Cooperative Student Assessment Method: an Evaluation Study

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Abstract — **Training through the Internet poses a series of technical problems and pedagogical issues. Traditional training is not indiscriminate but takes on different forms according to the needs of the subject being trained and the context where such training occurs. In order to make the systems adaptable in this way, a model of the student's characteristics - the student model - has to be set up, maintained and updated. However, there are many difficulties involved in obtaining sufficient information to create an accurate student model. One way to solve this problem is to involve students in the student modeling process, stimulating them to provide the necessary information by means of a dialog in which the student and system build the student model according to a collaborative process.**

The present work describes a cooperative student modeling method (Cooperative Student Assessment - CSA) which builds a joint system-student assessment of student's activities on the basis of the student's self-assessment ability estimation and a prototype system for children, addressing the learning of fractions, in which CSA is implemented. The article also reports the result of an experimentation carried out with learners attending primary school aiming at evaluating the effectiveness of involving students in the assessment process by comparing two versions of the same system: one using cooperative student modeling and the other the traditional overlay model.

Index Terms — **Adaptivity, Cooperative student modeling, Self-assessment, Web-based systems.**

I. Introduction

Since the advent of e-learning networks there has been a shift from the use of the information product to the realization of learning environments that can not only impart learning content but also stimulate interaction among the actors involved in the learning process, thanks to the use of the communication tools made available by the web.

Nevertheless, training through the Internet poses a series of technical problems and pedagogical issues. Traditional training is not indiscriminate but takes on different forms according to the needs of the subject being trained and the context where such training occurs. Moreover, the trainer aims to achieve a dual goal: enabling the learners to acquire new knowledge and fostering the development of metacognitive skills such as deeper reflection powers. In order to take into account these needs in the e-learning context, adaptive personalized environments need to be built, which can guide the interaction according to the learner's needs, interests, knowledge and skills level, and choose the material and presentation forms best suited to each stage of the educational process.

In order to make the systems adaptable in this way, a model of the student's characteristics - described as the student model - needs to be set up, maintained and updated.

The approach to student modelling can be defined as passive, active or interactive according to the extent to which the system involves (cooperates with) the student in the process of building and updating the model [12]. In passive modelling the system infers the model without any explicit help by the student; in active modelling the system can ask the student questions to derive help in building the model; in interactive modelling, not only can the student access the model but s/he is actively involved in modifying it.

Traditional student modelling techniques used in Intelligent Tutoring Systems - overlay [8], buggy [5] - build the student model (which is invisible to the user) on the basis of the domain model and pose the problem of how to collect the data on the user. To solve this problem, more and more frequently the cooperative or open modelling solution is adopted (e.g. [1], [13]), actively involving the learner in the process of creating the model.

The use of cooperative modelling techniques makes it possible to develop more efficacious models representing the students' cognitive features, which will make more reliable forecasts of their future behaviour. This increases the reliability of the assessments themselves, and encourages better, more in-depth learning on part of the students because it stimulates them to reflect on their cognitive aspects [4].

A study on the involvement of the student in the assessment process concluded that with this approach there is a real improvement in the student's depth of reflection and understanding of the domain [10].

Cooperative assessment thus seems to be far and away the best way to foster and develop the desired metacognitive skills [17]. In fact, if students become active participants in the assessment process, able to assess their abilities and aptitudes, they will become more aware of their progress in specific areas and be able to define future learning targets.

However, one of the side effects of students' involvement in assessing their knowledge is that too frequent querying of the student might be invasive, distracting and instil a sense of unease that could negatively affect the learning process.

The present work aims to explore the use of a particular cooperative student modelling method in the context of web-based learning environments. In addition to student's characteristics already considered in the literature on student modelling, it has been analysed the possibility of modelling a student's metacognitive ability - self-assessment - to build the student's assessment and to adapt, consequently, the interaction between the system and the student.

The remainder of this article is organised as follows: section II presents the proposed cooperative method, section III describes the implementation of this method in a web-based hypermedia system for children (Frazionando), section IV reports and discuss results of an experimentation carried out to test the CSA method, finally, section V summarizes and draws conclusions related to the work and presents future research directions.

II. CSA: Cooperative Student Assessment

This section describes a possible approach to solve the problem of collecting data on the learner and to promote her/his reflection, by exploring the use of a particular cooperative student modelling method in the context of web-based learning environments. The method is called CSA (Cooperative Student Assessment) because the system involves the learner in the student assessment process.

The CSA method builds a joint system-student assessment of student's activities on the basis of the student's self-assessment ability estimation. In fact, besides considering typical student's characteristics already considered in the literature on student modelling and well described in [6], [7], it has been analysed the possibility of modelling a student's metacognitive ability - self-assessment - to build the student's assessment and to adapt, consequently, the interaction between the system and the student. According to Mitrovic [14] "Self-assessment is one of the meta-cognitive skills necessary for effective learning. Students need to be able to critically assess their knowledge in order to decide what they need to study."

The method was presented initially in [16], [11], but some problems have been detected by using systems implementing this method. Therefore, the version presented here has been partially changed to better model the student's self-assessment ability.

CSA is based on calculation of the student's self-assessment ability that is used to obtain a shared tutor-student assessment. The tutor and user's assessments are variably weighted according to the system estimate of the user's self-assessment ability. However, to avoid excessive invasiveness of the tutor, which could systematically distract and condition the student if the request for self-assessment were too often reiterated, the choice to give her/his opinion is optional in each case.

After doing each exercise, students are communicated the results and given the option of making a self-assessment. If they do not wish to do so, they can go directly to the next phase, namely studying a new lesson, revising already studied lessons or solving a new exercise. Otherwise, the process for calculating the shared assessment is activated and leads to an integrated assessment that merges the student's and tutor's assessments, by calculating the weighted mean of the two assessments.

The method for calculating the shared assessment is based on a succession of Confidence Factors (F_i), that act as weights mediating between the student and tutor's opinions.

The factors involved in the calculation of the shared assessment are the following:

- A_{tutor}: it represents the system opinion about the learner. At the 1st step (exercise) its value corresponds to the system assessment of the exercise, then it corresponds to the final (shared) assessment calculated at the previous step;
- A_{test}: it represents the system assessment of the current exercise;
- F_i (confidence factor): it indicates the system confidence in the student's self-assessment ability;
- $A_{student}$: it represents the student's assessment of the current exercise.

The procedure for calculating the shared assessment is as follows:

1. The starting Confidence Factor is $F_0 = 0.5$

At the i-th step (i≥1):

2. The mean of the tutor's assessments is calculated as: $A_{tutor\text{-}test} = ½\cdot*(A_{tutor} + A_{test})$
3. The shared assessment is calculated as:

$$A_{final} = F_i * A_{student} + (1 - F_i) * A_{tutor\text{-}test}$$

4. The new Confidence Factor, F_{i+1}, is calculated.

Notice that, the higher is F_i, the lighter is the weight of the system assessment in the calculation of the shared assessment and vice versa.

There are four main factors involved in the calculation of the new confidence factor: the number of student's assessment corresponding to those of the system, the previous Confidence Factor, the student's mean self-assessment ability and the constancy of the student's self-assessment behaviour.

To this purpose two indexes have been defined, consisting of the mean student's self-assessment ability and the constancy of the student's self-assessment behaviour.

The mean student's self-assessment ability (Self Assessment Mean Capability Ratio - SAMCR) is defined as follows:

$$SAMCR_i = mean(A_{student\ j} - A_{final\ j})_{j=1,\dots,i}$$

where i indicates the i-th N of self-assessments made. At each step, this index represents the mean of the student's assessment errors.

The domain of this index is [-2, 2].

The Constancy Index (CI), whose domain is [0, 2], is a measure of the student's constancy in her/his self-assessment behaviour. In other words CI indicates if the trend of the student's self-assessment behaviour is constant or not, both in positive and negative sense (i.e. how constantly the student correctly/incorrectly estimates, or over/underestimates her/his performance). CI will be kept unchanged if the student's self-assessment behaviour is constant, otherwise it will be increased.

Once obtained the indexes SAMCR and CI, it is necessary to calculate the new confidence factor by combining these two indexes. Actually, looking at the Fig. 1, it is possible to notice that there is a relation between SAMCR and CI values and the lengths of hypotenuses. The smaller these indexes are, the smaller the length of hypotenuse is and the better the student is at self-assessing her/his performance. Therefore, the length of the hypotenuse of a triangle having respectively the measure of the indexes SAMCR and CI as its base and height is used as the only evaluation parameter of the student, in place of SAMCR and CI.

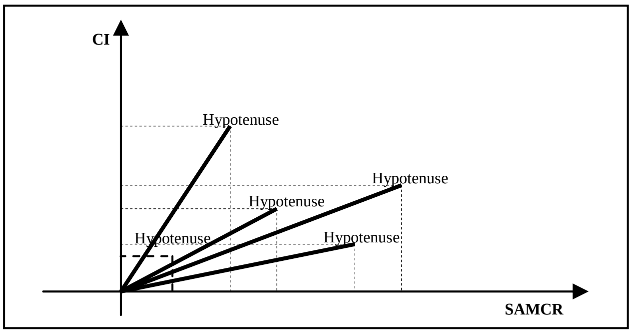

Figure 1. Lengths of the hypotenuse according to SAMCR and CI values

At the i-th step the new confidence factor is calculated as:

$$F_{i+1} = min(f\,(F_i, SAMCR_i, CI_i), 1) = min(FID_i * F_i\ , 1)$$

where FID is calculated according to the hypotenuse value and is used to increase or reduce the old confidence factor.

After establishing the shared assessment for the current skill, the student receives a message containing the final shared assessment (opening of student model to promote the student reflection) and suggestions about her/his next learning steps (providing the student with navigation support). In addition to teaching advice, the student receives suggestions guiding her/his self-assessment ability, aiming to improve it. The types of messages given depend on the estimate of the student's self-assessment ability. According to the fluctuations of the SAMCR and CI indexes, the student is encouraged to be more cautious or less optimistic:

If $(SAMCR_i, CI_i) \in A \Rightarrow$ the student should pay more attention

If $(SAMCR_i, CI_i) \in B \Rightarrow$ the student should be less optimistic

If $(SAMCR_i, CI_i) \in C \Rightarrow$ the student should be more optimistic

If $(SAMCR_i, CI_i) \in D \Rightarrow$ the student estimates correctly her/his performance

where A, B, C and D are the sections of the Cartesian plane illustrated in Fig. 2.

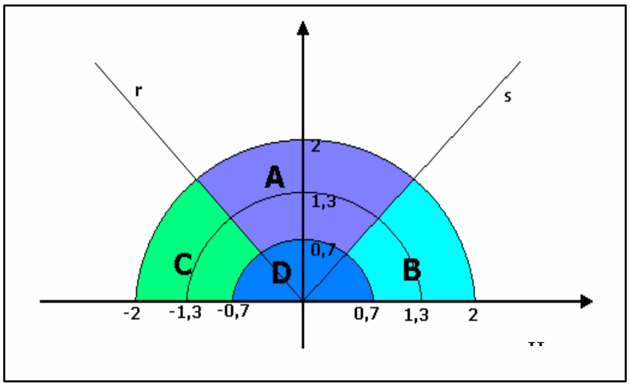

Figure 2. Types of student self-assessment

III. FRAZIONANDO

Frazionando is a web-based hypermedia system in which the CSA method is implemented. It is addressed to students of primary school, and offers an overall view of fractions conforming to the ministerial program for this subject at this scholastic level. Frazionando has a client-server component-based architecture and was implemented in Microsoft ASP.NET, Macromedia FLASH MX 2004 PRO and ActionScript 2.0, by using web service technology.

Frazionando maintains a simple (open) model of each student which stores her/his general data such as her/his name and surname, her/his self-confidence and the system opinion about his/her knowledge, the student's and system assessment of each exercise solved by the student, the shared assessment of the exercises, the current confidence factor and all the data related to the CSA algorithm calculation.

Students are registered with the system by an administrator (typically their teacher) who has the possibility of creating new user accounts, viewing the list of students registered with the system, managing user profiles, viewing information held in the student model about each student and using the on-line help.

After the login phase, each student can navigate through the teaching materials by using buttons, solve exercises related to the current subunit, use a game tool which allows representing fractions as cake slices, provide her/his self-assessment, view the system feedback messages and using the on-line-help.

The teaching material is hierarchically organised in three learning units. Among these teaching units there is a prerequisite relationship. Therefore, as such units have to be learned in a specific order, the system obliges the student to study unit by unit. To this purpose, access indicators are used for each teaching unit.

Each teaching unit consists of a certain number of learning subunits, while each teaching subunit consists of a certain number of pages displaying explanations or examples or exercises related to a specific topic. Among subunits in the same unit there are no prerequisite relationships, so the student is free to start her/his navigation where s/he wants.

At the end of each teaching subunit the system proposes an exercise related to the specific topic. Every exercise consists of two parts: one to evaluate the knowledge acquired by the student and the other to evaluate the student's competence, i.e. the ability to apply the newly learned concept. Different kinds of tests are used in the exercises, such as true-false questions, multiple-choice, short answer questions etc.

After doing the exercise, the student is given a self-assessment option by the system. However, to avoid excessive invasiveness on part of the system, the choice to give her/his opinion is optional in each case.

If the pupil does not wish to give her/his opinion s/he can go directly to the next phase (namely studying a new lesson, revising already studied lessons or solving new exercises which are randomly chosen by the system for each subunit), otherwise, the process for calculating the shared assessment is activated..

In case of student's self-assessment, after establishing the shared assessment for the current skill, the student receives a message containing the final shared assessment for both the theoretical and the practical part. In addition to teaching reinforcement, the student receives suggestions guiding her/his self-assessment ability, aiming to improve it. As described in the last section, according to the fluctuations of the SAMCR and CI indexes, the student is encouraged to be more cautious or less optimistic.

After giving its feedback messages to the student, the system can suggest the best next learning step (navigation through teaching materials) on the basis of the student's knowledge and ability to solve exercises, and the estimate of the student's self-assessment ability. In detail, the system takes into account the solution given by the student to the last exercise and the current value of the hypotenuse. Then, it is able to propose different next learning steps to the student.

The basic idea is supporting the revision of specific teaching materials and the solution to exercises according to the student's ability and self-confidence; in other words, the aim is to give more freedom to students that are doing well and are showing high self-assessment ability and to provide more guidance to less mature students.

All system feedback messages and the navigation support are intended to promote student's reflection on her/his own performance and, consequently, a deeper learning.

The externalisation of the student model in Frazionando is done in the unit and subunit pages by using the traffic light and star metaphor (Fig. 3 and Fig. 4). This is a very simple and understandable way of representing the student's level of knowledge and ability to solve exercise. It allows a young student to monitor continuously her/his performance and to understand in which point of her/his learning path s/he is, by providing a form of adaptive navigation support. Partial access to the models was preferred to a more complete externalisation, because a complete representation could be so overwhelming that the student could be confused and not to comprehend it. Moreover, traffic lights and stars are familiar to children and very often used, even in the classroom. It was found that the use of familiar objects to represent student models might help students to understand the meaning of their open models [2].

In the teaching unit map, the traffic lights indicate whether the units are accessible or not to the student. The stars in the balloon indicate the student's ability to solve exercises in the units. They are lit up according to the mean student's ability to solve the exercises presented in the related subunits.

Figure 3. Teaching unit menu

In the teaching subunit map, the stars in the road signs indicate the student's ability to solve the exercises in the subunit. They are lit up according to the student's ability to solve the exercises presented in the subunit.

Figure 4. Teaching sub-unit menu

Frazionando is a system with a cooperative student model, visible to student and teacher anytime. The student model externalises graphically the student's knowledge and ability, allowing the student to monitor continuously her/his performance and decide about following activities, and the teacher to help the cognitive and metacognitive development of the student. The student is always aware about the system assessment, so s/he has access to every source of data existing in the student model (student and system) which is similar to the underlying representation. All these characteristics, according to the SMILI☺ framework for Student Models that Invite the Learner In [3], guarantees that Frazionando CSA is able to promote student's and teacher's reflection on student work, increase the accuracy of the student model and help the student in monitoring her/his own work and planning future activities. This was proved by the results of an experiment carried out with children attending a primary school in Bari (Italy).

IV. The Evaluation of the System

The main goal of this work was to evaluate whether students learn more effectively when they are given the opportunity to reflect through an open student model. To achieve this, an evaluation of Frazionando was carried out with the help of students attending the fourth classes of a primary school in Bari (Italy). Two versions of Frazionando were implemented and then compared: one based upon an overlay model and the CSA method (Frazionando CSA) and the other only upon an overlay Model (Frazionando OM).

The experiment was run in laboratories and classrooms during the students' ordinary school hours, throughout a period of two weeks. Participation was anonymous, but great care was devoted to motivate pupils to get the best from their interactive experience with Frazionando. It was clearly explained to children that their performance would have been carefully evaluated by the teachers as part of their class-work. Previous studies of another hypermedia system addressing learning of logic demonstrated that motivation is an important factor that can question the validity of experiments with children [9].

Finally, the teachers monitored the children's activity throughout the experiment, without interfering in it.

To control the experiment, students were divided into two groups: an experimental group, which interacted with Frazionando CSA, and a control group, which interacted with Frazionando OM.

In each lab session, students randomly chose workstations and were not aware of the different versions of the system.

Each session lasted no longer than 80 minutes and each student participated in one session during the week. Data collection consisted of four stages: pre-testing, system interaction, post-testing.

In order to evaluate the didactic effectiveness of both Frazionando CSA and OM, and to demonstrate that Frazionando CSA could have a better pedagogical potential than Frazionando OM, pre-test and post-test were analysed by a two-way mixed design analysis of variance, with learning as the within-subjects factor and student model as the between-subjects factor.

The participants were 34 pupils attending the fourth class of "XXIV Circolo Didattico Clementina Perone" primary school of Bari. They were divided into two groups of 17 participants each: Experimental Group (EG) and Control Group (CG). Students assigned to EG group interacted with Frazionando CSA, while students assigned to CG group interacted with Frazionando OM.

Before starting the experiment, the mathematics teachers of the classes involved in the study filled in a brief questionnaire, which aimed at collecting general information about the students.

EG and CG groups were formed according to the initial questionnaire and the results of the pre-test administered to the students to evaluate their knowledge of fractions. Great attention was devoted to matching gender, previous knowledge of fractions, metacognitive ability and pre-test scores in EG and CG groups, thus obtaining groups of comparable heterogeneity.

Before using the system, students were administered a pre-test to evaluate their initial knowledge of fractions. The test was developed in collaboration with the teachers of the school and consisted of five questions (final scores ranged from 0 to 10).

After the pre-test, students of EG and CG groups were free to interact with the assigned version of Frazionando. Then they were administered a post-test which consisted of five questions as the pre-test. To avoid carry-over effects the wording of the post-test was slightly different.

A. *Results of the experiment*

Table I shows the mean and the standard deviation of pre-test and post-test score for the EG group.

TABLE I. Pre-test and post-test results of students in EG and CG groups

	EG group		CG group	
	Pre-test score	Post-test score	Pre-test score	Post-test score
Number of students	17	17	17	17
Mean	5,47	8,35	5,41	6,88
SD	2,18	1,11	1,8	1,73
	T = 5,57	t =2,12	T = 3,42	t = 2,12

A paired T-test (α=0.05) was performed within subjects for both EG and CG groups to evaluate whether students' performance improved after interacting with the assigned version of the system.

The null hypothesis (equality of mean) was rejected. The post-test mean was higher than the corresponding pre-test mean revealing that, on average, students improved their performance as a result of the interaction with the system. These results confirmed the didactic efficacy of both Frazionando versions.

Table II shows the mean and the standard deviation of learning gain (difference between post- and pre-test scores) for both EG and CG groups.

TABLE II. Learning gain for EG and CG groups

	EG group	CG group
Number of students	17	17
Mean learning gain	2,88	1,47
SD of learning gain	2,09	1,77
	T = 2,136	t = 2,037

To assess whether students in the EG group learnt more than those in the CG group, the learning gain (difference between post- and pre-test scores) for each student in both groups was calculated and the mean gains of the groups were compared by means of a T-test

(α=0.05).

The null hypothesis was rejected. The test revealed that the assigned system had significant effect on students' learning gain suggesting that students who used Frazionando CSA on average improved their performance more than those who used Frazionando OM. These results pointed out that there is a significant difference between the didactic efficacy of Frazionando CSA and OM, confirming that the involvement of the students in the student modelling process promotes deeper and more reflective students' learning.

After using Frazionando CSA the number of students with very low scores was remarkably reduced (SD of EG group passed from 2,18 in pre-test to 1,11 in post-test). On the contrary, after using Frazionando OM the number of students with very low scores witnessed just little reduction (SD of CG group passed from 1,8 in pre-test to 1,73 in post-test).

These findings allow considering Frazionando (with and without the cooperative self-assessment method) a good educational tool for children, able to act almost in the same way as a human teacher. A direct comparison between learning by means of Frazionando and classroom instruction would be necessary to demonstrate this claim. However, previous studies of hypermedia learning environments for children [9], [15] showed their high acceptability as pedagogical tools in primary education. This allows foreseeing that also Frazionando is able to perform in the same way.

The positive results of the study confirm that the choice of a simple representation of the model and the use of familiar icons motivated students to reflect on their model. The side effect of this reflection is represented by better achievements of students in the experimental group than those in the control group. This provides further confirmation that the externalisation of student models and the involvement of students in the assessment process, i.e. the use of open student model, promote deeper learning.

V. CONCLUSION

This article has presented the CSA method and its application in an e-learning system for children addressing learning of fractions and an experiment carried out to verify the promotion of student's reflection on learning process through the exposition of the student model.

It has been proved that the self-assessment process promotes student's reflection on her/his work, increases the accuracy of the student model and helps the student in monitoring her/his own work and planning future activities.

In Frazionando, navigation support is provided according to the student's knowledge and ability to solve exercises, and the estimate of the student's self-assessment ability. Concerning the self-assessment ability, there is just a rough differentiation between student able to self-assess and not able. Further development of the systems foresees a better distinction of the last three cases, thus providing different support and suggestions to students who constantly overestimate or underestimate their performance or have alternate assessment behaviour.

Finally, further possible application fields in which it might be possible to verify the didactic efficacy of using the student's self-assessment ability are cooperative learning and m-learning environments. In the former, CSA might be used by the tutor component to decide whether to encourage more or less participation of students in cooperative activities. In the latter, it might be used as parameter to adaptively provide students with the appropriate materials to be used on their handheld device.

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Manuscript received 17 June, 2006.