# Designing an Adaptive Feedback Scheme to Support Reflection in Concept Mapping

Evangelia Gouli, Agoritsa Gogoulou, Kyparisia Papanikolaou, and Maria Grigoriadou

Department of Informatics and Telecommunications, University of Athens, Panepistimiopolis, GR-15784 Athens, Greece
{lilag, rgog, spap, gregor}@di.uoa.gr

**Abstract.** In this paper, we present an adaptive feedback scheme, which is incorporated in the "Knowledge Reconstruction + Refinement" process of a web-based concept mapping tool, named COMPASS, in order to support the reflection process in concept mapping. The feedback scheme includes multiple informative and tutoring feedback components and combines a stepwise presentation of these components with a multiple try strategy, aiming to provide personalized feedback. The adaptation of the scheme is based on the learner's knowledge level, preferences and interaction behaviour. Two pilot empirical studies were conducted in order to investigate whether the design of the feedback components as well as the proposed adaptive feedback scheme can stimulate learners to reflect on their beliefs and appropriately revise their maps. The results revealed from the studies are encouraging, as the feedback provided, led the majority of the students to reconstruct/refine their knowledge and accomplish successfully the concept mapping tasks.

## 1 Introduction

Concept mapping, as a knowledge elicitation technique, stimulates learners to articulate and externalise their actual states of knowledge during the learning process. A concept map is comprised of nodes (concepts) and links (relationships between concepts), organized in a hierarchical structure to reflect the central concept of the map. Meaningful relationships between concepts form propositions. It is important to emphasize the inherently reflective nature of concept mapping, as it requires from learners to reflect on their understanding of concepts and their relationships [9].

Various applications of concept maps in learning and assessment and a number of concept mapping software tools are presented in [1]. During the assessment process, feedback is usually provided to learners according to specific common errors identified on their concept maps [2], [3]. These approaches do not take into account any learner's individual characteristics or needs. More specifically, in [2], the system analyses the learner's map by comparing it with the teacher's map and provides hints (feedback strings defined by the teacher) about specific errors such as missing propo-

sitions. In [3], the system gives appropriate hints to the learner in the form of partial propositions. Moreover, to our knowledge, very few studies focus on the adaptation of the provided feedback according to learners' individual differences. In [7], a study was conducted, examining the effects of adaptive feedback (adjusting the amount of feedback based on learners confidence in their answer) on learning outcomes and learning efficiency. In [6], a framework for the provision of feedback, based on the nature of the learning task and the learner's achievement level and prior knowledge, is presented. In [11], the incorporation of adaptive feedback into the proposed system is one of the researchers' plans.

In this context, we are developing a tool, named COMPASS (COncept MaP ASSessment tool) [4], aiming to provide a more flexible and learner-centered approach in the accomplishment of assessment activities based on concept mapping tasks and help learners to reconstruct/refine their knowledge. COMPASS supports the "Knowledge Reconstruction + Refinement" (KR+R) process by providing multiple informative and tutoring feedback components, tailored to the learners' knowledge level, preferences and interaction behaviour, through a stepwise presentation. The provided feedback aims to stimulate learners to reflect on their beliefs and proceed with the appropriate revisions. Two pilot empirical studies were conducted in order to investigate whether the design of the feedback components and the proposed adaptation scheme can help learners in revising their beliefs and refining their knowledge.

The paper is organized as follows. In Section 2, a description of the functionality of COMPASS is outlined. Then, in section 3, the adaptive feedback scheme, incorporated into the "KR+R" process, is presented. The results revealed by the two empirical studies are presented in Section 4 and the paper ends with concluding remarks and some directions for future work.

## 2 The COMPASS Tool

COMPASS is a web-based concept mapping tool aiming to assess the learner's understanding as well as to support the learning process. In particular, COMPASS serves (i) the *assessment process* by employing a variety of activities and applying a scheme for the qualitative and quantitative estimation of the learner's knowledge, and (ii) the *learning process* by providing different informative and tutoring feedback components, tailored to each individual learner, through the "KR+R" process.

More specifically, COMPASS supports the elaboration of assessment activities employing various mapping tasks such as the construction of a concept map from scratch ("free construction" task), the completion and evaluation of a concept map using an available list of concepts/relationships ("concept-relationship list completion/evaluation" task) [4]. After the learner has completed the assessment activity, COMPASS activates the *diagnosis process* for (i) the identification of errors on the learner's map (according to Table 1), based on the similarity of the learner's map to the teacher's one, and the qualitative analysis of the errors, (ii) the qualitative diagnosis of learner's knowledge, which is based on the proposed error categorization (Ta-

ble 1) and concerns the identification of the unknown concepts, incomplete understanding and false beliefs, and (iii) the quantitative estimation of learner's knowledge level on the central concept of the map and subsequently on the assessment activity, which is assigned to one of the characterizations {Insufficient (Ins), Rather Insufficient (RIns), Average (Ave), Rather Sufficient (RSuf) and Sufficient (Suf)}; this assignment is based on specific assessment criteria defined by teacher [4]. The learner may check/verify his/her map through the "Analysis" tool (Fig. 1). This tool provides the "Visual Feedback" option and the "Interactive Feedback" option. In case learner selects the "Visual Feedback" option, COMPASS graphically annotates the errors on the map, if any, following the proposed error categorization. In case of the "Interactive Feedback" option, COMPASS activates the *"KR+R" process* resulting to the provision of the appropriate feedback for each of the errors identified on the map.

## 3 The Adaptive Feedback Scheme

Feedback is considered as one of the most important sources of information to assist learners in restructuring their knowledge [6]. According to [5], effective feedback provides the learner with two types of information: verification (a judgement of whether the learner's answer is correct/incorrect) and elaboration (relevant cues to guide the learner toward a correct answer). Depending on the levels of verification and elaboration incorporated into the feedback, different types and forms of information may be combined (e.g. explanations for correct/incorrect answers, hints about useful sources of information, the knowledge of response) [6]. As one of the factors that contribute to the informative and tutoring value of feedback is the individual characteristics of the learner (e.g. learning objectives, prior knowledge and skills, motivational prerequisites), many researchers propose to tailor feedback to learner's individual needs and characteristics [10], [8].

In the context of COMPASS, the "KR+R" process aims to provide feedback, tailored to each individual learner in order to support the reflection process, to tutor and guide the learners and subsequently to enable them enrich/reconstruct their knowledge structure. The feedback scheme, adopted in the "KR+R" process, incorporates informative and tutoring feedback components (ITFC) and combines a stepwise presentation of these components with a multiple try strategy (see Activating the "KR+R" process). The ITFC include (i) an initiating question (IQ) consisting of the learner's belief, and a prompt to think of the concepts included in the proposition and to write any keywords describing the concepts, (ii) specific error-task related questions (E-TRQ), (iii) tutoring feedback units (TFU) relevant to concepts/relationship included in the concept map, and (iv) the knowledge of correct response (KCR). The ITFC concerning the E-TRQ and/or the TFU are provided according to the learner's individual characteristics (i.e. learners' knowledge level, preferences and interaction behaviour). Moreover, the stepwise presentation of the ITFC provides gradually the appropriate feedback components that are considered to be necessary in order the learner to modify/enrich his/her knowledge structure. Below, we present the design of

the E-TRQ and the TFU, the adaptation of the feedback scheme as far as these specific feedback components are concerned, and the stepwise feedback presentation.

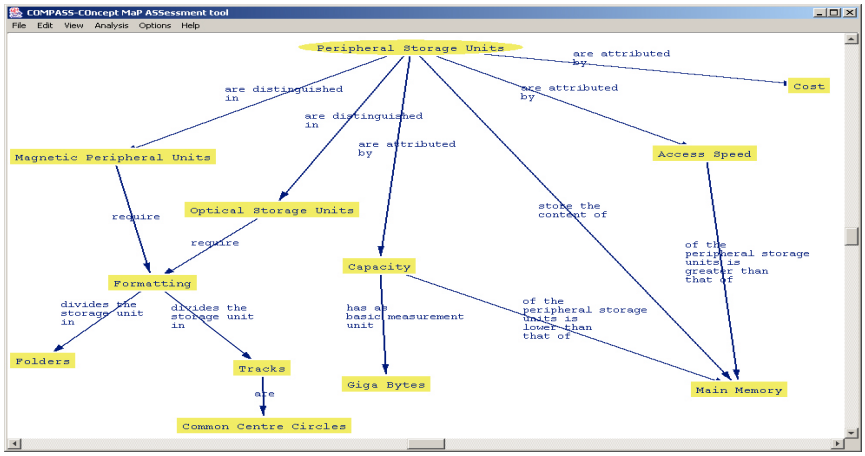


**Fig. 1**. A concept map constructed by a learner for a "concept-relationship list completion/evaluation" task.

**The Design of the E-TRQ and the TFU.** The error-task related questions, incorporated (E-TRQ) into the feedback scheme, aim to redirect the learner's thinking and give a hint for correcting the error and completing the task. In the context of COMPASS, the form of the questions is differentiated according to the error categories that may be identified on the learner's map. The form of the questions that are associated with each error category as well as an example of such a question for the learner's map illustrated in Fig. 1, are presented in Table 1.

The tutoring feedback units (TFU) aim to allow the learner to review educational material relevant to the attributes of the desired/correct response. In the context of COMPASS, the TFU concern: (i) the concepts represented on the teacher's concept map and/or the concepts included in the provided list of concepts (if a list of concepts is provided according to the mapping task) (TFUC), and (ii) specific propositions that the teacher anticipates a learner's false belief (TFUP) [4]. TFUC are organised in two levels, TFUC1 and TFUC2 differing on the level of detail of the feedback information. TFUC1 presents the corresponding concept in general and it is independent of the mapping task (i.e. the same TFUC1 can be provided for different mapping tasks, which include the specific concept). TFUC2 presents the corresponding concept in more detail, focusing on the relationships of the concept with the other concepts of the map. Thus, TFUC2 depends on the concepts that may be represented on the particular concept map. TFUC2 is provided only if the learner insists on his/her belief after providing TFUC1. The feedback units (TFUC1 and TFUP) are associated with educational material consisting of knowledge modules, which constitute multiple representations of the concepts included in the proposition (i.e. a definition/description, an example, and/or an image of the concepts).

**Table 1.** The qualitative diagnosis of learners' knowledge based on different categories of errors and the form of error-task related questions according to the error categorization.

| Qualitative Diagnosis of Learners' Knowledge | Categories of the Learners' Errors | |
|---|---|---|
| | **Form of E-TQR**<br>[C1], [C2], [C3] … are concepts, while R, R1, R2 … are relationships between concepts | **Example of Error-Task Related Question** |
| **Unknown Concepts** | **Missing concept and its relationships**: specific concepts, which should be represented on a map and have been defined by the teacher as fundamental concepts for the specific task/map [4], are missing. | |
| | *Do you consider that you could add on your concept map the concept of [C1]?* | Do you consider that you could add on your concept map the concept of [Sectors]? |
| **Incomplete Understanding** | **Incomplete relationship**: the relationships between two concepts are incomplete, as several relationships are missing (e.g. concepts [C1] and [C2] are related with m relationships on the teacher's map, while on the learner's map n relationships appear, where n<m). | |
| | *Do the [C1] only R the [C2]?* | Not applicable to the example |
| | **Missing relationship**: the relationship between two concepts that should be related is missing. | |
| | *Do you consider that you could add a relationship between the concepts of [C1] and [C2]?* | Do you consider that you could add a relationship between the concepts of [Cost] and [Main Memory]? |
| **False beliefs** | **Superfluous relationship***:* two concepts are related although they should not. | |
| | *Do you really believe that the concepts [C1] and [C2] are related with the specific relationship?* | Do you really believe that the concepts [Optical Storage Units] and [Formatting] are related with the specific relationship? |
| | **Incorrect relationship**: two concepts are related with an incorrect relationship, which should be substituted. | |
| | *The [C1] R [C2]. Do you agree with this?*<br><br>(where R is the correct relationship as represented on the teacher's concept map) | The [Capacity] of the peripheral storage units is greater than that of [Main Memory]. Do you agree with this? |
| | **Superfluous concept**: a superfluous concept appears which should be deleted. | |
| | *Do you want to reconsider the relationship of the concept [C2] with (i) the concept [C1], and (ii) the central concept of the map?* | Do you want to reconsider the relationship of the concept [Folders] with (i) the concept [Formatting], and (ii) the central concept of the map? |
| | **Incomplete propositions***:* a concept (presented on the map) is not related to all the required concepts because the related concepts are missing. | |
| | *Do you really believe that [C1] only (i) R1 [C2] and (ii) R2 [C3]?* | Not applicable to the example |
| | **Incorrect concept**: a concept is related to an incorrect concept, which should be replaced with another concept. | |
| | *Do you really believe that the [C1] (correct concept) R [C2] (incorrect concept) [and the concept of [C2] is related with the concepts of [C3] and [C4] ]?*<br>(where the concepts [C3] and [C4] are the children of the concept [C2]) | Do you really believe that the [Capacity] has as basic measurement unit [Gigabytes]∗?<br>∗: the concept [Gigabytes] has not children, so the rest of the question is not applicable |

**The Adaptation of the Feedback Scheme**. The adaptation of the feedback scheme, regarding the provision of TFU and/or E-TRQ, is based on information concerning the learner's knowledge level, preferences (i.e. preferences on ITFC and on knowledge modules) and interaction behaviour (i.e. knowledge modules of TFUC1 or TFUP more often provided, ITFC more often provided and frequency of errors made) (this information is provided by the learner model). Indicative rules that have been adopted in the adaptation scheme are:

- If the knowledge level of the learner has been evaluated as (Ins) or (RIns) on the assessment activity, then both TFU and E-TRQ are provided (TFU+E-TRQ).
- If the knowledge level of the learner has been evaluated as (Suf) or (RSuf) on the assessment activity, then E-TRQ are provided.
- If the knowledge level of the learner has been evaluated as (Ave) on the assessment activity, then according to the learner's preferences (ITFC preferred) and interaction behaviour (ITFC more often provided and frequency of errors made), E-TRQ or TFU+E-TRQ is provided. For example, (i) if the learner's favourite ITFC is E-TRQ but TFU+E-TRQ is more often provided, then TFU+E-TRQ is provided, (ii) if the frequency of a specific error identified on the learner's map is minimal (e.g. the learner's map includes very few incorrect relationships), then E-TRQ is provided.
- If TFU+E-TRQ is to be provided, then according to the error category, TFUC1 and/or TFUP is provided. TFUP is provided when the error belongs to the categories of "incorrect relationship", "incomplete relationship", "incomplete propositions" and "superfluous relationship". TFUC1 may concern more than one concepts according to the error category (e.g. in case of "incorrect concept", TFUC1 concerns only the incorrect concept of the proposition, while in case of "superfluous relationship", TFUC1 concerns both the concepts [C1] and [C2]).
- If TFUP and/or TFUC1 is to be provided and both types are available for the specific error (e.g. "superfluous relationship"), then TFUP is firstly provided and if the learner insists on his belief and/or asks for more help, TFUC1 is provided.
- If TFUC1 or TFUP is to be provided, then according to learner's preferences on knowledge modules and/or learner's interaction behaviour (types of knowledge modules more often provided), specific types of knowledge modules (i.e. definition/description, example and/or image of the concept) are provided.
- If the learner insists on his/her belief although TFUC1 was provided, then TFUC2 is also provided (in case it is available).

**Activating the "KR+R" Process**. COMPASS incorporates the abovementioned feedback scheme as well as the adaptation mechanism in the "KR+R" process. The "KR+R" process is activated when the learner completes an activity or asks for support/help during the task. The following sequence of interactions is taken place:

- *First Step:* After detecting an error on the learner's concept map, COMPASS indicates the error by providing the learner with an initiating question (IQ). The IQ gives learners the possibility to rethink their beliefs and to identify and check their own errors. This form of feedback may be sufficient for learners with high knowledge level. The applicability of the step depends on the category of error

(e.g. for a "missing relationship" error, this step is not applied). Following, the tool enters in a "wait" state, expecting the learner's action.

- *Second Step*: If the learner insists on his/her belief, then according to the abovementioned rules E-TRQ and/or TFU+E-TRQ are provided. COMPASS enables the learner to think about the feedback and proceed with any changes; the tool enters again in a "wait" state, expecting the learner's action.
- *Third Step:* If an impasse is reached (learner insists on his/her belief) or the learner asks for the knowledge of correct response, then COMPASS informs the learner about the correct response (KCR feedback component).

It is important to mention that during the interaction between the learner and the tool, the learner has always the option to select the feedback component and the knowledge modules that s/he prefers, ignoring the ones provided by the tool.

## 4 The Empirical Studies

The design of the "KR+R" process was carried out in parallel to two empirical studies that we conducted as a pilot evaluation before proceeding with the implementation of the process in the context of COMPASS. The two studies were carried out during the winter semester of the academic year 2003-2004, in order to investigate whether the design of the feedback components, as well as the adopted adaptation scheme, could stimulate learners to reflect on their beliefs and appropriately revise their maps.

**First Empirical Study.** In order to investigate whether the design of the E-TRQ, as the only source of feedback, can help learners towards the direction of identifying their errors, reconsidering and correcting them appropriately, we conducted an empirical study. Six high school students volunteered to take part. The students had to accomplish a "concept-relationship evaluation" concept mapping task concerning the central concept of "Magnetic Peripheral Storage Units". After the accomplishment of the activity, the teacher interacted with each one of the students, simulating the stepwise presentation of the "KR+R". The duration of the empirical study was 2 hours.

For the six students, the percentage of correct responses for each error category, before the provision of feedback and after the stepwise feedback presentation (for the 2nd step only the E-TRQ were provided), is presented in Fig. 2. The reader may notice that all the students improved their performance and the questions helped them to reconsider their beliefs and correct the majority of the errors. However, there are some cases that the questions didn't help the students to find all the errors (e.g. the case of the 3rd student in the error categories of "incorrect relationship", "superfluous relationship" and "missing relationship"). As far as any modifications to the form of the E-TRQ are concerned, the study drew implications about the form of the questions posed for the error categories of "incorrect concept" and "superfluous relationship" (the modified versions of the questions are presented in Table 1). Regarding the process (i.e. steps), it is important to mention that in several cases, the application of the first step (i.e. the provision of the IQ) was proved to be adequate and helped students to check for accidental constructions. There were cases that the students weren't

able to correct their errors even if E-TRQ were provided; in these cases, the teacher tried to explain in details the concepts involved in the proposition. This observation led us draw the conclusion that the specific ITFC (i.e. IQ and E-TRQ) are not adequate in all cases; additional feedback should be provided.

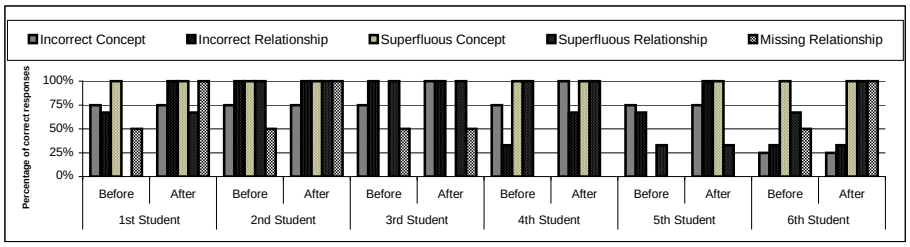


**Fig. 2**. The percentage of the correct responses concerning specific categories of errors.

Summarizing the results, it seems that the form of the E-TRQ can help students, especially those with knowledge level above average, in revising their beliefs and refining their knowledge. In cases of students with low knowledge level, a form of tutoring feedback is required in order to help them identify and correct their beliefs. Therefore it was considered important to incorporate TFU in the feedback scheme.

**Second Empirical Study.** In the second empirical study, the feedback provided to the learners included both the TFU and the E-TRQ. The aim of this study was to investigate whether the design of the proposed adaptation scheme, can stimulate learners to reflect on their beliefs and appropriately revise their maps. Ten high school students volunteered to take part in the study, which lasted 3 hours.

A pre-test was conducted in order to estimate the students' prior knowledge level. The pre-test had the form of open questions such as "Mention keywords that describe the concept of Formatting", "Mention the kinds of Peripheral Storage Units". The pre-test questions address the concepts/relationships that could be represented on the map of the task that the students had to accomplish after the pre-test. The teacher assessed their answers and estimated their knowledge level (1 student as (Suf), 3 as (RSuf), 3 as (Ave), 2 as (RIns), and 1 as (Ins)). The students' preferences concerning the types of knowledge modules (description, example or image) and the ITFC (TFU+E-TRQ and E-TRQ) were also recorded. The task, that the students had to accomplish, was a "concept-relationship list completion/evaluation" task. After its accomplishment, the teacher interacted with each one of the students, simulating the stepwise presentation of the "KR+R". To this end, the learner's interaction behaviour was not considered.

The 1st step of the process (i.e. the IQ feedback component) was adequate only for one student (the 3rd student claimed that he made the errors by accident and was able to recognize and correct them). In the context of the 2nd step of the process, the E-TRQ were used for those students whose knowledge level was characterized as (Suf) and (RSuf). The E-TRQ were proved to be effective in helping the students to identify their errors and correct them appropriately (see Fig. 3). All the students whose knowledge level was characterized as (RIns) and (Ins), improved their performance

(see Fig. 3) after the TFU+E-TRQ were provided and they identified and corrected a considerable number of errors. Two of them (5th and 6th student) didn't manage to correct all the errors; in two error cases the KCR was finally provided. In the case of the 7th student, the TFUC1 and TFUC2 were provided, helping him to accomplish correctly the mapping task. For those students whose knowledge level was characterized as (Ave), their preferences concerning the TFU+E-TRQ and E-TRQ (one student selected E-TRQ and two students selected TFU+E-TRQ) were taken into account. All three students, after the provision of feedback, accomplished the task successfully.

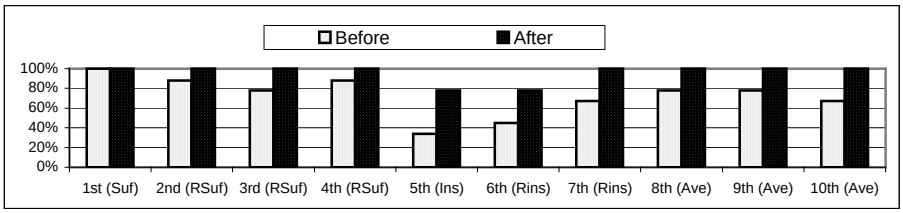


**Fig. 3.** The percentage of correct responses before and after the provision of feedback

Summarizing the results, it seems that the ITFC that were provided, following the stepwise presentation stimulated students to review their maps and reconsider their beliefs, as the majority of them spent some time thinking of them. It has to be mentioned, that the teacher, in all the cases, tried to elicit from students why they proceed with the desired corrections. The impression was that the students had fully understood their errors and refined their knowledge. The adaptive feedback scheme can be characterized as promising as the majority of the students accomplished successfully the mapping task and refined their knowledge. The results revealed from the two studies provided useful indications on the effectiveness of the proposed adaptive feedback scheme. However, data gathered from a larger sample, using COMPASS in real working conditions, under longer periods of time, are considered necessary for the aim of inferring learners' attitudes and evaluating the effectiveness of the adaptive feedback scheme.

## 5 Conclusions and Further Research

In this paper, we presented an adaptive feedback scheme, which is incorporated in the "Knowledge Reconstruction + Refinement" (KR+R) process of COMPASS in order to support the reflection process in concept mapping tasks. The discriminative characteristics of the "KR+R", and in particular of the proposed adaptation scheme are: the adoption of different informative and tutoring feedback components (ITFC) and the stepwise feedback presentation, the adoption of error-task related questions (E-TRQ) based on a categorization of learners' common errors, the adoption of the two levels of the tutoring feedback units (TFU) and the adaptation of feedback to the learner's knowledge level, preferences and interaction behaviour. The results from two empiri-

cal studies conducted, even performed on a limited number of subjects and in a simulated environment, are encouraging indicating that the provided feedback support reflection and help students to identify and correct their errors.

The presented research work contributes to the field of adaptive feedback, giving some promising directions for further research. Additional studies need to be conducted in order to compare the efficiency of the proposed informative and tutoring feedback components to other feedback components such as the knowledge of response and the effects of the proposed adaptive scheme to a standard feedback scheme as it is implemented in most learning environments. Our future plans include the enrichment of the informative and tutoring feedback components with additional forms as well as the conduction of a series of empirical studies with a wider group of learners, in order to evaluate COMPASS regarding the effectiveness of the provided feedback components and the adaptive feedback scheme.

## References


1. Cañas, A., Coffey, J., Carnot, M., Feltovich, P., Hoffman, R., Feltovich, J., Novak, J.: A Summary of Literature Pertaining to the Use of Concept Mapping Techniques and Technologies for Education and Performance Support. Final report to CNET. Retrieved 2003 from http://www.ihmc.us/users/acanas/Publications/ConceptMapLitReview/IHMC%20Literature%20Review%20on%20Concept%20Mapping.pdf
2. Cimolino, L., Kay, J., Miller, A.: Incremental student modelling and reflection by verified concept-mapping. In Supplementary Proceedings of the AIED2003: Learner Modelling for Reflection Workshop (2003) 219-227
3. Chang, K., Sung, T., Chen, S-F.: Learning through computer-based concept mapping with scaffolding aid. Journal of Computer Assisted Learning 17 (1) (2001) 21-33
4. Gouli, E., Gogoulou, A., Papanikolaou, K., Grigoriadou, M.: COMPASS : An Adaptive Web-based Concept Map Assessment Tool. In Proceedings of the First International Conference on Concept Mapping (CMC 2004) (2004) (to appear)
5. Kulhavy, R Stock, W.: Feedback in written Instruction: The place of response certitude. Educational Psychology Review 1(4) (1989) 279-308
6. Mason, B., Bruning, R.: Providing Feedback in Computer-based Instruction: What the research tells us. Retrieved 2004 from http://dwb.unl.edu/Edit/MB/MasonBruning.html
7. Mory, E.: Adaptive feedback in computer-based instruction: Effects of response certitude on performance, feedback-study time, and efficiency. Journal of Educational Computing Research 11 (3) (1994) 263-290
8. Narciss, S., Huth, K.: How to design informative tutoring feedback for multimedia learning. In H. M. Niegemann, R. Brünken & D. Leutner (Eds.) Instructional design for multimedia learning. Münster, Germany: Waxmann (2002) 181-195
9. Novak, J., Gowin, D.: Learning how to learn. Cambridge University Press, UK (1984)
10. Schimmel, B.: Providing meaningful feedback in courseware. In D. Jonassen (Ed.), Instructional designs for microcomputer courseware. Hillsdale, NJ: LEA (1988) 183-195
11. Tsai, C-C., Chou, C.: Diagnosing students' alternative conceptions in science. Journal of Computer Assisted learning 18 (2002) 157-165