HOW COMPASS SUPPORTS MULTI-FEEDBACK FORMS & COMPONENTS ADAPTED TO LEARNER'S CHARACTERISTICS

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Abstract. In this paper, we present the feedback process of a web-enabled concept mapping learning environment, referred to as COMPASS. Different forms of feedback (text-, graphical- and dialogue-based) are supported and multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available, in terms of delivering individualized feedback. The ITRFC aim to stimulate learners to reflect on their beliefs, to guide and tutor them towards the achievement of the learning outcomes addressed by the concept mapping activity, to inform them about their performance and to serve learner's individual preferences and needs. The adaptive functionality of the feedback process is based on learner's knowledge level, preferences and interaction behaviour and is implemented through (i) the technology of adaptive presentation that supports the provision of alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components in the dialogue-based form of feedback. Moreover, COMPASS gives learners the possibility to have control over the feedback presentation process by making the desired selections.

1 Introduction

Feedback is considered as a key aspect of learning and instruction (Mory, 1996). Effective feedback aims to (i) assist learners in identifying their false beliefs, becoming aware of their misconceptions and inadequacies, and reconstructing their knowledge, (ii) help learners to determine performance expectations, identify what they have already learned and what they are able to do, and judge their personal learning progress, and (iii) support learners towards the achievement of the underlying learning goals (Mory, 1996; Mason and Bruning, 2001). Thus, feedback should guide and tutor learners as well as stimulate and cultivate processes like self-explanation, self-regulation, and self-evaluation, which require reflection (Chi et al., 1994). Moreover, feedback should be aligned, as much as possible, to each individual learner's characteristics, since individuals differ in their general skills, aptitudes and preferences for processing information, constructing meaning from it and/or applying it to new situations (Jonassen & Grabowski, 1993).

In the field of computer-based concept mapping, recently developed environments attempt to embed a scheme for feedback provision. Specifically, in the Reasonable Fallible Analyser (RFA) (Conlon, 2004), feedback is provided about the quantitative score of learner's map accompanied with explanation of how the score is obtained. For concepts and propositions that learner believes that have not been properly credited, a dialogue between the RFA and the learner could begin. Also, hints concerning missing concepts and links as well as incorrect relationships are provided. The system proposed by Cimolino et al. (2003) provides hints (feedback strings defined by the expert) about specific errors such as missing propositions. In (Chang et al., 2001), the system gives appropriate hints after the analysis of learner's map; the hints concern specific types of errors and are provided in the form of partial propositions (e.g. for an incorrect concept the hint has the form "*Bytes* are the basic measurement unit of ???). The networked knowledge mapping system of Hsieh and O' Neil (2002) provides knowledge of response feedback (i.e. a list indicating whether each concept on a map needs a little, some or a lot of improvement) and adapted knowledge of response feedback (i.e. the same information as knowledge of response complemented with information about how student had improved on his/her map since the last time s/he got feedback and a description of the most useful way to use this information). From the literature review, it becomes obvious that feedback in the aforementioned environments has mainly an informative and guiding orientation and is tailored to specific common errors identified on learner's concept map after the comparison of learner's map with the expert map. Moreover, none of the systems takes into account learners' individual differences.

In this line of research, we developed COMPASS (COncept MaP ASSessment & learning environment) which provides feedback aiming to inform learners about their learning progress, guide and tutor them in the direction of enriching/reconstructing their knowledge, support reflection and accommodate their learning needs and preferences. To this end, COMPASS supports various feedback forms (i.e. text-, graphical- and dialogue-based form) and multiple feedback components (i.e. Informative, Tutoring and Reflective Feedback Components (ITRFC)). In dialogue-based

form, the ITRFC are structured in different layers to support the gradual provision of the right amount of feedback information. The adaptive functionality of the feedback process is implemented through (i) the technology of adaptive presentation that supports the provision of the alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components (in dialogue-based form). Learner's knowledge level, preferences and interaction behaviour are used as a source of adaptation. Additionally, learners have the possibility to intervene in the feedback presentation process by selecting the preferred feedback form and component, in accordance with their own perceived needs and desires. The rest of the paper is structured as follows. In Section 2, an overview of COMPASS is presented. In section 3, the feedback process is described in terms of the different forms of feedback supported, the ITRFC provided, the adaptive functionality of the feedback process and the learner support and control offered. The paper ends with the main points of our work and our near future plans.

2 An Overview of the COMPASS Environment

COMPASS (available at http://hermes.di.uoa.gr/compass) is a web-enabled concept mapping learning environment, developed at the Educational & Language Technology Laboratory of the Department of Informatics & Telecommunications at the University of Athens. COMPASS 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 (Gouli et al., 2004b).

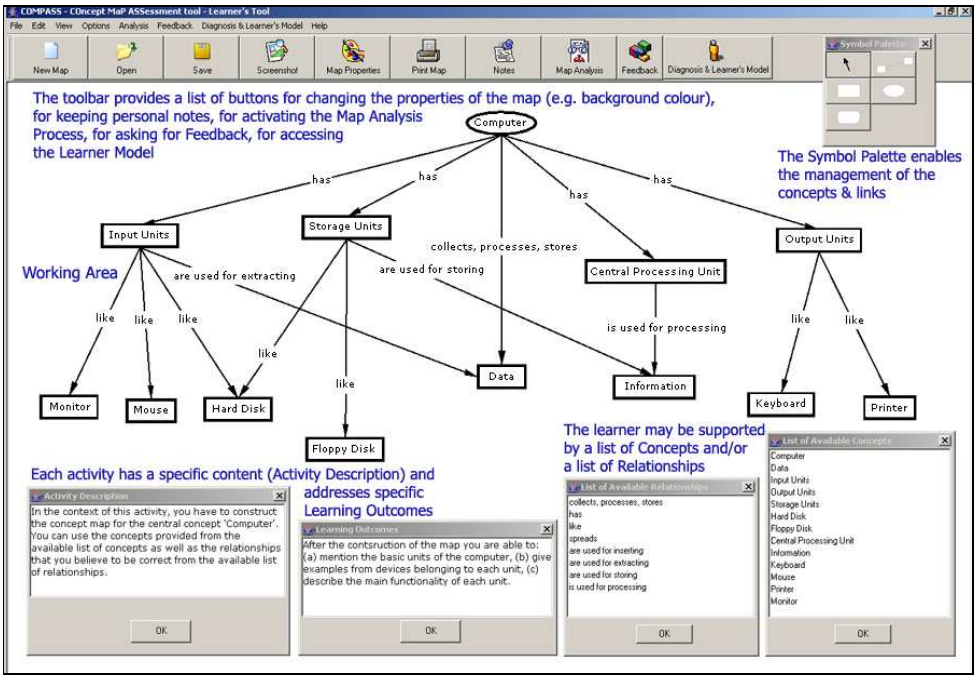

Figure 1. The main screen of COMPASS. The Working Area presents a concept map constructed by a learner in the context of a construction task supported with a list of concepts and relationships. The specific task is one of the activities provided in the context of the learning goal "The Computer Architecture".

Based on the learning goal that learner selects, which corresponds to a fundamental topic 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 (Ruiz-Primo & Shavelson, 1996). 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 learners; learners 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. The provided lists may contain not only the required

concepts/relationships but also concepts/relationships that play the role of distracters. In Figure 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 learners have to evaluate/correct, or extend or complete) are presented.

Depending on the attributes of the activity, learner's concept map may be assessed either automatically by COMPASS, or by teacher or by peers through the PECASSE (PEer and Collaborative ASSessment Environment) environment (available at http://hermes.di.uoa.gr:8080/pecasse). 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 the quantitative analysis. The qualitative analysis is based on the qualitative characterization of the errors and aims to contribute to the qualitative diagnosis of learner's knowledge; that is learner'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 accompanied with an example is given in (Gouli et al., 2005). The results derived from the map analysis are represented to learners in an appropriate form during the feedback process.

3 The Feedback Process in COMPASS

The feedback provided in COMPASS aims to serve processes of assessment and learning by (i) informing learners about their performance, (ii) guiding and tutoring learners 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 learners to "stop and think" and giving them hints on what to think about. Different forms of feedback are supported with respect to the addressed learning outcomes and learner's preferences: text-based, graphical-based and dialogue-based form. Multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available during the feedback process in an attempt to stimulate learners to reflect on their beliefs, to guide and tutor them towards the achievement of the learning outcomes, to inform them about their "current" state and to serve learners' individual characteristics. Below, we discuss in more detail the available ITRFC, the dialogue-based form of feedback, the adaptive functionality of the feedback process and the learner control and support offered during the elaboration of the activity.

3.1 Informative, Tutoring and Reflective Feedback Components

The term ITRFC refers to the different components of feedback, which exploit various feedback types reported in literature and offer different levels of verification and elaboration in order to serve learners' individual preferences and needs. The ITRFC are classified in the three feedback types, presented in Table 1.

Feedback Type	Feedback Component	Available in …
Informative *aims to inform learner about the correctness of his/her answer and*	Correctness-Incorrectness of Concept/Proposition & Type of Error (CI-TE): *informs learner whether his/her represented concept/ proposition is correct/ incorrect, and in case of a false belief (i.e. proposition) which is the type of the error.*	*Text-based* form of feedback (see Figure 2). *Graphical-based* form of feedback. The learner's map is graphically annotated; different annotations are used for each error category and for complete-accurate propositions. *Dialogue-based* form of feedback (available at stage 1, see next section).

his/her performance	Correct Proposition (CP): *supplies learner with the correct proposition represented on expert map.*	*Dialogue-based* form of feedback (available at stage 1 or 3, see next section).
	Expert Map (EM): *supplies learner with the expert map itself.*	*Graphical-based* form of feedback.
	Performance Feedback (PF): *informs learner about his/her current state, that is (i) learner's knowledge level,(ii) learner's incomplete understanding and false beliefs, (iii) learner's performance during the elaboration of the activity (i.e. the progress of learner's knowledge level, as this is recorded after the map analysis), and (iv) statistics such as the number of times that map analysis performed, the number of times that feedback was asked, the total time spent for the accomplishment of the activity/task, the learner's preferences on feedback components during the elaboration of the activity.*	*Text-based* form of feedback. *Graphical-based* form of feedback depicting learner's progress during the elaboration of the activity.
Tutoring *aims to tutor learner by enabling him/her to review learning material relevant to the attributes of the correct concept /proposition*	Tutoring Feedback Units (TFU): *supply learners 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. The material of the learning goal level is available for all the activities for which the specific concept is represented whilst the material of the activity level is available only for the specific activity. The TFU are associated with various types of knowledge modules such as a description or a definition of the concept under consideration, an image, an example, a counterexample, a task or a case. The different types of knowledge modules aim to serve learners' individual preferences and to cultivate skills such as critical thinking, ability to compare and combine alternative tutoring feedback units etc.*	*Text-based* form of feedback. *Dialogue-based* form of feedback (available at stage 2, see next section).
	Explanation of the Proposition (EP): *explains why the false belief (proposition) is wrong or why the correct belief is correct.*	*Dialogue-based* form of feedback (available at stage 2 or 3, see next section).
Reflective *aims to promote reflection and guide learner's thinking, explore situational cues and underlying meanings relevant to the error identified*	BP-RW Belief Prompt-Rethink Write (BP-RW): *consists of (i) learner's belief in order to bring learner "in front" of his/her belief and encourages him/her to rethink his/her belief, and (ii) a prompt to write any keywords and/or explanations concerning his/her belief.*	*Dialogue-based* form of feedback (available at stage 1, see next section).
	Reflective Questions (RQ): *give learner hints, in the form of questions, to rethink and correct the identified false belief (proposition). The RQ may refer to the errors identified (error-related RQ) or may model a human teaching strategy (Collins, 1987) (inquiry-related RQ). The form of the error-related RQ is differentiated according to the error categories that may be identified on map. For example, an error-related RQ may ask learner to rethink the relation between the two concepts or the position that a concept is placed or how a concept can be added to the map. The inquiry-related RQ may give learner a consequence of his/her false belief and prompts him/her whether s/he insists on his/her belief or may suggest an incorrect hypothesis and ask learner to think what could be happened or may ask learner to consider an alternative prediction, etc. The inquiry-related RQ are available for specific propositions that the teacher anticipates errors/false beliefs from his/her experience and aims to bring learner confronting with information that help him/her to rethink his/her belief.*	*Dialogue-based* form of feedback (available at stage 2, see next section).

Table 1: The Informative, Tutoring and Reflective Feedback Components available in the feedback process.

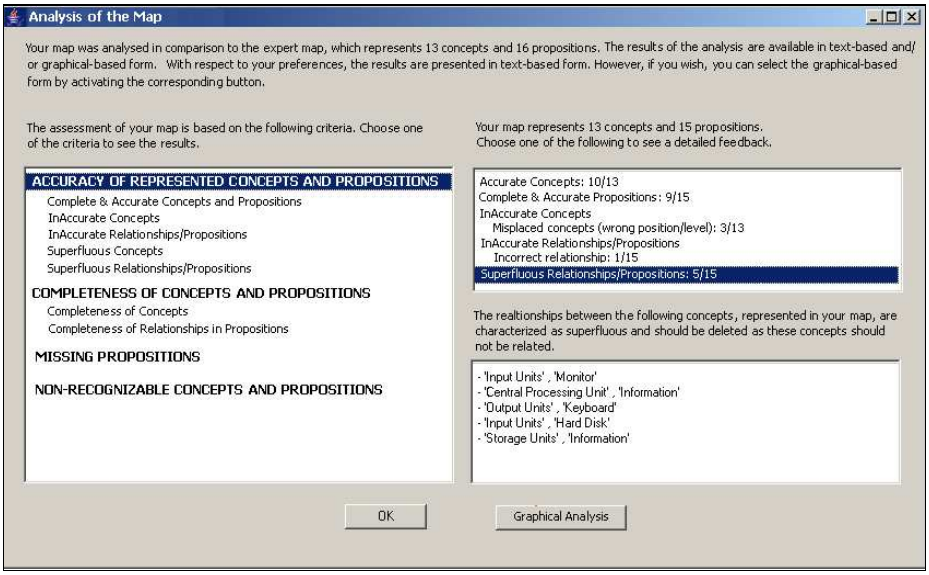

Figure 2. The results, in text-based form, derived from the analysis of the learner's map depicted in Figure 1. The learner has selected to see the results concerning the criterion of "Accuracy of Represented Concepts and Propositions" (left window), and more specifically the results for superfluous relationships/propositions (right up window). The corresponding CI-TEs are presented in the right bottom window.

3.2 Providing Feedback in Dialogue-based Form

In dialogue-based form, the available feedback components are structured in different layers with respect to the stages of the dialogue process and a stepwise presentation of the components is realized, following their layered structure. The stepwise presentation aims to provide gradually the appropriate amount of feedback information to each learner, and enable learners at each step to exploit the feedback information and return to his/her concept map in order to correct the identified false belief. On the basis of the qualitative characterization of each proposition represented on learner's map after the map analysis, the dialogue between COMPASS and learner is as follows:

- if a proposition is characterized as *complete and accurate* and the teacher has defined that it should be explained by the learner, then COMPASS presents learner's belief and asks him/her to give a description of the concepts included in the proposition and explain in few words why s/he believes the specific proposition (provision of BP-RW) (stage 1). After the learner saves his/her description, an explanation of the proposition defined by the expert is available (provision of EP) (stage 2). The learner has the possibility to change his/her description as many times s/he wishes.
- if a proposition is characterized as *non-recognizable*, COMPASS informs learner about the concepts and/or the propositions that were not assessed (provision of CI-TE), provides the concepts/propositions from the expert map that could substitute the non-recognizable ones (provision of CP) and asks learner to rethink/correct them (stage 1).
- if a proposition is characterized as *inaccurate (inaccurate-superfluous)*, the dialogue is carried out in 3 stages.
  - The *1st stage* aims at enabling learner to rethink his/her beliefs and getting into a self-explanation process in order to identify any errors made mainly by accident. Thus, COMPASS informs learner about the inaccuracy of the concept or the proposition under consideration and asks him/her to describe in few words the concept(s) included in the proposition (provision of BP-RW).
  - The *2nd stage* aims to (i) guide learners and redirect their thinking by giving them a hint, and (ii) tutor learners by enabling them to review learning material relevant to the inaccurate concepts/propositions. At the beginning COMPASS gives learner hints in the form of questions on the basis of the error identified (provision of error-related RQ). For example for the proposition "Input Units are used for extracting Data", depicted on the map of Figure 1, which is characterized as inaccurate (incorrect relationship error), the following error-related RQ is provided: "Do you really believe that the concepts [Input Units] and [Data] are related with the specific relationship, forming the proposition [Input Units] are used for extracting [Data]?". Following, the learner may select to follow up with inquiry-related RQ (if there are available) or has the possibility to select for study the available tutoring feedback units (TFU). In the latter case, the

selected TFU in conjunction with the corresponding error-related RQ are provided. Each TFU may be accompanied with additional material and explanations. For example, for the aforementioned proposition, if the learner selects to follow up with inquiry-related RQ, the following RQ is provided "You believe that [Input Units] are used for extracting [Data]. If it is true then with the Mouse, which is an Input Unit, we could extract Data. How is it possible to extract Data using Mouse? Do you insist on your belief?". The inquiry-related RQ are defined for specific propositions that the teacher anticipates errors/false beliefs from his/her experience and are presented following a pre-specified order (defined by the teacher).

- *The 3rd stage* aims to inform learner about the correct belief and to provide explanations of why his/her belief is incorrect. COMPASS provides learner with the correct proposition(s) (CP) and with the explanation of the proposition (EP) (if supported).

In each stage of the dialogue, learner is free to choose any of the already provided system's proposals from previous stages. An example of the stages of the dialogue is depicted in Figure 3.

- if a proposition is *incomplete or missing*, the dialogue is generated in 2 stages similar to the 2nd and the 3rd stages mentioned above (the inquiry-related RQ and the EP are not supported).

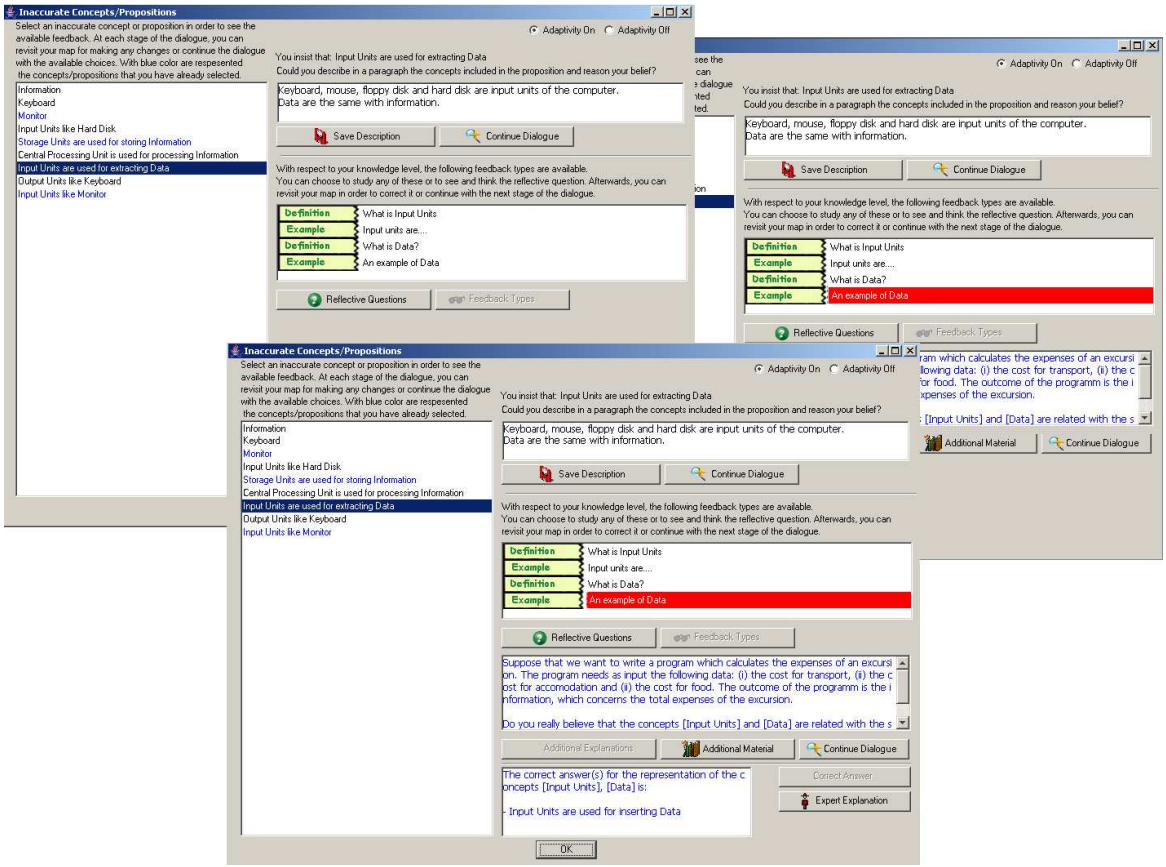

Figure 3. The stages of the dialogue for Inaccurate Concepts/Propositions. For the false proposition "Input Units are used for extracting Data", which is depicted in Figure 1, the learner in the first stage of the dialogue has given a description of the concepts included in the proposition and has chosen to Continue the Dialogue. Then the available feedback types, with respect to his/her knowledge level, are presented (first figure at the left). Following, the learner has selected to study the knowledge module "An example of Data" and the corresponding TFU in conjunction with the error-related RQ are presented in the second figure at the right. Afterwards, the learner has chosen to continue the dialogue and the correct answer for the specific proposition, with respect to his/her preferences, appears (centred figure).

3.3 Supporting Adaptation in the Feedback Process

The adaptive functionality of COMPASS is reflected to the personalization of the provided feedback in order to accommodate a diversity of learners' 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 learner's characteristics, which are maintained in learner model and recorded either through learner's interaction with the system or defined by the learner explicitly, are used as a source of adaptation. In particular, the learner model keeps information on learner's knowledge level, preferences on different feedback forms and components and interaction behavior (i.e. the times that the learner under consideration has selected specific feedback forms). The learner model may be accessed and modified by the learner at any time during the interaction and is continuously updated in order to keep always the "current state" of the learner.

The presentation of the results derived from the map analysis is differentiated according to learner's preferences and interaction behaviour. Initially, based on learner's preferences, the map analysis results are presented either in text-based or graphical-based form. However, the learner may select to see the results in the alternative form (i.e. graphical- or text-based). The system keeps track of learner's selections, which constitute his/her interaction behaviour and tailors the feedback presentation form to learner's interaction behaviour.

The dialogue-based form of feedback is supported either unsolicited (with respect to the learning outcomes of the concept mapping activity, the teacher defines if the specific form of feedback would be available) or solicited (learner has the possibility to define his/her preference to the specific form of feedback if s/he wishes). Moreover, in the dialogue-based form of feedback, the learner's knowledge level and preferences are used as the main source of adaptation during the provision of feedback components of the 2nd and the 3rd stage of the dialogue. More specifically, in the initiation of the learner model, the learner has the possibility to define if only the knowledge level or the preferences or both will influence the adaptation process. COMPASS incorporates various strategies in order to determine the feedback components that should be presented, depending on the sources of adaptation. For example, in case only the knowledge level is used as a source of adaptation, the following strategies for the provision of the feedback components of the 2nd stage are applied:

- *Strategy A*: aims to tutor learners with low knowledge level by providing them appropriate learning material. To this end, if learner's knowledge level has been evaluated as low/average on the concept mapping activity, then the available tutoring feedback units (TFU) are provided; learner is encouraged to select and study one of the available TFU and then return to his/her map in order to correct the identified error(s).
- *Strategy B*: aims to guide learners with high knowledge level in order to rethink their false belief. To this end, if learner's knowledge level has been evaluated as high on the activity, then reflective questions are provided; the learner is encouraged to spend some time thinking the questions provided and return to his/her map in order to correct the false belief.

3.4 Learner Support and Control

Having as an objective to support learners during the elaboration of the activity, the following feedback components are available for study: (i) the expert map (EM), (the availability of the expert map depends on the concept mapping task and the decision of the teacher according to the learning outcomes of the activity), and (ii) educational material (TFU) for all the concepts represented on expert map and/or the concepts included in the provided list of concepts. Moreover, as it is considered essential to allow learners to play an active role and take control over their own learning in order to meet their needs and preferences, COMPASS gives learners the possibility to (i) personalize the feedback process by accessing and initiating/updating their learner model in terms of the feedback presentation parameters (e.g. feedback form for presenting the results derived from map analysis, preferences on the types of feedback components, preferences on the characteristics that could be used as source of adaptation), and (ii) 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. Also, at any stage of the dialogue, learner has the possibility to inactivate the adaptation of the feedback process.

4 Conclusions and Further Research

In this paper, we presented the feedback process of the COMPASS environment. The discriminative characteristics of the feedback process are: (i) the different forms of feedback supported (text-, graphical- and dialogue-based), (ii)

the provision of multiple Informative, Tutoring and Reflective Feedback Components (ITRFC), which serve processes of informing, guiding/tutoring and reflection, (ii) the adoption of reflective feedback components that encourage learners to "stop and think" and give them hints indicating potentially productive directions for reflection, (iii) the different knowledge modules of the tutoring feedback components that support learners with different preferences and aim to cultivate various skills, (iv) the structure of the ITRFC in multiple layers and their stepwise presentation that supports the gradual provision of feedback and enables learners to elaborate on the feedback information and return to their map in order to correct any errors, (v) 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 behavior, and (vi) the learner support and control offered over the feedback process. A preliminary evaluation of the feedback process during its implementation phase (performed on a limited number of subjects and in a simulated environment) revealed that the incorporation of multiple ITRFC and their structuring/presentation enabled the majority of learners in reviewing their maps, reconsidering their beliefs and accomplishing successfully the concept mapping task (Gouli et al., 2004a). However, a comprehensive evaluation study is in progress in order to investigate several issues such as the effectiveness of the feedback process in learning achievement, in supporting processes of guiding/tutoring and reflection, and in accommodating learner's individual differences.

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