Concept Mapping in Didactics of Informatics. Assessment as a Tool for Learning in Web-based and Adaptive Educational Environments

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Abstract. Regarding assessment as an integral and essential part of the processes of teaching and learning, in the context of this thesis, alternative assessment methods (i.e. self-, peer- and collaborative-assessment) and tools (i.e. concept maps) are studied, aiming to promote learning, to evaluate cognitive skills and to cultivate/develop meta-cognitive and social skills. Furthermore in the direction of promoting meaningful learning through assessment, computer-based learning environments are developed, which exploit these methods and tools and have as basic unit the concept of the activity.

Keywords: assessment, concept mapping, feedback, adaptation, self-assessment, peer-assessment, collaborative-assessment.

1 Introduction

Assessment is central to the practice of education and one of the most powerful educational tools for promoting and motivating effective learning. Whereas in the past, assessment is considered as a means to determine measures and thus certification, there is now a notion of assessment as a tool for learning and a realization that the potential benefits of assessing are much wider and impinge on in all stages of the learning process [6]. Birenbaum [1] has made a useful distinction between two cultures in the measurement of achievement and relates them to developments in the learning society. In traditional so-called *testing culture*, instruction and assessment (testing) are considered to be separate activities and the testing culture fits well with the traditional approach to education where teaching is seen as an act of depositing the content which students receive, memorize and reproduce [1], [6]. The changing learning society has generated the so-called *assessment culture* which strongly emphasizes the integration of instruction and assessment and assessment culture is in accord with the constructivist approach to education where learning is viewed as a process through which the student creates meaning [1], [6]. Assessment culture can be used to change

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instruction from a system that transfers knowledge into students' heads to one that tries to develop students who are capable of learning how to learn.

In many cases, poor assessment practices can often be held responsible for low quality instruction and learning and may lead to undesirable consequences such as learning difficulties and reduction of students' motivation for learning. Many researchers argue that sound assessment practices can be used to improve instruction [6]. The exploitation of alternative methods and tools may make the assessment process a valuable learning experience, contribute to changing the culture amongst students from a testing culture to an assessment culture, foster a deep approach to learning and encourage students to engage continuously and change their learning methods. In this context and regarding the assessment of student learning as an integral and essential part of the processes of teaching and learning, the main goal of the research was: (i) to study alternative tools and assessment methods which aim to promote learning, to evaluate cognitive skills and to cultivate/develop meta-cognitive and social skills, and (ii) to develop computer-based learning environments, which have as basic unit the concept of the activity and exploit alternative assessment tools such as concept maps and assessment methods such as peer-, self- and collaborative-assessment.

Concept maps are considered to be a valuable tool of an assessment and learning toolbox, as they provide an explicit and overt representation of learners' knowledge structure and promote meaningful learning [17]. A concept map is comprised of nodes (representing concepts), and links, annotated with labels (representing relationships between concepts), organized in a structure (hierarchical, cyclic or hybrid) to reflect the central concept of the map. The triple <u>Concept</u>-*Relationship*-<u>Concept</u> constitutes a proposition, which is the fundamental unit of the map. Concept mapping, the process of constructing a concept map, is considered to be a creative activity, in which students must exert effort to clarify concept meanings in specific domain knowledge, by identifying important concepts, establishing the concepts relationships, and denoting their structure [17]. Various applications of concept maps in education and a number of concept mapping software tools are presented in [4]. Towards the direction of exploiting the value of concept map as assessment and learning tool, an adaptive web-enabled concept mapping environment, referred to as COMPASS (COncept MaP ASSessment and learning environment) was developed. The aim of COMPASS is twofold: to assess learners' understanding as well as to support the learning process.

Regarding the exploitation of alternative assessment methods, contemporary educational theories indicate that self-, peer- and collaborative-assessment enable students to actively participate in the assessment process, think more deeply, develop important cognitive skills such as critical thinking, evaluative abilities, teamwork, decision-making, self-monitoring and regulation, get inspiration from their peers' work, learn to collaborate, criticise constructively and suggest improvements, and reflect on the amount of effort they put into their work and judge the appropriateness of the standards they set for themselves [6], [19], [20]. However, students require exerting more effort than in traditional assessment methods as they undertake multiple roles such as the role of author and assessor and have to be trained and understand their role in the assessment process. An overall overview of studies of self-, peer- and collaborative-assessment can be found in [19], [21]. In an attempt to elaborate and contribute to the realization of these assessment methods, a web-based environment, referred to as

PECASSE (PEer and Collaborative ASSessment Environment) was developed, which engages learners in self-, peer- and collaborative-assessment activities.

The paper is organized as follows. In Section 2, a description of the web-enabled adaptive concept mapping environment COMPASS is provided. Afterwards, in section 3, the PECASSE environment is presented and, the paper ends, in section 4, with the main points of the research and its contribution.

2 An Overview of COMPASS

COMPASS (available at http://hermes.di.uoa.gr/compass) is a web-enabled concept mapping assessment and learning environment, which aims to assess learner's understanding as well as to support the learning process by employing a variety of concept mapping activities, applying a scheme for the qualitative and quantitative estimation of learner's knowledge and providing different informative, tutoring and reflective feedback components, tailored to learner's individual characteristics and needs [11].

Based on the learning goal that student selects, which corresponds to a fundamental topic/concept of the subject matter, COMPASS provides various activities, addressing specific learning outcomes. Depending on the outcomes, the activities may employ different concept mapping tasks, such as the construction of a map, the evaluation/correction, the extension and the completion of a given map; each of these tasks provides a different perspective of learner's understanding [18]. The concept mapping tasks are characterized along a directedness continuum from high-directed to low-directed, based on the context of the task and the support provided to students; students may have at their disposal a list of concepts and/or a list of relationships to use in the task and/or may be free to add the desired concepts/relationships. In Fig. 1, the main screen of COMPASS is shown. It consists of (i) the menu and toolbar, which provide direct access to several facilities such as the provision of feedback and the analysis of the map, and (ii) the Working Area, on which the central concept (in case of the construction) or the working map (constructed by the teacher) (e.g. the map that students have to evaluate/correct, or extend or complete or comment) are presented.

In the following, we discuss the assessment scheme applied for the evaluation of students' concept maps and the feedback process followed.

Evaluating a Concept Map in COMPASS. Concept maps have been extensively used, especially in science education, to assess learners' knowledge structure, in large-scale as well as in classroom assessment. The assessment is usually accomplished by comparing learner's map with the expert's one [18]. Two most commonly investigated assessment methods are the structural method and the relational method. The structural method [17] is limited to hierarchical maps and takes into account only the valid map components (e.g. propositions, examples, links/cross-links). The relational method focuses on the accuracy of each proposition, presents a high degree of inter-rater reliability and the evaluation results correlate well with both classroom and standardized tests [18]. Furthermore, most of the assessment schemes proposed in literature either have been applied to studies where the assessment of concept maps is human-based [18], or constitute a theoretical framework [15]. Regarding the computer-based assessment of concept maps, it seems that it is in its infancy as the number of systems that have embedded a scheme for automated assessment and for feedback provision is minimal. For example, the system proposed by [3] takes into account only the valid components, ignoring the invalid ones, which may contribute to the overall knowledge structure, whilst the assessment in Reasonable Fallible Analyzer (RFA) [5] is based on the identification of quite a few errors.

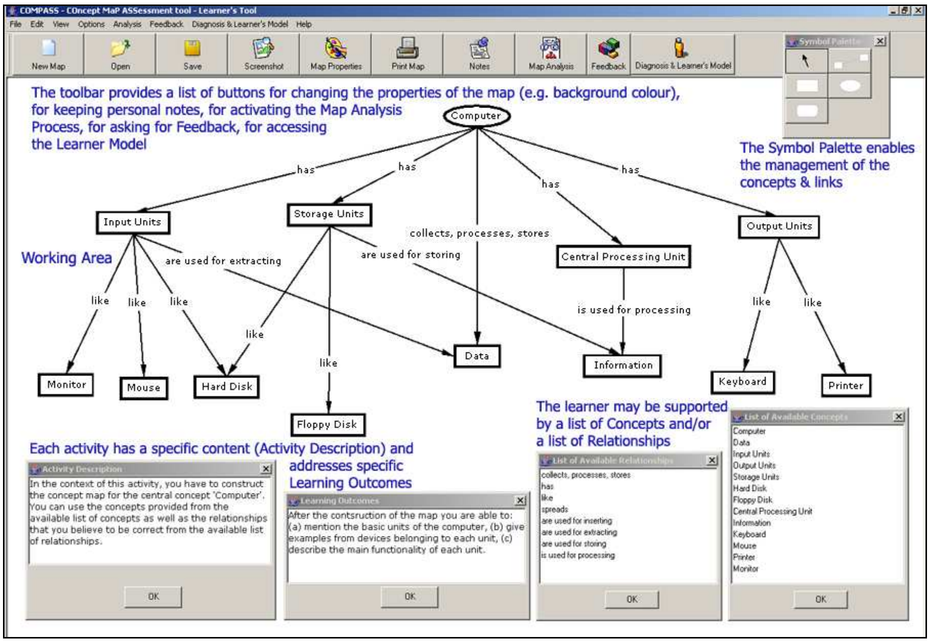

Fig. 1. The main screen of COMPASS. The Working Area presents a concept map constructed by a student in the context of a construction task supported with a list of concepts and relationships. The specific task is one of the activities provided in the context of the learning goal "The Computer Architecture"

Our work is an extension of this line of research. We propose a scheme for the assessment of concept maps and subsequently for the evaluation of learner's knowledge level on the central concept of the map. The proposed scheme adopts the relational method by examining the accuracy and completeness of the presented propositions on students' map and taking into account the missing ones, with respect to the propositions presented on the expert map. The analysis of the map (i) is based on the assessment of the propositions according to specific criteria concerning completeness, accuracy, superfluity, missing out and non-recognizability, (ii) results into the identification of specific error categories, and (iii) is discriminated in the qualitative and quantitative analysis. The qualitative analysis is based on the qualitative characterization of the errors and aims to contribute to the qualitative diagnosis of student's knowledge; that is student's incomplete understanding/beliefs and false beliefs. The quantitative analysis aims to evaluate learner's knowledge level on the central concept of the map and is based on the weights assigned to each error category as well as to each concept and proposition that appear on expert map. The weights are assigned by the teacher and reflect the degree of importance of the concepts and propositions as well as of the error categories, with respect to the learning outcomes addressed by the activity. In this way, the teacher has the possibility to personalize the assessment process. An analytical description of the assessment scheme incorporated into COMPASS is given in [10]. The results derived from the map analysis are represented to students in an appropriate form during the feedback process.

The Feedback Process in COMPASS. Recently developed computer-based concept mapping environments attempt to embed a scheme for feedback provision [3], [5], [14]. The feedback has mainly an informative and guiding orientation and is tailored to specific common errors identified on student's concept map after the comparison of the map with the expert one. For example, in the RFA [5], feedback is provided about the quantitative score of student's map accompanied with explanation of how the score is obtained. For concepts and propositions that student believes that have not been properly credited, a dialogue between the RFA and the student could begin. Also, hints concerning missing concepts and links as well as incorrect relationships are provided. The system proposed by [2] provides hints (feedback strings defined by the expert) about specific errors such as missing propositions. Moreover, none of the systems takes into account students' individual differences.

In this line of research, COMPASS provides feedback aiming to serve processes of assessment and learning by (i) informing students about their performance and their "current" state, (ii) guiding and tutoring students in order to identify their false beliefs, focus on specific errors, reconstruct their knowledge and achieve specific learning outcomes addressed by the activity/task, and (iii) supporting reflection in terms of encouraging students to "stop and think" and giving them hints on what to think about, indicating potentially productive directions for reflection [11], [12]. To this end, different forms of feedback are supported with respect to the addressed learning outcomes and student's preferences (text-based, graphical-based and dialogue-based form) and multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available during the feedback process in an attempt to serve processes of informing, guiding/tutoring and reflection. The Tutoring Feedback Components (TFU) supply students with learning material for the concepts represented on expert map and/or the concepts included in the provided list of concepts. The TFU are structured in two levels (the learning goal level and the activity level) and are associated with various types of knowledge modules (e.g. description or a definition of the concept under consideration, an image, an example, a counterexample, a task or a case) which aim to serve students' individual preferences and cultivate skills such as critical thinking, ability to compare and combine alternative feedback units etc. The ITRFC are structured in multiple layers and their stepwise presentation supports the gradual provision of feedback and enables students to elaborate on the feedback information and return to their map in order to correct any errors. The adaptive functionality of COMPASS is reflected to the personalization of the provided feedback in order to accommodate a diversity of students' individual characteristics and is implemented through (i) the technology of adaptive presentation that supports the provision of various alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components in the dialogue-based form of feedback. Specific student's characteristics (i.e. knowledge level, preferences, interaction behaviour), which are maintained in learner model and recorded either through student's interaction with the system or defined by the student explicitly, are used as a source of adaptation. COMPASS gives students the possibility to have control over the feedback presentation process at any time during the interaction with the environment by selecting the preferred form of feedback and by intervening in the stepwise presentation process of the dialogue in order to activate the desired stage and select the desired feedback components.

Evaluation of COMPASS. During the formative evaluation of the COMPASS environment, two empirical studies were conducted. The aim of the first study was to investigate the validity of the assessment scheme incorporated into COMPASS, as far as the quantitative estimation of students' knowledge level is concerned. In particular, we investigated the correlation of the quantitative assessment results obtained from COMPASS with the results derived from two other approaches; the holistic assessment of concept maps by a teacher and the assessment of concept maps based on the similarity index algorithm [9]. The results revealed that there is a high degree of convergence on the three scores assigned to the students' concept maps. Also, the estimation of student's knowledge level generated by COMPASS correlates closely with the similarity index, which is considered a valid indication of the quality of students' knowledge and has been taken as evidence of validity of the assessment of concept maps in other studies [16].

The second study was conducted in order to examine the hypotheses that COMPASS would help students positively on learning. In particular, the aim of the study was to investigate the effects on students' learning that have different instructional methods (concept mapping with COMPASS vs. traditional teaching) and to record the students' opinions of the COMPASS environment. Prior to the intervention, all students were administered pre-tests in achievement. After the pre-test, students were randomly assigned to one of the groups (experimental vs. control). At the conclusion of the intervention, all participants completed the post-achievement test and the students of the experimental group were asked to fill a questionnaire for COMPASS. The concept of 'Peripheral Storage Units' was used as the experimental content. The experimental group studied the concept of 'Peripheral Storage Units' by using the COMPASS environment. They were asked to construct a concept map concerning the specific central concept. They had at their disposal a list of concepts, a list of relationships and the feedback material provided by COMPASS. The control group participated in a lecture, where the instructor introduced the specific central concept and a traditional classroom teaching was followed.

The results shown that although the difference on pre-test performance is not significant (t=-0.255, df=63, 2-tailed p=0,799), the average performance after the intervention for the experimental group was significantly higher (t= 4.179, df=63, 2-tailed p<0.001) than that of the control group. Moreover, for the experimental group as well as for the control group, the difference on the performance between the two time-conditions was significant (*experimental group*: t=-24.035, df=32, 2-tailed p<0.001, *control group*: t=-10.080, df=31, 2-tailed p<0.001). The results indicated that both groups improved their performance after following one of the instructional methods, but the participants of the experimental group following the instructional method with COMPASS significantly outperformed the participants who followed the traditional teaching method. This is an indication that the COMPASS environment had a better learning impact on students than the traditional teaching method. Moreover, the students of the experimental group were able to represent more accurate concepts on their maps and construct more accurate relationships among these concepts. This provides evidence supporting the inference that experimental group students were able to achieve overall higher measures of performance than control group students.

From the analysis of students' responses to the questionnaire was found that all of the students enjoyed their activity with COMPASS and found the process of constructing a concept map with COMPASS interesting. Most of the students reported that they were able to use all the supported functions immediately with minimal difficulty and they found the environment pleasant and enjoyable. The available list of concepts, the structure/steps of the dialogue-based form of feedback and the educational material stood high in most of the students favour. Among the facilities that were characterized as most useful were the explanation of the expert for the false/accurate beliefs, the educational material, the reflective questions and the performance feedback. Most of the students reported that the provided feedback helped them to learn the concepts, understand their errors and construct their concept map. All of the students reported that their activity with the COMPASS environment helped them to understand most of the underlying concepts and learn the central concept of 'Peripheral Storage Units'.

3 An Overview of PECASSE

PECASSE is a web-based environment, which engages students in self-, peer- and collaborative-assessment activities and can be used for distance education or blended learning or distance learning modes of study (available at http://hermes.di.uoa.gr:8080/pecasse). In PECASSE, students may act as (i) "*authors*" being able to submit their work/activity, which has been carried out either individually or collaboratively, (ii) "*assessors*" being responsible to evaluate (a) their own work in a brief way or according to specific criteria (self-assessment), and/or (b) their peers' work on their own or by collaborating with other learners (peer-assessment) and/or by collaborating with the instructor (collaborative-assessment), and (iii) "*feedback evaluators*" being able to evaluate the quality of feedback, provided by their assessors.

The literature review of systems developed to support self-, peer- and collaborative-assessment reveals that most of the systems focus mainly on peer-assessment and there is a lack of a system that supports all the assessment methods (self-assessment, peer-assessment and collaborative-assessment) and their possible combinations (e.g. peer- and collaborative-assessment, self- and collaborative-assessment). In most systems, authors are individuals and just a few systems support group of learners as authors. Moreover, the possibility of assessors to be group of learners is limited. The grouping of learners (in systems that authors/assessors are group of learners) as well as the assignment of assessors is mainly done randomly; none of the systems takes into consideration learners' individual differences such as knowledge level or ability to evaluate peers' work. Regarding the review process, alternative approaches for setting the standards of the review and the form of scoring are not supported; the assessors do not have the possibility to set their own criteria/questions, enrich the criteria/questions set by the instructor and define the form of scoring.

Having as an objective to extend this line of research, we developed PECASSE, which is a discipline-independent web-based environment. In addition to the basic functions such as the uploading of assignments, the scoring/commentary of the work assessed and the presentation of the results to authors, PECASSE supports self-assessment, peer-assessment, collaborative-assessment and their combinations, individual and collaborative elaboration of the activities, review of the activities by one or group of learners, grouping of learners and assignment of assessors following alternative strategies and taking into consideration learners' individual differences, collaboration of authors and/or assessors in a synchronous and asynchronous way, alternative review methods (i.e. commentary letter or assessment form) and a variety of strategies for setting the assessment scheme applied in the review process (i.e. the instructor sets the assessment scheme or the instructor defines a template of the assessment scheme and the assessor has the possibility to modify the proposed template or the assessor proposes the criteria/questions and the form of scoring and collaborates/discusses with the instructor in order to result in an acceptable scheme or the assessor defines his/her own criteria and questions as well as the form of scoring).

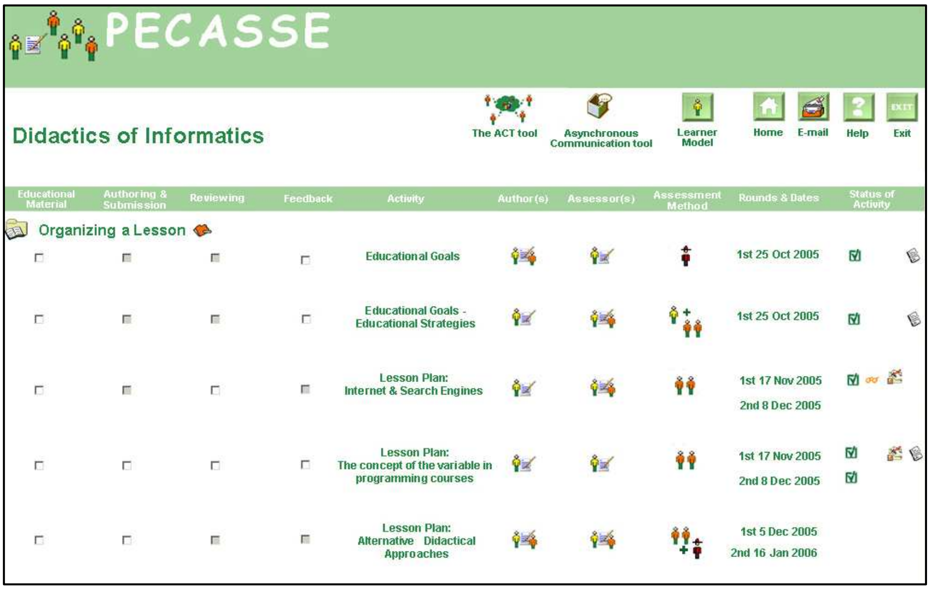

Fig. 2. A screen shot of the main screen of the PECASSE environment

In PECASSE, students have the possibility to actively participate in the assessment process which involves the following steps and can be carried out in three consecutive rounds at most, that is Step 1, 2 and 3 can be repeated up to three rounds:

- *Step 1 - Authoring & Submission*: The author is responsible to submit the activity until the deadline and proceed to self-assessment by filling a brief form.
- *Step 2 - Reviewing*: After the deadline of the submission phase, assessors are informed about the activities that they have to review. The assessors have the possibility to be anonymous or eponymous with respect to their preference. Different strategies can be followed for setting the assessment scheme with respect to the learning outcomes of the activity. In case of collaborative-assessment, the instructor collaborates with assessors in order to clarify objectives and negotiate details of the assessment process. The assessors (i.e. individual learner or group of learners) of the same activity have the possibility to collaborate in order to discuss their comments regarding the activity under review.
- *Step 3 - Feedback*: This step includes the provision of feedback to authors, the revision of the initial submitted work and the evaluation of assessors. After the deadline of the review process, the activities accompanied with grades and/or comments are returned to authors. The 'best' activities with respect to the grades assigned by the assessors and the instructor are published. Authors have the possibility to revise their work submitted to the 1st Step, taking into account their assessors' comments and the 'best' activities. Moreover, authors can communicate with assessors in order to clarify any non-understandable comments. Furthermore, authors are asked to evaluate their assessors through an evaluation form.

Fig. 2 presents the main screen of the environment after student's selection of a specific learning goal. More specifically, the learning goal of "Organizing a Lesson" in the context of the subject matter "Didactics of Informatics" and a set of five activities are presented. The first activity entitled "Educational Goals" is a collaborative one (see icon for author(s)), it is going to be assessed by one assessor (see icon for assessor(s)) and the collaborative-assessment method is followed (see icon for assessment method). Students have the possibility to access their learner model, which is dynamically updated during their interaction with PECASSE in order to keep track of their "current state". Students can see the information held in their learner model concerning their progress and communication. Furthermore, students can communicate with the instructor and their peers in the context of the subject matter in a synchronous (icon "The ACT tool" [8]) or asynchronous way (icon "Asynchronous Communication tool"). For each activity appearing in Fig. 2, students have the possibility to select the available steps of the assessment process with respect to the deadlines defined.

The group formation of students and the assignment of assessors (that is the construction of groups "authors-assessors") is facilitated by a group formation tool, referred to as OmadoGenesis [7]. OmadoGenesis enables the following strategies: (i) random assignment by the system, (ii) assignment by the instructor on the basis of his/her preferences or learners' demands, and (iii) assignment by the system on the basis of learners' individual characteristics. In any case, the instructor has the possibility to intervene and rearrange the group members in cases where conflicts are encountered and undesirable groups are formed. The instructor defines the strategy that will be followed, the group size (i.e. the desired number of learners in a group or the desired number of activities for review) and the students that will be grouped for a specific activity. In case of the third strategy, the group formation of students as well as the assignment of assessors is based on learners' model. The instructor selects students' characteristics (up to 4) that wish to be taken into consideration such as learner's learning style and knowledge level. Then, for each selected characteristic, the instructor defines (i) if the group members will have similar values (homogeneity of the group) or dissimilar (heterogeneity of the group) and (ii) the algorithm that is going to be used and its parameters in order to find an optimal solution (for a description of the algorithms see [7]).

Evaluation of PECASSE. The study for the evaluation of PECASSE [13] showed that the majority of the participant-students were satisfied with the usefulness and the usability of the available facilities and the realization of the assessment methods. Most of the students asserted that PECASSE promotes and enhances the learning process. However, students characterized the process followed in PECASSE as time and effort consuming. In line with other researches in the area [19], the majority of the students had a positive attitude towards peer-assessment, asserting that they had received a great benefit from assessing their peers' work. More specifically, they commented that their involvement in peer-assessment made them work at a deeper level of understanding and they benefited both from the experience and the wide range of comments they received. In the context of the collaborative-assessment, most of the students characterized the role of the expert-assistants as necessary, guiding and encouraging. Moreover, they consider that the assistants' participation gave them the possibility to share a good mutual understanding of the assessment scheme through discussions and negotiations. Regarding self-assessment, most of the students did not understand the importance of self-evaluating their own activity.

As far as students' role as assessors is concerned, the quality of their work was rather high. Most of the students managed to construct the assessment form including a number of new and correct-defined criteria and question items, apply the criteria in a successful way and provide quality feedback. Moreover, most students suggested that the feedback they received from their peers was valuable for the revision of their initial work. Students also consider that the template of the assessment form and the support provided by expert-assistants helped them to design their own assessment form, provide useful feedback and cope with their role as assessors. The major problem of the review process was the difficulties that students encountered in identifying all the problems and weaknesses of the work under review. Probably, this is due to students' limited experience in the underlying learning task concerning the design and evaluation of lesson plans. In the future, we intend to use additional subjective measures such as interviews in order to analyze students' perspectives and clarify the specific problem. Two important issues revealed from the particular study that is worthwhile to mention are the need for instructor/assistant participation in the whole process and the training of students before undertaking the role of assessor.

4 Conclusions

The research presented contributes to the fields of educational assessment, didactics of informatics, concept mapping and design of computer-based adaptive learning environments. The main contribution of the work lies in the development of learning environments that exploit alternative assessment tools such as concept maps and assessment methods such as self-, peer- and collaborative-assessment and aim to support the learning and assessment processes.

COMPASS is a web-enabled discipline-independent concept mapping environment, which aims to assess learner's understanding as well as to support the learning process. The discriminative characteristics of COMPASS are the provision of various concept mapping activities, the proposed scheme for the qualitative and quantitative estimation of learner's knowledge, the different forms of feedback supported (text-, graphical- and dialogue-based), the provision of multiple ITRFC, which serve processes of informing, guiding/tutoring and reflection, the adaptivity of the feedback process that interweaves the gradual provision of the ITRFC with the adaptive presentation of alternative forms of feedback and feedback components, accommodating learners' knowledge level, preferences and interaction behaviour, and the learner support and control offered over the feedback process.

PECASSE provides a web-based assessment environment for learners to criticize others' work, review and revise their own ideas/work, collaborate with the instructor and their peers and share their ideas. The discriminative characteristics of the PECASSE environment are the support of self-assessment, peer-assessment and collaborative-assessment as well as their combinations with respect to the learning outcomes of the activity, the options offered for the definition of authors and assessors, (i.e. the author and/or the assessor of an activity could be an individual or a group of learners), the variety of strategies offered for the assignment of assessors and the group formation of students, taking into account learners' individual differences, and the variety of strategies offered for the setting of the assessment scheme applied.

COMPASS and PECASSE could be valuable tools of instructor's toolbox, aiming to foster a learning approach to assessment. Possible enhancements of the research could be the development of facilities that support collaborative concept mapping and the exploitation of the environments within the daily educational practice.

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