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EXPLOITING COMPASS AS A TOOL FOR TEACHING AND LEARNING

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Abstract. In this paper, an overview of the concept mapping learning environment COMPASS is given. The most important features of COMPASS are the support of students in working out various concept mapping activities, the analysis of students' concept maps, the qualitative and quantitative estimation of their knowledge, the provision of different forms of feedback and feedback components, the adaptive functionality of the feedback process and the CAT tool, which enables teachers to author mapping activities and monitor students' progress. The results revealed from an experimental study conducted in a classroom setting are positive and encouraging, regarding the exploitation of COMPASS as an alternative teaching and learning tool.

1 Introduction

In educational settings, concept maps have become a valuable tool of a teaching, assessment and learning toolbox, as they enhance learning, promote reflection and creativity and enable students to externalise their knowledge structures (Novak & Gowin, 1984). The most natural way to construct concept maps seems to be the use of paper and pencil or the "Post-it" notes. However, this form poses constraints, such as the inhibition of the construction, revision, assessment and feedback processes. Over the last years, the introduction of information and communication technologies in the educational practice resulted into the development of a number of computer-based and web-based concept mapping environments, aiming to compensate these constraints and to eliminate communication restrictions. The available concept mapping software environments are either commercial such as Inspiration (http://www.inspiration .com) or have been developed in the context of research programs. In research level, the environments aim to (i) support students in working out concept mapping activities, support instruction with the use of concept maps and enable teachers to design and organize their lessons, such as TPL-KATS (Hoeft et al., 2003), CM-ED (Rueda et al., 2004) and LEO (Coffey & Canas, 2003; Coffey, 2007), (ii) promote and facilitate collaborative learning, such as CmapTools (Cañas et al., 2004), and (iii) support the assessment and feedback process during the elaboration of an activity, such as RFA (Conlon, 2006), Java Mapper (Hsieh & O' Neil, 2002) and Verified Concept Mapper (Cimolino et al., 2003).

In this line of research and having as an objective to support the learning process and to assess learner's understanding, we developed an adaptive concept mapping learning environment, referred to as COMPASS (COncept MaP ASSessment and learning environment). The discriminative characteristics of COMPASS are (i) the possibility of students to work out various concept mapping activities, which employ different concept mapping tasks, (ii) the analysis of students' maps and the application of an assessment scheme for the qualitative and quantitative estimation of their knowledge, (iii) the provision of different forms of feedback (text-, graphical- and dialogue-based) and feedback components, which serve processes of informing, guiding/tutoring and reflection, (iv) the adaptivity of the feedback process that accommodates students' knowledge level, preferences and interaction behaviour, (v) the learner control over the feedback process, and (vi) the teacher-expert support through the CAT tool (COMPASS Authoring Tool), which enables the design/authoring of concept mapping activities and feedback components, the definition/configuration of the assessment scheme applied and the monitoring of students' progress. The rest of the paper is structured as follows. In Section 2, an overview of COMPASS is given. In Section 3, the results of an experimental study are presented, focusing on the effectiveness of COMPASS in teaching and learning and on students' opinion. The paper ends, in Section 4, with the main points of our work and our near future plans.

2 An Overview of COMPASS

COMPASS (http://hermes.di.uoa.gr/compass) is a discipline-independent concept mapping learning environment, developed at the Educational & Language Technology Laboratory of the Department of Informatics & Telecommunications at the University of Athens (Gouli et al., 2004; 2006). In Figure 1, the main screen of COMPASS is shown, which consists of (i) the menu and toolbar, providing direct access to several facilities such as feedback, student model and analysis of the map, and (ii) the Working Area, on which the central concept or the activity map (e.g. the map that students have to evaluate/correct, extend, complete or annotate) is presented. COMPASS was designed to support any language at user interface level (currently English and Greek interface is supported). In the following sub-sections, a brief description of the domain knowledge of COMPASS, the assessment scheme applied for the evaluation of students' concept maps, the feedback process followed and the CAT tool is given.

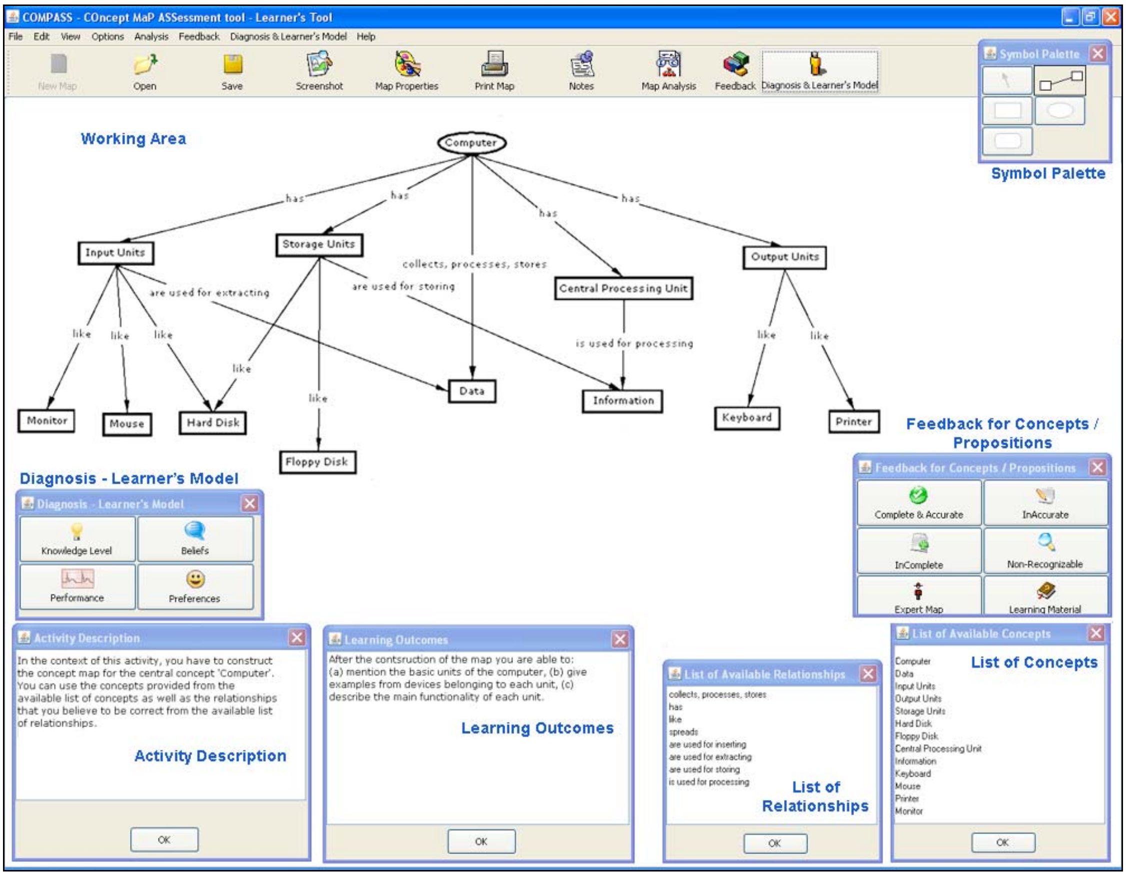

Figure 1. The main screen of COMPASS. The Working Area presents a concept map constructed by a student in the context of a construction mapping task supported with a list of concepts and relationships. The specific task is one of the activities provided in the context of the learning goal "Computer Architecture".

2.1 The Domain Knowledge of COMPASS

The domain knowledge of COMPASS is based on the notion of a learning goal that student can select. A goal corresponds to a fundamental topic of the subject matter and is further analysed to specific learning outcomes, which are realised through various learning concept mapping activities. An activity accomplishes specific educational functions, such as ascertaining students' prior knowledge, promoting knowledge construction/ identifying conceptual changes, and assessing knowledge construction (Gouli et al., 2004). Depending on the outcomes and the functions, the activities may employ various concept mapping tasks, such as the construction of a map, the evaluation/correction, the extension, the annotation and the completion of a given map or combinations of the abovementioned tasks (e.g. evaluation and completion of a given map); each of these tasks provides a different perspective of student's understanding. 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 and/or may be free to add the desired concepts/relationships on their maps. The provided lists may contain not only the required concepts/ relationships but also concepts/relationships that play the role of distracters (i.e. concepts that can be characterized as superfluous and relationships that are incorrect). Also, the domain knowledge of COMPASS contains the feedback components, which are available through the feedback process and the model of teacher's knowledge. In Figure 2, the constituent parts of the domain knowledge of COMPASS are presented, while in Figure 3, the model of a concept mapping activity in COMPASS is depicted.

2.2 The Assessment Scheme in COMPASS

Depending on the attributes of the activity, student's concept map may be assessed either automatically by COMPASS (by activating the "Map Analysis" button from the toolbar or the "Analysis" menu), or by teacher through the CAT tool or by peers through the PECASSE (PEer and Collaborative ASSessment Environment)

environment (Gouli et al., 2008). A scheme has been developed for the assessment of concept maps and subsequently for the evaluation of student'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 student's map, taking into account the missing ones, with respect to the propositions represented on the expert map (Gouli et al., 2005). The analysis of the map (i) is based on the assessment of the propositions according to specific criteria, such as completeness, accuracy, superfluity, missing out and non-recognizability, (ii) results into the identification of specific error categories (e.g. incomplete relationship, incorrect concept, superfluous relationship, missing proposition), 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 student's knowledge level and is based on the weights assigned to each error category as well as to each concept and proposition that appear on expert map, reflecting their degree of importance. Pre-defined weights for error categories are supported; the teacher has the possibility to personalize the assessment process and configure the weights through the CAT tool when s/he constructs the expert map, with respect to the learning outcomes addressed by the activity under consideration. The results derived from the analysis are represented to students in an appropriate form during the feedback process.

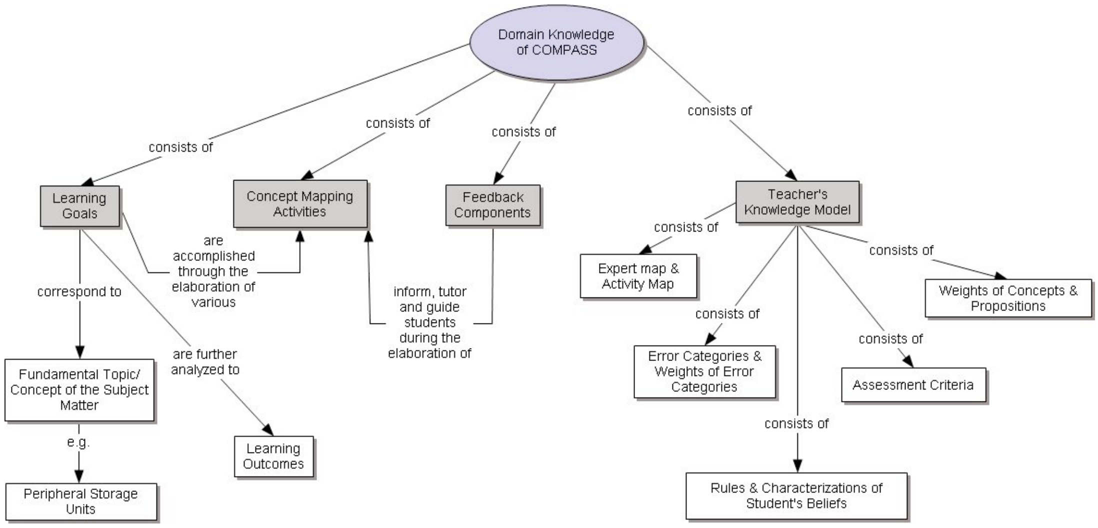

Figure 3. A representation of the domain knowledge of COMPASS.

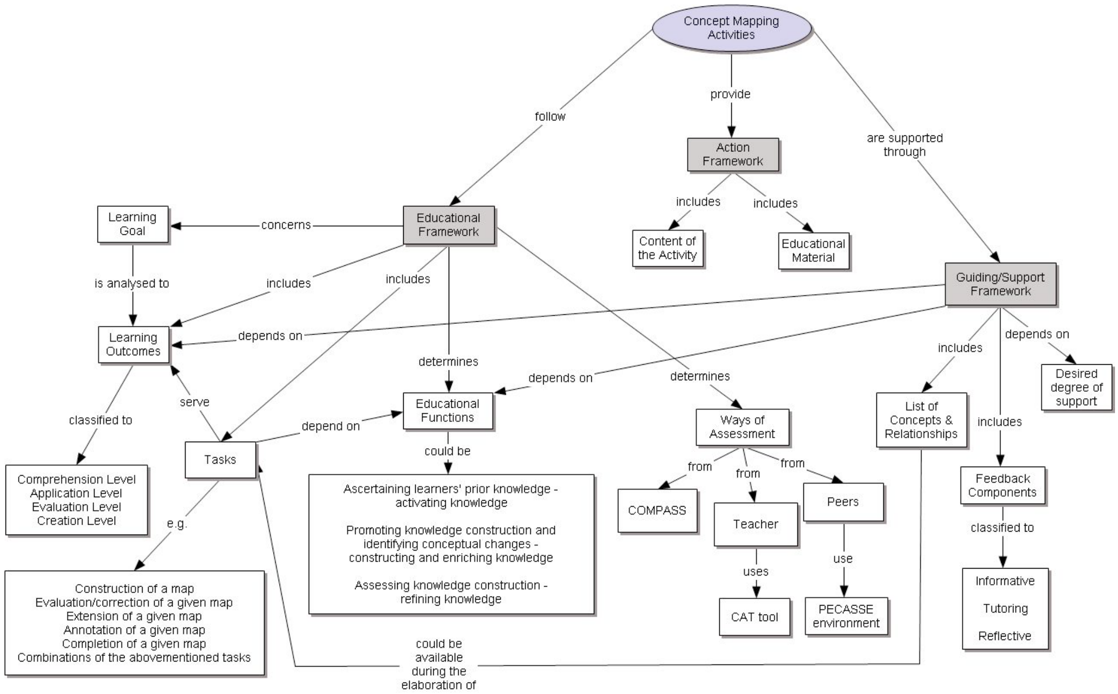

Figure 4. The model of a concept mapping activity in COMPASS.

2.3 The Feedback Process in COMPASS

The provision of feedback in COMPASS aims to (i) inform students about their performance and their "current" state, (ii) guide and tutor 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) support 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 (Gouli et al., 2006). Different forms of feedback (i.e. text-based, graphical-based and dialogue-based form) are supported with respect to the addressed learning outcomes and students' preferences and multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available during the feedback process. The Informative Feedback Components (i.e. Correctness-Incorrectness of Concept/Proposition & Type of Error, Correct Proposition, Expert Map and Performance Feedback) aim to inform students about the correctness of their answer and their performance. The Tutoring Feedback Components (i.e. Tutoring Feedback Units and Explanation of the Proposition) aim to tutor students by enabling them to review learning material relevant to the attributes of the concept/proposition represented on expert/student map and/or the concepts included in the provided list of concepts. Finally, the Reflective Feedback Components (i.e. Belief Prompt-Rethink Write, Error-Related and Inquiry-Related Reflective Questions) aim to promote reflection and guide students' thinking, in order to explore situational cues and underlying meanings relevant to the error identified. 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 student model and recorded either through student's interaction with the environment or defined by the student explicitly, are used as a source of adaptation. COMPASS incorporates various strategies in order to determine the feedback components that should be presented, depending on the sources of adaptation (Gouli et al., 2006). Moreover, COMPASS gives students the possibility to (i) personalize the feedback process by accessing and initiating/updating their student model in terms of the feedback presentation parameters (e.g. preferences on types of feedback components and characteristics that could be used as source of adaptation), and (ii) have control over the feedback presentation process at any time during their 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. Also, at any stage of the dialogue, students have the possibility to inactivate the adaptation of the feedback process.

2.4 The CAT tool

The CAT tool (COMPASS Authoring Tool) supports teachers in developing concept mapping activities and monitoring students' progress. More specifically, the CAT tool:

(i) enables teachers to author concept mapping activities that students can work out through COMPASS. In particular, the teacher has the possibility to (a) configure the characteristics of a concept mapping activity (e.g. the learning goal, the learning outcomes, the task, the form of feedback and the components that could be available during the elaboration of the activity, the assessment scheme, the weights of the various error categories), (b) construct the expert map and the activity map (i.e. when the task refers to the evaluation, extension, completion, or annotation of a given map), and (c) author the tutoring feedback units, the reflective questions and the explanation of the propositions for the various concepts and propositions, which are depicted on the expert map or could be represented on the student map,

(ii) supports teachers in assessing students' concept maps, that are not automatically assessed by COMPASS and providing feedback and comments to students for their work,

(iii) enables teachers to monitor students' progress by having access to their students' model, the log files maintained and the various versions of the maps recorded during the elaboration of the activity, and

(iv) supports the collaboration of teachers in authoring concept mapping activities. In particular, teachers have the possibility to (a) access concept mapping activities that have been created and published by others, (b) evaluate published activities and send comments to their authors, and (c) collaborate with other authors for designing an activity or creating feedback units through an asynchronous communication tool.

3 Experimental Study

The focus of the study was to examine the hypotheses that COMPASS could be used effectively as a teaching tool and would help students positively on learning. In particular, the aim of the study was to investigate the effects on students' learning following different teaching methods (concept mapping with COMPASS vs. traditional teaching) and to record students' opinions of the COMPASS environment. A pre-post design with (i) an experimental group, exploiting COMPASS as a teaching and learning tool, and (ii) a control group, participating in a traditional teaching lesson, was employed.

Sixty-five students (n=65), 35 females and 30 males, participated in the study. The students were 13-14 years old and selected randomly from four classes of a junior high school in Athens, Greece. The students were studying their second semester course of Informatics. Students were already familiar with the concept mapping technique, as it was used from the beginning of the school year, as the main teaching and assessing strategy. 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). No significant difference was found on the *t*-test performed, comparing the two groups on pre-test performance (t=-0.255, df=63, 2-tailed p=0,799).

The concept of 'Peripheral Storage Units' in informatics teaching was used as the experimental content. Two experienced informatics teachers selected the concepts that would be represented on the expert map (20 concepts). With the selected list of concepts, each teacher constructed a concept map. The similarity index between the two expert maps, as it results from the similarity index algorithm of Goldsmith et al. (1991), was 0.85. The expert map used in all the phases of the study resulted from teachers' collaboration and negotiation and included 20 concepts and 28 propositions. The teachers also collaborated and negotiated on (i) the lists of concepts and relationships that were available during the activities (performed in COMPASS and in pre-post tests); the provided list of concepts included the 20 concepts represented on the expert map and a number of concepts playing the role of distracters, and (ii) the appropriate weights (error categories, concepts and propositions) for the assessment of students' concept maps by COMPASS. At the end, the two teachers cooperatively constructed the feedback material available in COMPASS (i.e. tutoring feedback units, inquiry-related reflective questions and explanations of propositions).

3.1 Procedure

The five week experimental study consisted of the following phases:

(i) *introduction to COMPASS environment* (1st and 2nd week) - lasted 1 ½ hour: The functionality of COMPASS was demonstrated and all the students worked out a concept mapping activity (construction task) concerning the concept of 'Main Memory' (already taught).

(ii) *pre-testing* (2nd week) – lasted 30 minutes: All the students took the pre-achievement test.

(iii) *studying the central concept of 'Peripheral Storage Units'* (3rd week) – lasted 2 hours:

- The experimental group studied the central concept by using the COMPASS environment. Students were asked to construct a concept map concerning the specific central concept. They had at their disposal a list of 24 concepts and a list of 21 relationships and were asked to represent the appropriate concepts from the available list and relate them with the appropriate relationships, ignoring the ones playing the role of distracters. For each concept of the list, students had the possibility, at any time of the task, to access the available tutoring feedback units (i.e. a description or a definition of the concept, an image, an example, a counterexample, a task or a case). Also, during the elaboration of the task, students had the possibility to activate the analysis of their map, to receive feedback in dialogue-based form and to access the expert map and the performance feedback. Moreover, the feedback components that were available are: the correctness-incorrectness of concept/proposition & type of error, the correct proposition, the explanation of the proposition, the tutoring feedback units, the belief prompt-rethink write, and the error- and inquiry-related reflective questions. The role of the teacher was guiding and supportive as far as the functionality of the COMPASS environment was concerned.
- The control group participated in a lecture, where the teacher introduced the specific central concept following a traditional classroom teaching. During the lesson, the teacher asked students questions in order to ascertain their prior knowledge for the concepts being taught, introduced the unknown concepts, discussed with students the problems that they encountered in understanding the taught concepts and finally asked questions in order to assess their knowledge.

(iv) *filling the questionnaire* (4th week) – lasted 20 minutes: The students of the experimental group were asked to answer six open questions, concerning their opinion of the COMPASS environment. Indicative questions are: 'Do you believe that the COMPASS environment helps you to learn the central concept?', 'Which facilities of the system, do you think that help you more during the elaboration of the activity?'.

(v) *post-testing* (5th week) – lasted 1 hour: All the students took the post-achievement test.

3.2 *Pre-test & Post-test*

The pre-test was composed of a concept mapping activity on the central concept of 'Peripheral Storage Units'. Students were asked to construct a concept map of the central concept with paper-and-pencil using a list of 20 concepts (e.g. 'Hard disk', 'Optical Storage Units', 'Capacity', 'Byte', 'Cd-Rom'). For the evaluation of the pre-test, the similarity index algorithm of Goldsmith et al. (1991) was adopted. The similarity index may be viewed as an index of accuracy and completeness of the student concept map and as a valid indication of the quality of students' knowledge (McClure et al., 1999; Chang et al., 2001). The performance score of the pre-test, presented in Table 1, corresponds to the similarity indices of students' concept maps on a scale of 0-100 (the similarity index ranges from zero to one).

The post-test consisted of (i) a questions' test, and (ii) a concept mapping activity. The questions' test included 10 long answer items, in which each item scored 10 points. The questions' test was constructed to measure students' learning on the concept of 'Peripheral Storage Units' and included all the concepts that students learned either following COMPASS teaching method or traditional teaching. Two indicative items were: (i) 'Which are the basic categories of peripheral storage units? Try to mention the storage units that belong to each category.', (ii) 'What is formatting of a storage unit?'. The questions' test was scored by two informatics teachers. The Pearson correlation of raters was 0.953 (r=0.953, df=63, p<0.01). The scores rated by each teacher were summed and divided by 2, which was the performance score for the post-test (Table 1). The concept mapping activity included a construction task with paper-and-pencil for the central concept of 'Peripheral Storage Units', supported with a list of 25 concepts. For the construction of the map, students were asked to represent the appropriate concepts from the available list, ignoring the ones playing the role of distracters and relate them with their own defined relationships. The similarity indices of students' concept maps were calculated (Table 2). The concept mapping activity aims at providing another measurement of students' learning on the specific central concept and giving indications on how students' concepts maps and subsequently students' knowledge changed from pre-test to post-test.

3.3 *Results*

In order to investigate the effectiveness on learning of the teaching method followed, we examined students' performance on pre-test and post-test. More specifically, we examined (i) students' performance on pre-test activity as it was evaluated based on the similarity index and on various concept mapping measures (i.e. number of concepts/propositions represented on students' maps and number of accurate concepts/propositions), (ii) students' performance on questions' test of the post-test, and (iii) students' performance on post-test concept mapping activity and on the corresponding concept mapping measures. Descriptive statistics for pre-test and post-test performance by method of teaching are presented in Table 1. A t-test performed on pre-test performance revealed that the two groups were initially equivalent. Moreover, descriptive statistics for pre-test and post-test concept mapping measures by method of teaching are presented in Table 2.

Groups of Students – Method of Teaching	**Performance**	
	Pre-test	**Post-test**
Experimental Group – Working with COMPASS (n=33)	11.61 (8.11)	68.61 (17.22)
Control Group – Traditional Teaching (n=32)	12.13 (8.27)	48.63 (21.18)
Total (n=65)	11.86 (8.13)	58.77 (21.61)

Table 1: Means (and standard deviations) of the pre-test and post-test performance

The two-way mixed analysis of variance (ANOVA) with time (pre-test vs. post-test) as a within-subjects factor and method of teaching (working with COMPASS-experimental group vs. traditional teaching-control group) as a between-subjects factor was used to analyse the main effect of the method of teaching on students' performance. The interaction between method of teaching and time is statistically significant ($F_{1,63}$= 22.7, p<0.001). Although the difference on pre-test performance is not significant, the average performance after the intervention for the experimental group (M=68.61, SD=17.22) was significantly higher (t=4.179, df=63, 2-tailed p<0.001) than that of the control group (M=48.63, SD=21.18). 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: t=-24.035, df=32, p<0.001, control: t=-10.080, df=31, p<0.001). The results indicated that both groups improved their performance after following one of the teaching methods, but the participants of the experimental group working with COMPASS significantly outperformed the participants who followed the traditional teaching method. This provides an indication that the COMPASS environment had a better learning impact on students than the traditional teaching method.

Regarding the completeness and accuracy of students' concept maps (measured by the similarity index score) and consequently the students' performance, the results indicated significant two-way interactions between time and method of teaching ($F_{1,63}$= 17.032, *p*<0.001). The post-test score of the experimental group (M=58.45, SD=15.26) is higher than the score of the control group (M=43.63, SD=17.86). A *t*-test showed a significant difference (*t*=3.603, *df*=63, 2-tailed *p*=0.001). In line with the abovementioned results, in post-test, students working with COMPASS performed better and constructed more accurate and correct concept maps than those who followed the traditional teaching method. Insignificant differences were found comparing the concept mapping measures of the two groups on pre-test: (i) number of concepts (*t*=-0.741, *df*=63, *p*=0,461), (ii) number of propositions (*t*=-0.402, *df*=63, *p*=0,689), (iii) number of accurate concepts (*t*=-1.104, *df*=63, *p*=0,274), and (iv) number of accurate propositions (*t*=-0.532, *df*=63, *p*=0,596). This provides evidence supporting the abovementioned inference that the two groups were initially equivalent. As shown in Table 2, students' concept maps of both groups represented more concepts and propositions in post-test than in pre-test. Results indicated insignificant differences between the two groups for the number of concepts (*t*=1.713, *df*=47.498, *p*=0.093) and propositions (*t*=1.11, *df*=52.884, *p*=0.272) represented on post-test concept maps. However, results for the accuracy of the represented concepts (*t*=4.28, *df*=63, 2-tailed *p*<0.001) and propositions (*t*=3.54, *df*=63, 2-tailed *p*=0.001) indicated significant difference between the two groups. 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.

Concept Mapping Measures	**Experimental Group (n=33) Working with COMPASS**		**Control Group (n=32) Traditional teaching**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Similarity Index	11.61 (8.11)	58.45 (15.26)	12.13 (8.27)	43.63 (17.86)
Number of represented concepts	9.27 (2.5)	18.45 (1.95)	9.75 (2.69)	17.22 (3.6)
Number of represented propositions	8.42 (2.49)	19.36 (3.1)	8.72 (3.36)	18.25 (4.79)
Number of accurate concepts	3.85 (2.33)	16.58 (3.01)	4.5 (2.42)	12.97 (3.75)
Number of accurate propositions	2.88 (2.19)	15.97 (4.1)	3.19 (2.48)	12.06 (4.78)

Table 2: Means (and standard deviations) of the pre-test and post-test concept mapping measures

Students' responses to open questions revealed that the students of the experimental group enjoyed their activity with COMPASS and found the process of constructing a concept map with COMPASS interesting. Also, 67% of the students asserted that all of the system's functions were well organized and useful, while 15% of them expressed their negative attitude towards the expert map facility. Most of the students (31 out of 33) reported that the provided feedback helped them to learn the concepts, understand their errors and construct their concept map. The tutoring feedback units for the concepts as well as the various types supported (description, example, definition, images etc.) were very useful for most of the students (94%) as students during the elaboration of the activity at any time had the opportunity to study the concepts that were unknown or they didn't remember. It is worthwhile mentioning that a considerable number of students started the construction of the concept map after studying the tutoring feedback units provided for a number of concepts. The available list of concepts, the structure/steps of the dialogue-based form of feedback and the tutoring feedback units stood high in most of the students favour. Among the facilities that were characterized as most useful were the explanation of the propositions, the tutoring feedback units and the reflective questions. Some of the students (8 out of 33) asserted that there was no reason to see the expert map, as the correct answer/proposition in dialogue-based form of feedback was always available. Moreover, a considerable number of students reported that although they had at their disposal the expert map, they tried to avoid seeing it and preferred to find alone their errors. It is interesting to mention that a number of students advised the expert map at the end after completing their activity. The performance feedback provided by COMPASS seems not to influence the performance of a number of students (13 out of 33), as they tried to focus on the representation of the concepts and their relationships and they selected to see their performance after a number of trials in correcting and re-examining their represented concepts/propositions. Indicative students' comments were: '*I like working with COMPASS because I have the opportunity to learn the unknown concepts through the available material*', '*It was a specially-interesting experience*', '*I favoured the dialogue-based form of feedback as the sequence of the steps gave me the chance to receive as much help as I needed*', '*I would like to work out more concept mapping activities with COMPASS in the future*', '*I was impressed by the feedback provided. During the activity, I felt that I had always at my disposal as much help as I needed*', '*It was an enjoyable and creative activity*', '*I would like to work with COMPASS in various subject matters as concept mapping activities and the feedback provided help me to comprehend the various concepts under consideration*'.

4 Summary and Further Research

In this paper, an overview of the main features of the COMPASS environment was given and the results of an experimental study were presented, focusing on the effectiveness of COMPASS in supporting teaching and learning. The results were positive and encouraging, indicating that the concept mapping task that students worked out as well as the facilities of the environment (e.g. alternative feedback forms and components, analysis and assessment of students' maps) helped students in learning the underlying concepts. COMPASS could be a useful tool of a teacher's toolbox and could be exploited as an effective alternative teaching and learning tool. Our future plans include the exploitation of COMPASS as an assessment tool, the analysis of students' interaction with COMPASS and their preferences with the different feedback forms and components, and the development of appropriate modules that would support the collaboration of students.

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