

An abductive environment enables teacher's intervention in a robotics class

Ilkka Jormanainen¹, Meurig Beynon² and Erkki Sutinen³

^{1,3}University of Eastern Finland, School of Computing, P.O.Box 111, FI-80101 Joensuu, Finland

²University of Warwick, Department of Computer Science, Coventry CV4 7AL, United Kingdom

¹ (Tel: +358 45 872 6228, Fax: +358 251 13 251 7955)

¹ilkka.jormanainen@uef.fi

Abstract: We propose a novel approach to support teacher's work in an unpredictable learning environment, such as a robotics class. The Conflative Learning Environment (CLE) approach blends the roles of the student, the teacher, and the software developer by taking the diverse users of the learning environments beyond their traditional, fixed roles and blending the users' activities and working environments with each other. We report results from a qualitative study indicating that a novel monitoring environment developed by following the CLE approach helped teachers to recognize students' particular problems better than when observing the students without such support. Results of the study have been used to guide us in the further development of the CLE approach and the monitoring environment.

Keywords: agent, intervention, learning environment, robotics

1 INTRODUCTION

Educational robotics has a recognized status as an attractive tool for modern learning environments. Cheap and highly accessible robotics sets, such as Lego Mindstorms, provide a platform for different kinds of learning scenarios ranging from basic technology education in a primary school to advanced artificial intelligence studies in universities. Learning settings in robotic classes emphasize students' active participation and group-oriented working methods. These kinds of learning settings, especially at an elementary level, however, pose a particular challenge for teachers: How to follow all students' or an individual's activities? Project-based working methods, open-ended tasks, various problem solving strategies, and the iterative nature of robotics projects easily lead the students to take different paths in their work. This makes it difficult for the teacher to detect the students' problems and the right moments for intervention.

Traditionally, intelligent tutoring systems (ITSs) have been used to guide students and teachers in such learning settings. The deductive student modeling approach traditionally used in ITSs is based on pre-defined rules to model and predict students' progress in the learning environment. The systems reveal only the result of a modeling process to the teacher. However, the unpredictable nature of a robotics class requires that the learning environment leaves room for the teacher to explore through *abductive reasoning* what factors actually have led the students to the current situation.

In this paper, we present a *conflative learning environment* (CLE) approach that enables blending of roles. The teacher can adopt a software developer's tasks in his or her own work. This allows the teacher to exploit abductive reasoning to explain observed phenomena in the teaching setting, and to intervene accordingly.

This paper is organized as follows. In the next section, we review previous approaches to tackling the problem of tracking student activities in learning environments where unpredictable events easily take place. We describe how the CLE approach differs from the existing solutions. Then, we present the main findings from a qualitative study that analyzed the use of a monitoring environment built by following the CLE approach.

2 BACKGROUND

In previous research by other authors, the student modeling approaches are mostly theory-driven. The environments, based at least loosely on ITSs, have offered a selection of pre-defined choices by which the monitored data is classified and used for modelling the students. These systems give support for observing the overall progress of all students in the classroom, detecting the problems that the students have, and analyzing the actions of a particular group or even an individual student. Despres and George's research [3] is probably one of the closest to our approach in the educational robotics domain. They describe an intelligent tutoring system that allows the teacher to follow the students' activities in an educational robotics classroom. In the first instance, their system provides support directly

to the students, and if that fails, the system reports the difficulties to the teacher as well.

The main difference between the existing and CLE approaches is that, whereas many traditional ITS applications use a theory-based approach for building the learning model, the learning environments based on the CLE approach start from the empirical observations arising from the current learning situation. There are ITSs that apply an empirical approach for building the learner model (for example a multimedia ITS for Geometry by Cooper et. al [2]). However, the learning models in these systems are still at least partially predicted by theoretical assumptions. For example, a given set of features classifies the user's emotional self concept [2].

3 CONFLATIVE LEARNING ENVIRONMENT

A conflative learning environment (CLE) is a novel kind of open and flexible learning environment that was developed based on the observations that the Finnish authors of this paper have gathered during 10 years of running Kids' Club. Kids' Club is a combined after-school robotics and technology club and a living laboratory for designing novel educational technologies in conjunction with their intended users, particularly students and teachers. During the development of the club concept in various school and after-school settings, we have shown that the group-oriented working methods, iterative problem solving processes, group dynamics, and students' different roles in the groups easily lead the groups and individual students to proceed quite differently with their projects. Hence, there is a need for a framework to support the development of learning environments that allow the teacher to explore the learning process deeply.

2.1 Role blending in the CLE approach

The traditional division of the roles in educational technology development processes usually strictly separates the roles of developer, teacher, and learner from each other. Moreover, the tasks undertaken by these process participants usually follow each other in a cycle with predefined steps. The *Empirical Modelling* (EM) approach breaks this division by taking the users of the learning environments beyond their traditional roles and by blending their activities and working environments with each other [1]. In particular, EM has tools that allow the teacher to model students' behavior by his or her observations, thus - to a certain extent - becoming a developer.

The role blending in the CLE approach can take place between the teacher and the developer, the student and the

developer, or even between the student and the teacher. The role blending takes place through cyclic processes where the users contribute to building the learning environment gradually by modelling the empirical observations arising from the current learning setting (Figure 1). Modelling is an essential process for a functional learning environment. Traditional learning environments require advanced programming for enhancing the learning environment to match the unexpected, and hence unprogrammed, student behavior. In contrast, EM supports modeling that can be done without interrupting the learning process.

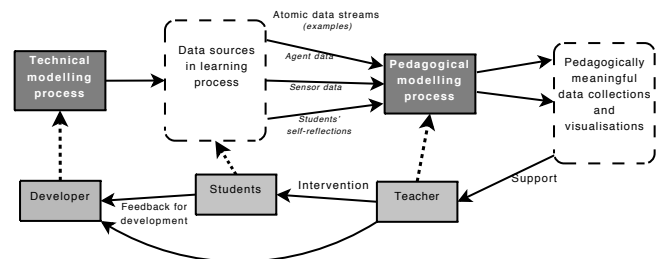


Fig. 1. Example structure of an application based on the CLE approach

2.2 Working processes in the CLE approach

The modelling process in the CLE approach (Figure 1) is based on individual data streams originating from the current learning process. The data can be, for example, information about the users' activities within the learning environment, or automatically collected sensor data, or students' self-reflections about their progress. A learning environment based on the CLE approach should provide appropriate tools for the teachers to process this primary data to obtain pedagogically meaningful collections that can be visualized. As an abstract approach, the CLE does not limit or define the ways in which the user can combine the primary data, or how the observations are presented. A CLE distinguishes development from modelling activities. When building a learning environment by following the CLE approach, there is, indeed, a need to have "traditional" software developers involved. They prepare the tools and the environment so that the users can then make their contribution whilst modelling *as if* in the role of a developer. 'Modelling' means that the users reflect upon their own surrounding and working environment through their observations of the learning environment.

Jormanainen et al proposed in [4] that to make the applications based on the CLE approach more accessible for the users, modelling of the learning process should be divided into two parts. The first part, *technical modeling*, consists of setting up the basic modules of the environment. This part of the modelling process can take place before

and even between classes, when the model can be redefined to meet the new requirements. The second part, *pedagogical modelling*, is the process that takes place during the classes. In this part of the modelling process the teacher defines the environment by identifying data collections meaningful for the teaching context and visualizations for the data that the agents collect. It may be that the collections and visualizations of a given instance are not usable elsewhere; for instance, they might depend on the phase at which the students are in their project. To put our work in context, we classify learning environments between the theoretical extremes of *model-based* environments and *modelling-based* environments (Table 1). The model-based environments are traditional ITSs that take deduction as a starting point for the learner’s modeling. At the other end, inductive modeling-based environments take empirical observations arising from the current learning setting as a starting point for modeling. It is important to recognize that these are theoretical extremes, and real systems usually fall between these alternatives, for instance, when an abductive approach to modelling is adopted.

Table 1. Model-based and modeling-based learning environments (based on [4])

	Model-based	Modelling-based
Modelling approach	Theory-based, deductive	Empirical, inductive
Learning model	Given	Constructed
Adaptation	Black box	Transparent
Roles in the learning community	Separated	Blended
Working environments	Separated	Conflated
Direction of modelling	Top-down	Bottom-up
Modifications to the tools	Through the software development process	On demand in the actual learning situation

4 OPEN MONITORING ENVIRONMENT

To help the teachers working in a robotics class, we have developed an *Open Monitoring Environment* (OME) by following a cyclic process of defining, testing, and evaluating as proposed in the CLE approach [4]. The core

idea of the OME is to help the teacher to detect the right moments for intervention in a robotics class and help to build his or her intervention strategies. The students design and build robots with Lego Mindstorms educational robotics sets, and they program the robots by using a visual programming environment. The OME automates data collection from the learning process by utilizing agents to observe students’ interactions within the robotics environment [4]. In addition, the OME environment contains a specific modelling environment for the teacher, where he or she can build the model representing the current learning scenario.

5 ANALYZING CLE AND OME

A qualitative analysis of the OME was conducted in a real school setting, where teachers used it for monitoring students’ activities in the robotics class. The main focus of the experiment was to address the question: *How does the OME help the teachers who are working in a robotics classroom?* Four teachers and 12 primary school students participated in the study. The participants were divided into two groups of two teachers and six students. During the study, the students worked in pairs for a given robotics task for a period of three hours. Neither teachers nor students had prior familiarity with robotics. The student groups were provided with pre-constructed wheeled robots, and a simple programming task was given to them. The teachers’ work during the experiment can be roughly divided into two parts. First, they observed students’ actions through the OME environment. When the agents delivered new data to the modelling environment, it was automatically updated to reflect the current situation. Secondly, the teachers used this output to determine when it was appropriate to intervene in students’ work (e.g. when they observed a problem). Data collection in the study was conducted in several ways. First, teaching sessions were recorded with a video camera. Second, data produced by the agents based on the students’ actions was saved to a database. Third, teachers’ actions with the OME were saved to log files. Finally, video-recorded interviews with the teachers were conducted. The research material was analyzed qualitatively. After transcribing the video and interview material, a codebook was built to help the analysis and make the analysis consistent. Before the actual analysis, the reliability of the codebook was tested statistically. Transcribed video and interview material was analyzed by categorizing material according to the codebook with the ATLAS.ti software.

The focus of the qualitative analysis was to identify the opportunities that the OME brings to teachers’ work, and to

identify the role that EM principles and tools play in implementing an environment based on the CLE approach. The new ideas and teachers' opinions about the additional information that the environment should provide were appreciated as potentially very valuable for improving the OME further. This process is an essential part of the CLE approach. The outcome of the research process serves as an input for the next iteration of technical modelling, and it also helps the researcher to identify ways in which the teacher adopt the role of developer in accordance with the CLE principles.

6 RESULTS

The qualitative analysis of the experiment material shows that the OME helped the teachers to intervene when the students had problems in their robotics exercises. The teachers were able to make informed decisions on what particular issues they would follow from the students' learning process based on the agent data. Furthermore, the teachers were able to recognize students' particular problems through the OME system better than when observing the students without such support. This was especially evident in situations where only one of the teachers was following the students' progress through the OME. In these cases, the teacher in the classroom did not notice that the students were having problems, but another teacher was able to see this through the OME and help the group with the problems. Most of these cases were related to technical problems when the students were unable to upload code to the robot due to the unreliability of the infrared link between the computer and the robot. It was typical for these cases that the students did not ask for help but repeatedly tried to upload the code to the robot, despite the error messages.

7 DISCUSSION

This experiment focused mostly on how the teachers used the OME. It is evident that the OME was beneficial for the teachers especially because they were novices in working with a robotics environment. However, as the idea of the CLE approach is to blend the roles of the teacher and the developer, the issue of being involved in the development was also introduced to the teachers. It was surprising that the teachers actually agreed that they could also develop the environment further if this was a natural part of the work flow. When the teachers looked back on the actual learning process and reflected on how different decisions might have enhanced the quality of the learning process, they identified both key pedagogical issues and

ways in which these might be addressed by modifying the learning environment. These issues could then have an impact on the design of a learning environment based on the CLE approach. This means that, by reappraising their decisions, teachers working with the CLE approach blended their traditional role with the role of a system designer.

8 CONCLUSION AND FUTURE WORK

The study reported in this paper gave us more evidence that Empirical Modelling has potential to support role conflation even more deeply than the current implementation of the OME allows. To realize this more effectively in practice, further development is needed to ensure a seamless integration of the EM tools with the learning environment construction process defined by the CLE approach. The analysis of the qualitative data and teacher's work in the classroom guided us in developing a data mining module for the OME [5] to enable automatic processing of agent data. In contrast to traditional data mining applications, a teacher can reconstruct a training set for a data mining algorithm on an on-the-fly basis and apply a new classifier in the environment at any time. The rules associated with the classifier are exposed for the teacher's revision. If the teacher is not satisfied with the resulting classifier, he or she can always modify the rules and changes will be effective immediately. Results from the study indicate that this open data mining process produces pedagogically useful and interpretable information about the students' progress with relatively small datasets [5].

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