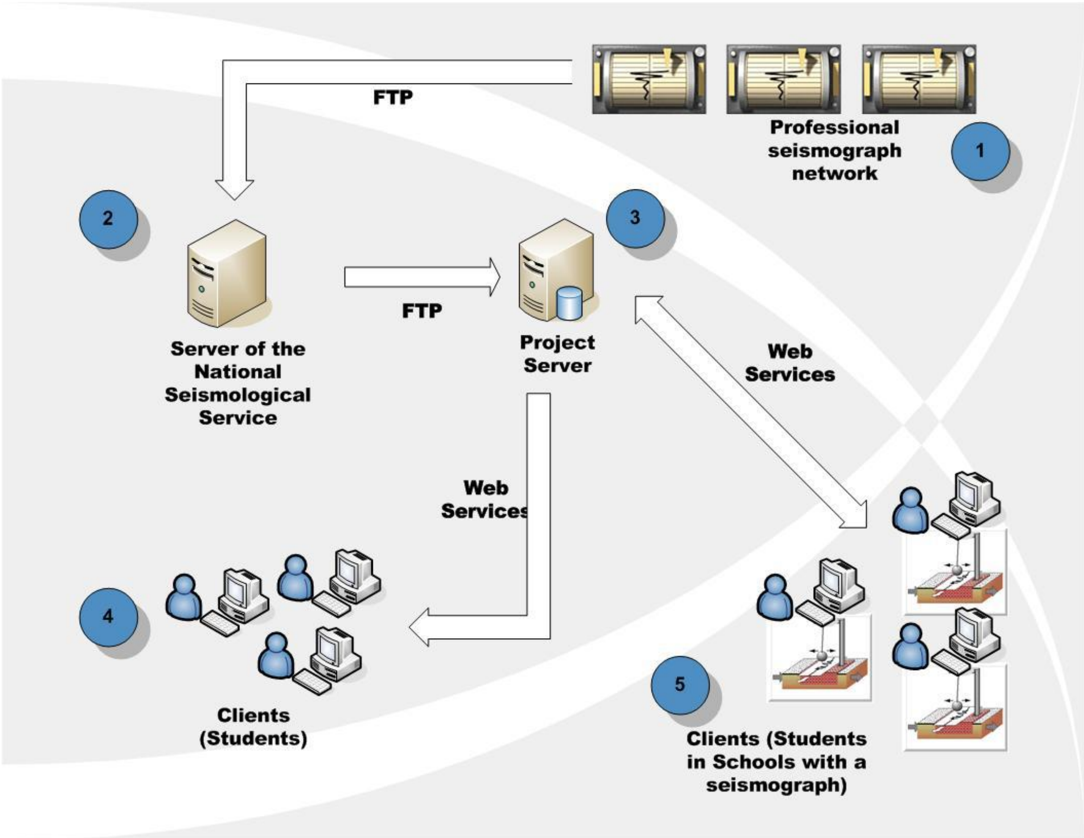

Figure 2. Data flow from its generation to the processing.

- Download the seismological data from the Seismological Service server once a day using FTP protocol. This means about 4-6 data files will be downloaded, according to the number of events recorded during the previous day.
- Allow client programs using Web Services to retrieve this data which is useful for computing the characteristics of the earthquakes that generated them.
- Allow students in schools having a seismograph to upload data to share it with other schools.

Figure 2 shows the architecture that allows the retrieval and sharing of data for the project: (1) represents the generation of data at the professional seismographs. The data is transmitted via ftp to the server of the Seismological Service (2). The data is then downloaded by the project server also via ftp (3), which is contacted by the students (4) using the Web Service protocol. Students from schools having a seismograph (5) upload their data to the project server and download the data from the professional seismographs using the Web Service protocol.

5. Challenge-based learning in a seismic scenario

Project-based and problem-based activities are usually focused on a driving question or problem (Jonassen & Murphy, 1999). In what we call Challenge-Based Learning (CBL) (Baloian et al., 2006), the question or problem is replaced by a challenge. This challenge may be initiated either by the teacher or a student group. The challenges to be solved might include ways to develop, design and implement solutions for problems related to scientific phenomena. A meaningful learning activity consistent with CBL is to present learners with a challenge scenario and to ask them to think about a number of possible solutions using a variety of interactive tools.

Several "Digital Experimentation Toolkits" (DExTs) have been developed within the COLDEX (2008) project to support educational classroom scenarios according to the CBL approach. A DExT includes experimental instructions, scientific background information, modeling and simulation tools, access to real scientific data, and the formulation of initial challenges providing an open-ended learning environment that stimulates learners to identify and solve a challenge according to Authentic Learning and CBL. These DExTs are intended to be handed out to schools to be used in, but not only, normal lessons. They provide innovative use of interactive media to enrich the curricula. Teachers should be enabled to integrate these new resources easily in their lessons. Since only a few teachers have time to spend on courses or time-consuming studies for "learning" to use these toolkits, they are mostly self-describing and trouble-free. DExTs are not to be seen as expert systems which present themselves as authoritative and definitive.

Therefore, setting the network of sensors and servers is only part of the work: a DExT for learning the geophysics of the earthquakes should be built. With this aim we developed a tool which enables students to download seismological data from the project server. The tool also assists the students to perform the computations to determine the distance to the epicenter, magnitude of the earthquake and other interesting derived data. The tedious but necessary computational work is encapsulated, in order to drive the students' whole attention to learning the important concepts behind the calculations. The students use a program implementing the following functionalities:

- Retrieve data from the local seismograph
- Publish the local data on the common server
- Download data from remotely located seismographs
- Provide a framework where students can do their computations and graphic operations to find the epicenter
- Provide a framework to compare and analyze the results obtained by other groups
- Provide a discussion framework

The tool called SeisModes was developed especially for this work on top of the CoolModes modeling tool (Pinkwart, 2003). This tool is then the DExT we planned to develop for learning earthquakes geophysics. On an abstract level, CoolModes can be seen as a graph editor, which allows the inclusion of various "palettes" defining a group of specific nodes and arcs with particular functionalities in order to model a certain system. For example, palettes exist for modeling Petri nets, mathematical graphs (Müller et al., 2004), calculating elevations on the moon (Hoeksema & Hoppe, 2004), etc. New palettes are implemented by extending basic nodes and edges, programming the new necessary functionalities and providing them with a convenient shape. The functionalities of saving and retrieving the work are provided by the tool, as well as the possibility of working collaboratively in a synchronous and asynchronous way (as discussed below). For this project, the idea was to model the data flow to do the necessary calculations and graphics in order to find the specific parameters which characterize an earthquake. For this purpose, a new palette was implemented with nodes providing the functionalities to retrieve data from the seismographs, show the shape of the generated wave permitting the measurement of the amplitude and the time difference between the hit of the two waves of an earthquake, calculate distances and show the necessary graphics to help finding the epicenter by triangulation. The tool supports the students in their calculations and graphics by providing a suitable working area, which is meant to contain the workflow of the students' activities. A workflow is represented as a network of different types of nodes, each one implementing a step towards the calculation of the epicenter. Students have to create the workflow graph by dragging the nodes from the palette and dropping them in the working area. The nodes have differing appearance according to their functionalities (Fig. 3). Adding an edge between two nodes transfers output values of one node as input values for the successor, but of course, this is allowed by the system only between nodes where this operation makes sense.

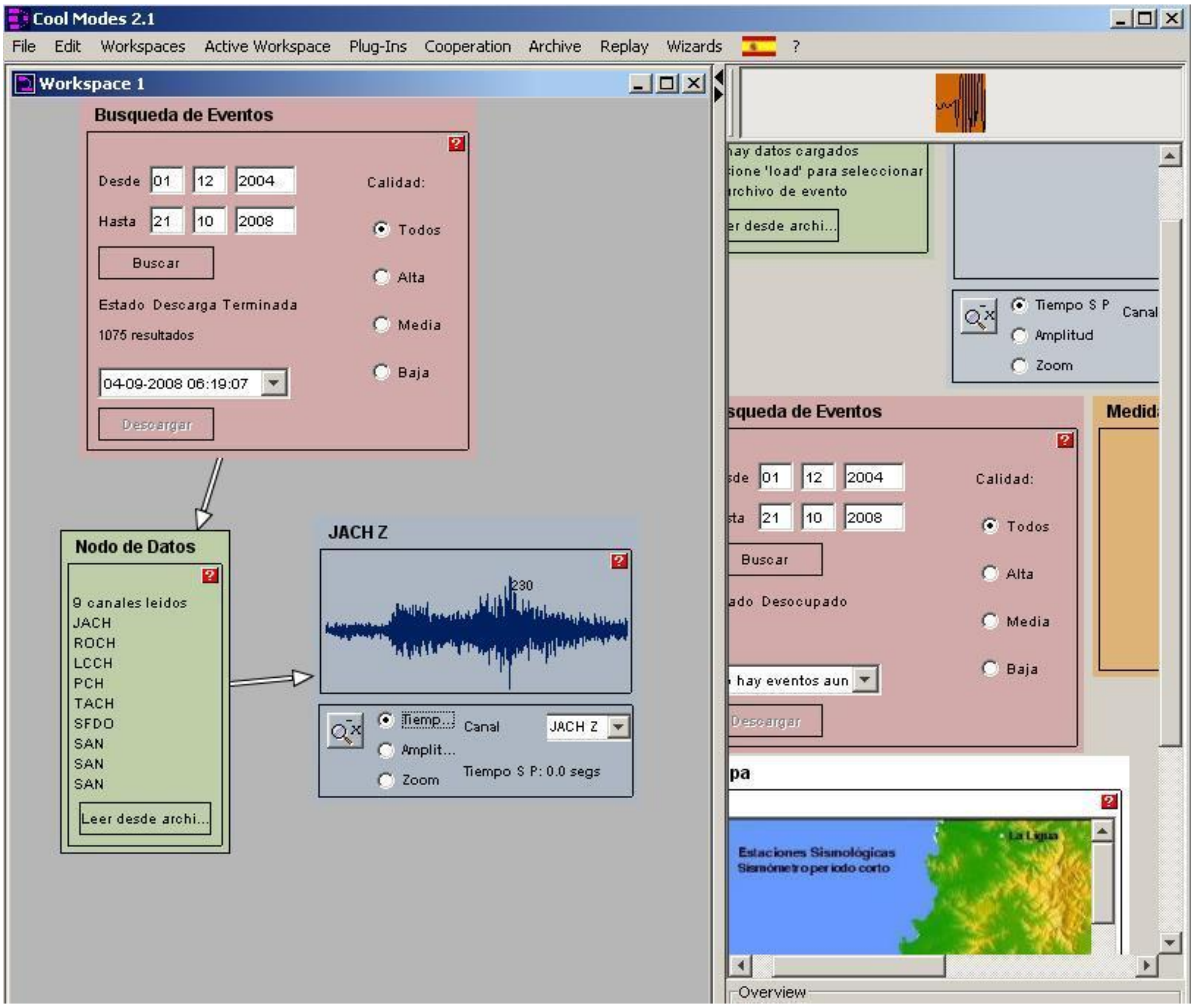

Figure 3. The figure shows at the right side the workspace with the nodes needed to search for an event and download its corresponding data, process the data, and show the wave corresponding to one seismograph. The palette with all the available nodes is shown on the right side.

One type of node (the first in the sequence of Fig. 3) is able to search for events in the repositories. Another one (second in the sequence) can read and store the data of a file generated by a seismic sensor. It also displays useful information like date and duration of the event. Another type of node (third in Fig. 3) is able to graphically display this information, if the students connect them with an arc. Thus, the students can easily determine the time lag between the primary and secondary wave, just by marking this space in the graphic node (as seen on Fig. 1). The student can also zoom in and out, scroll or mark relevant data points. The determined time lag is the basis for further calculations as mentioned above. The "calculation node" uses this value to compute the distance dependent on the time lag and the iteratively chosen depth. Establishing a connection with another node called "Map Node" displays the map of the specific region e.g., Santiago and the computed distances as well.

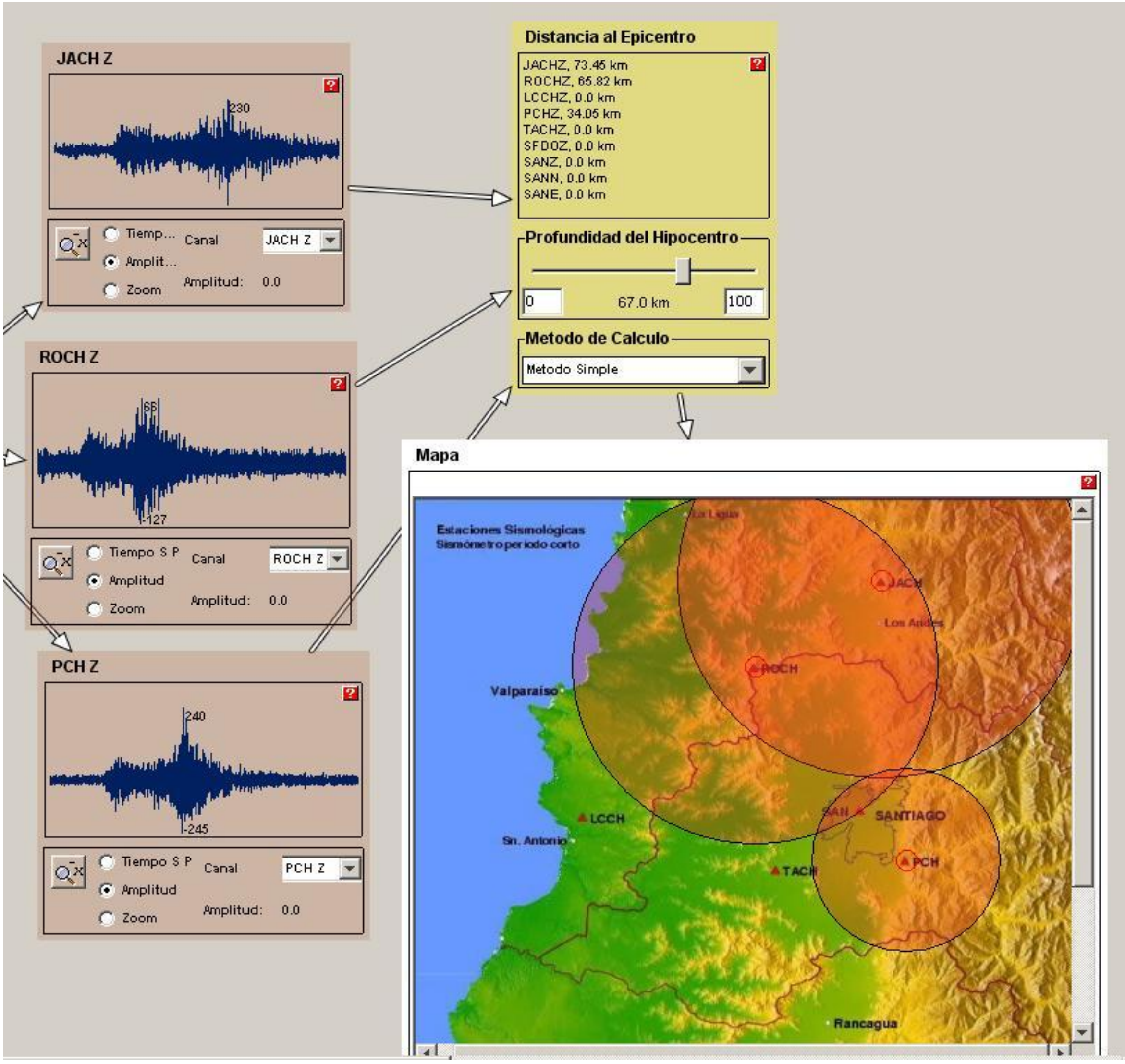

Figure 4. The figure shows part of the workspace while searching for the epicenter with data from three sensors. The map node is useful to find the intersection point.

The minimum of the intersection can easily be found using this two-dimensional top view (Fig. 4). In this way, this nodes network offers a workflow to exchange results and/or intermediate data. The way the tool implements the support calculation of the earthquakes' characteristics is the key to implement the CBL approach: teachers can assign different challenges with various degrees of openness and difficulty. On one end, students can be provided with an existing document with the whole workflow needed to make all the calculations and be asked to just download the data to determine the characteristics of an earthquake. On the other end, they can be confronted with very open questions like "how is the seismic activity around the city of Talca?" or "which was the largest earthquake during last week?" The system allows the students to find the information to answer these questions but the strategy followed by a student may differ from that used by another student.

6. Supporting Authentic Activities, Construction and Collaboration

As noted in the introduction, according to Bellamy (1996), three principles for the design of educational environments have been derived from Vygotsky's work: authentic activities, construction and collaboration. Let us see how the presented approach fits these principles.

- **Authentic activities:** Students 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 their characteristics using real professional data generated from the same sources experts use.
- **Construction:** Children should construct artifacts and share them with their community. SeisModes documents enable the collaborative construction of the workflow for calculating the characteristics of the earthquake, which they can share with other persons. On one hand, the system gives the appropriate scaffolding for doing data transformation and calculating complicated formulas, encapsulating them in order to drive the students' attention to the conceptual principles that are important to learn. On the other hand, it does not automatically do all the calculations from the source data, as some professional systems do: students must create the workflow.
- **Collaboration:** Educational environments should involve collaboration among experts and students and among individual learners and fellow learners. This setting allows various kinds of collaborative learning activities:

a) Collaboration inside 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 done by each participant. Creating coupled sessions supports synchronous distributed collaboration. For this purpose, the tool was integrated with MatchMaker (Jansen, 2003; Baloian et al., 2007). It permits the creation and coupling of shared workspaces where students can work synchronously constructing the same graph.

b) Collaboration among groups in the same earthquake region by exchanging data produced by the seismograph is the first collaborative step. 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.

c) Collaboration among groups in different regions is possible because the system is working over the Internet. The system 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. Asynchronous (and even "anonymous") collaboration is allowed by the implementation of a learning material repository which was set up for the COLDEX project. The CoolModes tool (and by extension also SeisModes) has a built-in function to upload the work currently in the workspace as a learning object. For this purpose, the system will try to automatically gather as much information as possible to fill in the values of the required metadata using e.g., the system's information, the language, the palettes being used, and the user identification if available. Missing metadata may be filled by the user. The system also allows searching for an existing learning object in the repository which has similar characteristics to the one on the workspace.

It should be noticed that an alternative DExT design could have forced students to cooperate. For example, each student group could have been provided with data from just one seismograph and, therefore, requiring them to communicate and collaborate for at least sharing the data. However, that approach would have been unnatural and thus opposed to the authenticity principle.

Our work has a lot of common ground with Edelson's CoVis work (section 3). Students have to learn immersed in a real environment facing open ended challenges. Communication among students is also a fundamental aspect in both projects. In our case we stress the use of scientific tools and real data. Our work is also coherent with van Joolingen's principles (as explained in section 3) since it merges scientific discovery learning with collaborative knowledge construction thanks to the use of the SeisModes tool.

7. Evaluation

7.1 Introduction

Although several teachers and students have been working with the tool during 2006 and 2007 with the developed system, we wanted to formally evaluate the students' perception on the suitability of the tool for supporting learning earthquakes physics, its potential to foster collaboration, and its ability to motivate the students, before deploying it on a large scale in many schools. Since Chile is a seismically active country, its Ministry of Education has instructed schools to carry out activities in order to increase the awareness of this phenomenon among the population. Thus, it was quite easy for the authors to approach schools and offer this material to be incorporated in the curricula. The software has been used in three schools including two of those having a seismograph installed in their premises and one which does not. We set up a formal SeisModes evaluation in one of the schools with a seismograph, after several formative assessments to get feedback information to improve it.

7.2 Method

The testing was made with subjects taken from a 10th school year class with all students aged 16 using SeisModes for the first time in a school which had a seismograph installed in the schoolyard. Twenty two students took part in the testing, being 15 of them male and 7 female. Eight of them said they used the computer more than 6 hours a week, 10 said they used it between 3 and 6 hours, and only 4 of them less than 3 hours. Eighteen students said they use it mainly for entertainment and socializing and 4 of them mainly for studying.

The testing was done in two sessions of about two hours each during a Physics laboratory activity. The first session consisted of a theoretical explanation about earthquakes, a visit to the seismograph and a short explanation on how to use the SeisModes program to calculate the earthquake characteristics. A pre-test was also taken before the first session in order to measure the previous knowledge about earthquakes. The same questions were asked at the end of the second session. For the pre-test and the post-test, the questions were evaluated by the teacher with a mark ranging from 1 (the student has no idea) to 5 (the student answered the question very well).

During the second session they received a worksheet with activities they had to carry on to answer some questions. The questions were:

- How many earthquakes happened during May 2006?
- Which was the strongest earthquake during that period of time?
- Where was the epicenter located?
- Paint the area on the map where people could feel that earthquake
- Can you find a stronger earthquake which took place in another period of time?

Students had to work with SeisModes to answer those questions, which were designed to be triggers for students to explore and learn about earthquakes. An observer was recording interesting facts about the way the students worked with the tool for completing the task. Two assistants helped the students with the usage of SeisModes during the testing. After working with SeisModes, the students filled a questionnaire which was designed to gather required information in order to validate or reject the following three hypotheses:

Hypothesis 1: *The tool is perceived as suitable for learning about the physics of earthquakes.*
Hypothesis 2: *The lesson involving the tool helps understanding the need for collaboration.*
Hypothesis 3: *The tool is considered as motivating.*

The 22 participating students were asked to indicate their level of agreement with 12 statements on a scale ranging from 1 to 4 (1 for strong disagreement, 2 for disagreement, 3 for agreement, 4 for strong agreement).

7.3 Results

The first stage of the testing began with the application of the pre-test, which took about 20 minutes. As expected, the background knowledge of the students was poor, which was reflected in the results. The questions for the pre- and post-test, as well as the evaluations for both tests are shown in table 1. After the pre-test, the students were taken to see the school's seismograph while explaining them how a seismogram works for about half an hour. After this, they returned to the classroom, where the teacher explained them the way an earthquake originates, how the waves are propagated and the form a regular seismogram has due to the arrival of two waves at different times. The in-classroom lecture took about 45 minutes.

The second stage of the testing took place one week after the first one. It began with a review of the concepts learnt the week before (10 minutes) and a demonstration of the SeisModes tool (20 minutes). After that, the students received the worksheet with the questions they had to answer using SeisModes. All students could complete the tasks within 90 minutes.

Table 1: *The pre- and post testquestions and their evaluation results*

Question	Pre-test	Post test
How does the ground moves during an earthquake?	2.77	4.23
How can you determine the distance from a sensor to an earthquake epicenter?	2.18	3.68
What is the earthquake epicenter?	1.91	4.14

What is the earthquake hypocenter?	1.45	3.45
How can you determine the location of the epicenter of an earthquake if you know the location of the hypocenter?	2.45	4.77
What is the earthquake magnitude?	2.50	3.77
Which data do you require to calculate the earthquake magnitude?	2.36	4.00
Mean	2.23	4.00

After completing the worksheet tasks, the students answered two questionnaires: the post-test for evaluating the acquired knowledge and the one for validating the four hypotheses. The questions for testing the hypotheses, along with the obtained results are shown in table 2.

Table 2: *The table shows the list of assertions associated to each hypothesis. Students expressed their level of agreement with each one with a number between 1 and 4. Assertions 1.6 and 3.2 were negatively formulated so we used the complementary value for calculating the mean value.*

Hypotheses and Related questions	**Result**
H1. The tool was perceived as suitable for learning about the earthquakes physics.	
1.1 The framework for calculation helped me to understand the necessary steps.	3.27
1.2 The tool helped me to understand how experts calculate the epicenter.	3.55
1.3 I found the tool suitable for learning about the earthquakes physics.	3.73
1.4 The visualization was helpful for understanding the waves propagation.	3.23
1.5 The tool helped me to understand the mutual dependency of the variables.	2.91
1.6 I do not know how the tool could help me to learn about earthquakes.	1.27 (2.73)
Mean value	**3.24**
H2. Working with the tool helps understanding the need for collaboration.	
2.1 Due to the tool I understood, why several people have to collaborate	3.00
2.2 I appreciated the discussion in class about how to optimize the measures. It helped us to obtain better results.	2.96
2.3 If possible I would appreciate a discussion among various groups at different schools each one managing one sensor.	3.18
Mean value	**3.05**
H3. The tool was experienced as motivating	
3.1 I would have preferred to learn only with textbooks and drawings	3.28
3.2 It was boring to work with the tool.	1.28 (2,72)
3.3 Working with the tool motivated me to learn more about earthquakes	3.42
3.4 The tool engaged me to explore variations in the steps and solution	2.68
Mean value	**3.03**

7.4 Analysis of the results

Comparing the results of the pre and post-tests we see a dramatic improvement of the students' knowledge: from a mean of 2.23 to 4.00. Certainly, a good reason for this result is the previous poor knowledge the students had. It is difficult to decide how this increase in knowledge was due to the tool or the teachers' instructions. While this is true for the whole analysis we do not consider this as an argument against the results since the tool is explicitly intended to be used as part of such instructional setting.

Hypothesis 1: *The tool is perceived as suitable for learning about the earthquakes physics.*

Six statements were used to evaluate this hypothesis including “I do not know how the tool could help me learn about earthquakes.” Negatively formulated statements like this last one were recoded for the statistical analysis so that high values reflect a positive evaluation of the tool. First, we conducted a reliability analysis that resulted in Cronbach’s Alpha = 0.95. Therefore it seemed reasonable to summarize the six items in one variable. This new variable was derived by averaging the evaluation of the corresponding six items. It yielded a mean value of $M = 3.40$ and a standard deviation of $SD = 0.68$. Applying a one-sample T-Test against the test value of 2.5 yielded highly significant results with $t(21) = 6.22$, $p \leq 0.001$. These results validate our first hypothesis. This is also coherent with the results obtained with the knowledge questionnaire: it seems the students do attribute an important part their knowledge improvement to the tool.

Hypothesis 2*: The lesson involving the tool helps understanding the need for collaboration.*

Three items contributed to this hypothesis. Again the scale comprising those three items was highly consistent with Cronbach’s Alpha = .87, the mean value $M = 3.05$ and the average standard deviation of $SD = 0.83$. Applying a one sample T-Test yielded highly significant results with $t(21) = 3.2$, $p = 0.005$, also confirming the validity of this hypothesis, although not as strongly as it was the case for the first hypothesis. This is also supported by the fact that during the testing we noted that some students spontaneously tended to form groups to compare results and discuss the correctness of their results, and the reasons why in some cases they obtained different results. This was one of the goals we wanted to achieve, as explained in section 6, subsections a) and b). Although the experimental results show that the tool does help understanding the need for collaboration while learning, the small scope of the experiment did not allowed testing the potentials of the tool for fostering asynchronous collaboration, during a longer period of time, as explained in section 6, subsection c).

Hypothesis 3: *The tool is considered as motivating.*

Three items contributed to this hypothesis. Cronbach’s Alpha was 0.89, the mean value $M = 3.03$ and the standard deviation $SD = 0.81$. Applying a one sample T-Test yielded highly significant results with $t\ (21) = 3.61$, $p = 0.002$. These results also confirm the validity of the hypothesis. In fact, the tool motivated the students who completed the worksheet earlier to work on new, self defined tasks, like confectioning a map showing the epicenter of earthquakes occurring in the last month, or a map showing the magnitudes an earthquake had at various locations.

We may conclude the students’ evaluation of the tool supported our hypotheses that the tool is suitable and motivating to learn about seismography and that the lesson involving the tool may foster an understanding of the need for collaboration.

8. Conclusions

In this work we presented a new way of implementing authenticity in learning activities through an open environment which includes the challenge component. Students work with real data generated by professional instruments but they are assisted in the stage of processing the data by a software environment which spares them from doing tedious computations but it does not do all the job for them. The software implements an open environment where different kinds of challenges with various degrees of difficulty can be proposed to the student in order to trigger a research activity which mimics the work of real professionals. This whole system consists of hardware, software, and connectivity and it implements access to real high-quality data generated from professional seismographs and to data generated from the seismographs in the schools, as well as functionalities to support the analysis of the data.

Giving the students access to instruments and data otherwise used only by professionals increases the motivation of the students for studying the phenomena but it is not enough to guarantee a successful learning process. It is also important to provide them with an environment where they can process their data to respond to open challenges with the necessary help and scaffolding to enable meaningful learning through remote or distributed collaborative experimentation.

The work described in this paper allows various types of collaborative learning, since the results of others are used 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. Of course, the SeisModes software could be used in a non collaborative way; this also occurs in the professional world using the corresponding tools. Consequently, the DExT designer has to decide between authenticity and imposed collaboration. Both have advantages and disadvantages. We believe the students will become convinced of the advantages of collaboration if they have the choice to do the work either individually or cooperatively and they can compare the results by themselves.

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

For students living in seismic areas, this is an opportunity to scientifically understand natural phenomena and be prepared for earthquakes. It is a way of educating people living in seismic active areas to increase their awareness and motivate them to be prepared for the eventuality of a large earthquake. An understanding of the phenomenon may also lead to reducing fear and anxiety. Moreover, this process of personal growing is done cooperatively with other students.

Currently, we are working on improving the tool itself, as well as on developing a setting in order to allow its usage on a larger scale. As for the tool itself, we are working on making it easily customizable to be adapted and used with data and maps from different seismic active regions. On the other hand, a plan is being developed to introduce the tool in schools nationwide. The goals we are trying to achieve are to fully integrate the learning activities into the school's curricula and to promote the creation of a learning community around geophysics. Geophysics itself is not a topic on the Chilean schools' official curricula, but the study of wave propagation is. Therefore we see a good opportunity to smoothly integrate learning activities with SeisModes into the regular curricula. In order to promote the creation of a learning community and collaboration we will adopt the model developed in the COLDEX project (see COLDEX, 2008; Baloian et al., 2006). First, a web page will be developed. This page will contain all the required material for working with SeisModes (including the software itself, instructions for its usage, and learning material in general). It will also implement a repository for uploading and downloading from SeisMode's pages, containing the students' work, thus allowing a "loose collaboration" among students from different schools by exchanging their works. This strategy will allow to finally test the ability of the setting to support collaboration as described in seccion 6, subsection c).

References

Baloian, N. Hoeksema, K., Milrad, M., Hoppe, H. (2006): Technologies and Educational Activities for Supporting an Implementing Challenge-Based Learning. IFIP, Volume 210, Education for the 21st Century. Kumar D. & Turner J. (Eds.). Springer, pp. 10-16. New York, N.Y.

Baloian, N., Pino, J. A., Jansen, M. (2007): Implementing the Coupled Objects Paradigm for Synchronizing Distributed Applications Through Firewalls, Lecture Notes in Computer Science 4402, 599-608. Springer.

Bellamy, R.K.E. (1996). Designing Educational Technology: Computer-mediated Change. In Nardi, B. A. (Ed.). Context and Consciousness: Activity Theory and Human-Computer-Interaction, pp. 123-146. Cambridge, MA: MIT Press.

Bertelsen, O.W. & Bodker, S. (2003). Activity Theory. In Caroll, J.M. (ed.). HCI Models, Theories and Frameworks. Toward a multidisciplinary science, pp. 291-324. New York, N.Y.: Morgan Kaufmann.
Bollen, L., Hoppe, H.U., Milrad, M. & Pinkwart, N. (2002). Collaborative Modelling in Group Learning Environments. XX International Conference of the System Dynamics Society. Palermo (Italy), July 2002. Retrieved online from http://www.systemdynamics.org/conferences/2002/papers/Bollen1.pdf. Last accessed: Nov. 15, 2008.
Boston College Educat. Seismology Project:
http://www2.bc.edu/~kafka/SeismoEd/BC_ESP_Home.html. Last accessed: Nov. 14, 2008.
COLDEX Project: http://www.coldex.info. Las accessed: Nov. 14, 2008.
COLLIDE Group: http://www.collide.info. Last accessed: Nov. 14, 2008.
Edelson, D. C. (1998). Realising authentic science learning through the adaptation of science practice. In B. J. Fraser & K. Tobin (Eds.), International Handbook of Science Education (pp. 317-331). Dordrecht, The Netherlands: Kluwer Academic.
Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. Journal of the Learning Sciences, 8, pp. 391-450.
Hoeksema, K., Hoppe, H.U. (2004): Combining Interactive Modelling and Scientific Discovery in the classroom . IADIS Conference of Cognition and Exploratory Learning in Digital Age, CELDA 2004, pp. 107-114.
IRIS (2007) http://www.iris.edu. Last visited: Nov 14, 2008.
Jansen, M. (2003). Matchmaker tng - a framework to support collaborative java applications. Proceedings of the AIED 2003. Amsterdam,The Netherlands: IOS Press, pp. 535-536.
Jonassen D. H. & Murphy, L. R. (1999). Activity Theory as Feamework for Designing Constructivist Learning Environments. Educational Technology Research and Development, 47(1), pp 61-79.
Joolingen, W. R., van (2000). Designing for Collaborative Intelligent Tutoring Systems. Lecture Notes in Computer Science 1839, pp 202-211, Springer.
Moher T., Hussain S., Halter T., Kilb D., (2005) Roomquake: Embedding Dynamic Phenomena within the Physical Space of an Elementary School Classroom. Proceedings of the CHI'05 conference, Portland, USA, New York, NY: ACM Press, pp. 1665-1667
Müller, J., Mühlenbrock, M., Pinkwart, N. (2004) Towards using concept mapping for math learning. IEEE Learning Technology Newsletter, 6(3), pp. 13-15.
Pinkwart, N., Hoppe, H. U. & Gaßner, K. (2001). Integration of Domain-Specific Elements into Visual Language Based Collaborative Environments. 7th International Workshop on Groupware, CRIWG 2001. Darmstadt, Germany, pp. 142-147. IEEE Computer Society Press.
Pinkwart, N. (2003) A Plug-In Architecture for Graph Based Collaborative Modeling Systems Proceedings of the 11th Conference on Artificial Intelligence in Education, pp. 535-536. Amsterdam, The Netherlands: IOS Press.
Quintana, C., Carra, A., Krajcik, J. and Soloway, E. (2001). Learner-Centered Design: Reflections and New Directions. In Carroll, J. M.(Ed.): Human-Computer Interaction in the New Millennium, pp. 605-624. Reading, MA: Addison-Wesley.
Reeves, T.C., Herrington, J., & Oliver, R. (2002). Authentic activities and online learning. In A. Goody, J. Herrington , & M. Northcote (Eds.), Quality conversations: Research and Development in Higher Education, Volume 25, pp. 562-567. Jamison, ACT: HERDSA.
Reinmann-Rothmeier, G., Mandl, H., (2001) "Unterrichten und Lernumgebungen gestalten," Chap. 13, Krapp, Weidemann (ed.), Pädagogische Psychologie, Beltz.
SEISAN Software: http://www.geo.uib.no/seismo/software/software.html. Last accessed: Nov. 14, 2008.
USESN: United States Educational Seismograph Network: http://www.indiana.edu/~usesn/ Last visited: Nov. 14, 2008.
Vygotsky, L. (1978) Mind in Society. Cambridge, MA: Harvard University Press.