Abstract

Along with the increase of the educational materials deployed on the Web, an increase in the needs and expectations also exists towards the adoption of Web-Based Learning Systems. In this respect, CSCL provides the technological infrastructure to conduct effective learning methodologies, since it allows the definition of new scenarios of learning as a social endeavor along with the means for their evaluation. In this paper, it is proposed the design of a methodology for the constructivist approach of collaborative learning based on the scientific method and the implementation of a Web-based framework for a course of Logic Circuits that support this model. The main contributions consist in (i) using the scientific method as a fundamental model for the acquisition of new knowledge derived from using software artifacts discovered and contributed by a community of students, and (ii) developing a computer-based framework that instruments this model in a new generation of CSCL frameworks.

1. Introduction

At the moment, educational collaborative environments have big aftereffects in our society; it is not a question of replacing the traditional education, but about of using these environments as effective complements to enrich the educational experience.

Computer-Supported Collaborative Learning (CSCL) [5] [10] provides the technological infrastructure to conduct such methodologies, since it allows the definition of new scenarios of learning along with the means for their assessment. Along with the increase of the educational materials deployed on the Web, an increase in the needs and expectations also exists towards the adoption of Web-Based Learning Systems. In this respect, CSCL provides the technological infrastructure to acquire new knowledge and to develop problem-solving skills on learning by-doing scenarios in semantically rich domains.

CSCL brings in different theoretical foundations from socio-cultural theory [20], situated cognition theory [2] and constructivist theory [3] [17]. These approaches are based on different conceptions on what is perceived as learning and on how to carry out its study. Nowadays, the approaches to constructivist theory [9], [10], [13], [14], [15], [22] converge in the construction of new knowledge from the own student’s learning experience. Nevertheless, the mechanisms currently used in those CSCL systems are insufficient in providing the means to generate, integrate and disseminate new knowledge as they lack of a more articulated instrumentation of constructivism on the Web.

Recent CSCL system prototypes have helped to develop competence in problem solving skills by cooperative learning. Cooperative learning involves students in the active exchange of ideas rather than the passive acquisition of factual knowledge, while promoting, at the same time, their cognitive development by sharing goals and discussing the different perspectives to attain them. In the absence of feedback, students tend to reason at more personal level, developing attitudes that prevent the discovery and sharing of knowledge. Unfortunately, constructivist models have stressed considerable emphasis in the phase of experimentation for the generation of knowledge, but they do not encourage the practice of reusing knowledge generated outside the group.

Although the students who use those systems have also get access to the materials currently available on Internet (for example Google, Lycos and CiteSeer), the proliferation of superfluous elements on the Web and the overabundance of search results lead to the well-known problem referred to as cognitive overload. Therefore, the information retrieval methods used cannot be identified as effective methods for knowledge discovery. Those systems do not allow the
learners to complete the process of creating, formalizing, evaluating and publishing new knowledge in the form of software artifacts that constructively solve the problem at hand. Therefore, education based on traditional information retrieval methods has lead to poor results in discovering, disseminating and integrating working solutions from the software artifacts published by students or other contributors.

With these antecedents we pose the fundamental problem to solve: Can be embodied the scientific method in a scaffolding tool that bring in the current practices of discovery, dissemination and reuse of knowledge for learning? The solution to this problem would guarantee that the students that have access to such a learning environment develop their problem solving skills by adopting the universally accepted practices of the scientific method that has characterized the development of our culture.

The goal of the work proposed here is to provide a methodology of learning instrumented as a CSCL system that implements the constructivist conception of the teaching-learning paradigm based on the scientific method. This proposal is implemented as scaffolding, named ECCLWeb (from the spanish Educación Constructivista de Circuitos Lógicos en la Web, Constructivist Approach to Education in Logic Circuits) that provides facilities to produce and conduct a course of Logic Circuit Design [16]. ECCLWeb contributes in the CSCL field by enforcing in the students the practice of the scientific method in most of the academic activities.

In that follows, we argue that such a learning environment can be constructed by using the Web Service technology [1], [19] available from modern Service Oriented Architectures [8].

The rest of the document is structured as follows. Section 2 describes the educational model based in the scientific method. Section 3 describes the use of Web Services to reuse of knowledge as software artifacts. Section 4 explains the design of ECCLWeb that implements this educational model. Section 5 describes the related works that have been developed in this research area, and Section 6 provides some concluding remarks.

2. Educational Model Based on the Scientific Method for the Constructivist Approach of Collaborative Learning

Computer Support Collaborative Learning (CSCL) systems are in increasing use every day. The results on practical experiences, conditions of use and type of interactions in these systems not only have been increased in quantitative terms but also in fundamental aspects of the learning process. Thus, CSCL provides an environment of research and development of great interest due to its intrinsically interdisciplinary nature (related to psychology, pedagogy, sociology, and information and communications technologies).

Science is a process of acquisition and assimilation of factual knowledge. The scientific method has as fundamental objective to solve problems by using a systematic procedure that splits a complex problem in several simpler ones. After getting enough understanding of the problem at hand, the scientific method prompts to formulate a hypothesis that may lead to a possible solution. The hypothesis should be verified through experimentation, by contrasting the hypothesis or its logical consequences against the experimental results. Then, it is possible to borrow some conclusions and to generalize the solution to other analogous problems.

The scientific method or scientific process is fundamental to scientific investigation and to the acquisition of new knowledge based upon the physical evidence accumulated by the scientific community. Scientists use observations and reasoning to propose hypotheses to explain natural phenomena. Predictions from these hypotheses are tested by various experiments that should be reproducible.

One of the main elements involved in the evaluation of the scientific practice is the publication of the research in scientific magazines in a process of arbitration judged by peers. Each element of the scientific method is subject to a peer review for possible mistakes. Such evaluation process reveals much of the collaborative effort behind the production of scientific knowledge.

The scientific method consists of:

1. Formalizing the statement of the problem.

2. Searching for any related material – Learning Objects (analogous known problems, previous known solutions, discussions about the different aspects of the problem, computational artifacts like simulators) in the ontology of terms and concepts called the knowledge repository. If any solution to the problem or part of the problem is found, collect all resources published.

3. Forming a hypothesis. It involves the elaboration of a theory (computational model) that explains the logical relationships among the elements introduced by the problem in terms of the collected resources borrowed from the knowledge repository.
4. Planning the experiments. It means, from our point of view, to conceive the solution of the problem. Dealing with a complex problem generally implies its decomposition into smaller ones. Solving the problem demands a collaborative effort of groups to coordinate the reconstruction of the solution from the solutions found of smaller problems.

5. Performing the experiments. It involves the construction of the proposed solution of the problem that may evolve from a prototype to a solution with varying degrees of sophistication. In complex problems, it requires the coordinated interaction among the collaboration activities deployed by the participating groups.

6. Analyzing experimental data. By contrasting the experimental results against those predicted by the theory, the student (or group of students) may provide some evidences about the validity of the hypothesis.

7. Interpreting results and drawing conclusions. The analysis of the evidences may either confirm or not the working hypothesis. If the evidences are not conclusive, new hypothesis or experiments can be proposed.

8. Communicating results. Dissemination of the knowledge (as Learning Objects) acquired from this process is submitted for its publication in the knowledge repository after a reviewing process.

The educational model based in the scientific method the problem as basic element and uses the metaphor of session of the learning, and it incorporates two differences with respect to the previous models: 1) integrated search of the previous knowledge and 2) spreading of the acquired knowledge.

Under this conception, our model enables the student to discover, analyze and experiment with the resources obtained from the knowledge repository utilizing the built-in components provided by ECCLWeb. Then, by actively pursuing the solution of the problem, the student may suggest, develop and validate the solution found. Finally, the student disseminates all the resources that implement the solution. The resources may take the form of computational artifacts whose programming interfaces are publicly available in the knowledge repository.

3. Learning Objects and Web Services Technologies for the Reuse of Knowledge

The convenience of reusing knowledge and educational resources independently from diverse learning environments has lead to the use of Learning Objects (LO). LO are platform independent units of instruction that can be reused in multiple contexts [21]. LO are generally understood to be digital entities deliverables over the Internet, meaning that any number of people can access and use them simultaneously. The great versatility of the elaborated educative contents from LO favors the application of the constructivist theory to the design of instruction.

As constructivism implies the individualization of the learning tasks that contributes with new experiences in different contexts of learning, it relates the interests of each participant in a collective goal. The learning process that uses LO provides a balance between free and guided exploration of the learning activities intended to demonstrate the working solution to the problem. Therefore, constructivism can be obtained from the generation, publication and reusability of knowledge in the form of LO, proposing the use of Web Services as mechanism for their discovery, experimentation and dissemination.

Web Services currently draw the attention of learning technology researchers and practitioners for decentralized, integrated support of Web-based learning processes, for enhancing the functionality, interoperability and extensibility of current and future learning platform solutions. The particular approach presented in this paper aims at implementing the discovery of learning objects from distributed reusable learning objects repositories.

Web Services allow the search, selection and integration of different educational materials (LO) located in different repositories. The adaptability of the user within the learning environment context includes: data collection, adjusting of the presentation details of the course material, the positioning system and its sequence at the cognitive levels of the student.

Figure 1 illustrates the approach for discovery (search) and dissemination (publication) of knowledge as LO in adaptive learning courses. This search mechanism can be explored from different Learning Objects Repositories and be shown according to the student needs.
The description of each LO has associated nine main categories metadata: General, Life Cycle, Metadata, Technical, Educational, Right, Relation, Annotation and Classification [7]. A metadata describes as it is the content of an educational object and identifies its more important characteristics, like for example: title, author, description, version and state. A natural solution for explicit definition of LO structure is an ontology.

One of the main motivations for having adopted Learning Objects and Learning Objects Repositories is that they allow educational resource to be reused as many people as possible. In order to make this possible, the characteristics of the learning objects should be exposed, so that other than their authors could locate and retrieve them. A very critical issue in this process is how to describe the educational resource and how to search for it in order to find those who really match the needs of certain potential users.

4. A Web-based Framework for a Course of Logic Circuits

We are developing a simple virtual learning environment to teach Logic Circuits [17], in order to illustrate the proposed approach. This section specifies the design of the ECCLWeb system that implements the educational model in the learning environment based on the scientific method from a constructivist point of view.

The basic architecture of the framework is conformed of 5 modules (see figure 2).

1) Administrative Service,
2) Education Learning,
3) Update,
4) Communications and
5) Management of the group.

Administrative Services Module: It allows controlling the access of the users to the system. Three types of users are distinguished:

1) Administrator: This user has the privileges to manage the system. Some actions to be taken by the administrator are to create accounts to the users of the system, and to grant or deny access to them.

2) Instructor or professor: This user has the privileges to add materials of the course and to assign it to each session, to modify the libraries (to add or to eliminate elements), to modify of student assessment results in the session (add/delete) and to advise in the learning of the students in the session.

3) Student: This user can participate in the session in which is enrolled, to propose solutions, to publish solutions and to communicate them with the instructor and other students.

Each user has a profile that allows defining the present state within the system: rights, files, and configuration. The sequence of actions in order to use the tool is to get access to the Web site that contains the tool from a navigator and to register its access to the system. For it, the user must provide an identifier (login) and password to begin the session; otherwise an error message is visualized.

Education/Learning Module: This module implements the model of learning. The course is structured in topics that are divided in Subjects or
Topics; each subject is boarded in different Sessions. Each session is structured in the phases that implement the scientific method: discuss the problem in the group, examine, experiment, validate and publish solutions. This module uses different tools for the search, the edition/simulation and the LO creation.

The search tool facilitates the phase of discovery. It allows the query of previously, stored and published knowledge that allows the learner to consolidate and to deepen the theoretical foundations of the problem. The queries are made in the knowledge base of the system that describes each one of the learning object’s components. If it some coincidence occurs in the knowledge space, the student can thoroughly examine the description of the learning object.

The edition / simulation tool allows the generation of new knowledge from the elements previously examined in the form of a learning object. It allows the learner to make tests and to define the equations of the behavior of the design made from the established components in the libraries. The student can evaluate the design and verify the output generated based on the inputs. Once finished, the student can submit to the professor his/her work and ask for its publication, so that this new circuit is stored as a new object learning and can be retrieved in later sessions.

In Subjects is included: a) general information on the course, the objectives and the methodology, b) the subjects and sessions that shape the course. Each session has its title and tasks. The student has access to Learning Objects Repositories (LOR) to discovery knowledge. In LOR he/she finds materials that provide a corresponding theoretical foundation with respect to the task at hand. In the libraries the student finds the components that allow him/her to prepare an answer. From the library, the student can obtain the component, take it to the simulator and prove that is properly working.

When the student has completed his/her design, he/she can verify if the proposed circuit conforms to the input-output table given as problem specification. If the answer is not positive, that is, in the verification process there is some error, this result is indicated to the student with a message that indicates the state of the execution.

Once finalized the design phase, the student ask for an evaluation to the professor and its authorization to publish the work. The action to publish causes that this solution be stored and later on to be consulted by other students.

**Update Module:** This module met two objectives: 1) to provide to instructors and professors the means to update about the information of the course and the LO provided to the students, and 2) allows to convert the new knowledge in the form of a learning object and to store it in a repository. For this purpose the tools of creation LO are used of and that allow specifying the description of the object.

**Communication Module:** This module implements the asynchronous communication among the participants of a session. In each session is shown the relation of the students who have gotten it up, and through the communication mechanism they can interchange opinions and information among them and with the instructor.

**Management of Group Module:** This module guarantees awareness within the system. Awareness information is always required to coordinate group activities whatever the task domain. When a collaborative system implements awareness technique, members of the group prove to be more productive and effective by understanding the activities of the whole group. The system implements the workspace awareness and it maintains a control of the users connected to the system within each session.

### 4.1. Study Case: Design of a Full Adder

The course is structured 5 topics: Logic Gates, Combinational Circuits, Sequential Circuits, Registers, Memory and Logical Design of Processors, and each one are divided in Subjects; each subject is boarded in different Sessions. Figure 3 shows to the interface of presentation with the subjects of the course and the methodological orientation that must be followed.

![Figure 3: Topics of Logic Circuit’s course](image-url)

The problem of designing a four-bit full binary adder with carry was explained rigorously by giving its input-output functionality, leaving unspecified its internal behavior and architectural decomposition.
ECCLWeb reinforces the application of the scientific method in the student by following the next steps:

a) Discuss the problem in the group. In order to guarantee that the student understands the problem, it is asked to respond some initial questions, for example to determine the number of variables to represent the inputs and outputs for represent this circuit. The student helping of the communication tool can communicate with the professor and the students can ask and consult. Typical examples of questions are the following: there exist some component in the base knowledge that makes this function?, how they interconnect to each other?, how to validate this design?, is it correct the amount of variables of inputs or outputs selected?. Once clarify the problem one goes to the following stage.

b) Examine the previous solutions: Fundamental element of the constructivist process of our model is to motivate to the student to analyze all the previous solutions and make a process of "discovery" of the previous experiences in that respect. For this end, the system provides a search tool that allows describing the component based on the functionality of the circuit that is desired, the amount of inputs and outputs, as well as of the type of learning object that the student wishes to examine: text, diagram, simulation, etc. Figure 4 illustrates the use of the search tool.

Once located, it can be loaded and examined by the student. The material provides important information to experiment with the potential solutions the student has in mind.

c) Experiment with new solutions: It is fundamental part of the process, with the data obtained previously. The student can design a circuit and experiment with it as a solution to the problem. Figure 5 shows to the use of the tool for edition / simulation of circuits.

d) Validate solutions: Once finalized the design phase, the student ask for an evaluation of the solution to the professor. If the solution is not correct, the student must return to the phase of experimentation.

e) Publish solutions: When the student makes a novel or interesting solution, the professor authorizes its publication. For it, the student uses the authoring LO tool and specifying the parameters necessary to make public this new knowledge in the form of LO.

In the student’s assessment, the ECCLWeb gallery of artifacts (Learning Objects) demonstrated to be a key factor in the instrumentation of the scientific method. All artifacts in the gallery have both functional and architectural descriptions accompanied with the usual graphical visualization of logic circuits along with some textual explanations. However the most important feature of the gallery is the ECCLWeb simulator (based on Web Services) that has the ability to integrate and to coordinate the interactions that result from the composition of the artifacts. Students were enthusiastic in discovering the complex artifacts that can be constructed from those already available in the gallery. When students were challenged to solve the problem of designing a four-bit full binary adder with carry, the students firstly tried to solve the problem by looking for a solution in the repository. After some unsuccessful attempts, a student discovered an artifact that may be used because it partially solved the problem requirements. In fact, this artifact corresponds to the half-binary adder, though it was not published under this name for obvious reasons.

This student communicated his findings to other students and provided some reasons illustrated with diagrams explaining why a solution could be built from this artifact. From these communications, the prototype artifact was tested, revealing that it does not work properly. Soon after some discussions, they reach the right solution that was confirmed by using the ECCLWeb simulator. They announced their results to the teacher in the form of a Learning Objects that
constructivism is applied to construct new concepts, where the activities are oriented towards the learning of the new subject; the concepts are presented accompanied by illustrations and situations that allow extending their explanation.

Zhuge reports the implementation of tools and the prototype of courses for the support of constructivist learning [23]. For this author the constructivist learning is an educational variant centered in the student, who motivates to the student by means of the rating of processes of interactive learning, investigative and active. The system proposes the incorporation of intelligent agents and a highly interactive hypermedia.

Mor describes the design of WebReport system, which supports collaborative work based on network oriented to find new ways to represent and to express mathematical and scientific knowledge in learning communities [15]. WebLabs uses two tools for its activities: one ambient of programming and a system of collaboration based on the Web. The constructivism is seen like the construction of activities and the use of a collaboration environment that allows expanding the communication where they are the students.

Collide [4] is a collaborative learning system that allows the efficient management of course delivery and the coordination of interactions among the participants (as in discussion forums, for example). However, it does not adopt a methodology based on the scientific method.

All the implemented constructivist approaches in the education tools - learning insists on the part of generation of new competitions, nevertheless they do not guarantee that the search of information and the reusability are made of suitable form. In our system the constructivism is seen as the combination of generation, publication and reusability of the new knowledge as LO.

6. Conclusions

In this paper we presented a model of education based on the scientific method, and the design and implementation of a tool for the teaching of logic circuit course based in this model. The proposed model follows the methodology and integrates automated tools cradles in services that make flexible the actions and allow the reusability of the generated knowledge as Learning Objects.

Future work will in first place concentrate on improving the visible end-user components of ECCLWeb (mainly the administrative aspects of the Website) and its reference implementation along with a set of basic Web services to enrich the discovery process.
The construction of Learning Objects calls for their effective use in education, a subject that attracts a great deal of activity in the e-Learning community, since they facilitate the reuse of knowledge. In this work we have shown their relations with a constructive approach of learning based in the scientific method.

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References