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Correctness- and Confidence-based Adaptive Feedback of Kit-Build Concept Map with Confidence Tagging

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Abstract. In this paper, we present an adaptive feedback of Kit-Build concept map with confidence tagging (KB map-CT) for improving the understanding of learners in a reading situation. KB map-CT is a digital tool that supports the concept maps strategy where learners can construct concept maps for representing their understanding as learner maps and can identify their confidence in each proposition of the learner maps as a degree of their understanding. Kit-Build concept map (KB map) has been already realized the propositional level automatic diagnosis of the learner maps. Therefore, KB map-CT can utilize both correctness and confidence information for each proposition to design and distinguish feedback, that is, (1) correct and confident, (2) correct and unconfident, (3) incorrect and confident, and (4) incorrect and unconfident. An experiment was conducted to investigate the effectiveness of the adaptive feedback. The results suggest that learners can revise their maps after receiving feedback appropriately. In "correct and unconfident" case, adaptive feedback is useful to improve the confidence. In the case of "incorrect and confident," improvement of the propositions was the same ratio with the case of "incorrect and unconfident." The results of the delay test demonstrate that learners can retain their understanding and confidence one week later.

Keywords: Adaptive Feedback, Kit-Build concept map, Confidence Tagging

1 Introduction

Feedback has a powerful influence in helping the learners to improve their learning achievements, thus it should be individually aligned with the characteristics of each learner as much as possible [1]. The correctness of learner's answer is generally used to estimate the characteristic of the learner, which the correct answer was interpreted as a representing the knowledge, while the incorrect answer was interpreted as a representing the misunderstanding. Especially the incorrect answers indicate that the learners require help to correct their misunderstandings. Moreover, the certainty of knowledge is an essential component to represent the belief of the learner as the quality of the knowledge [2-6]. For instance, confidence can encourage a deeper understanding of the material [7] and can increase reflection and justification of the answers [8]. Consequently, the answers of learners represent their understanding, and the con-

fidence in their answer indicates the degree of their understanding, such as the different degrees of the understanding between a learner who is sure in the correct answer and a learner who is unsure in the correct answer.

Although the correctness and confidence information can describe the degree of learner's understanding, this two information is not utilized to provide individual feedback for improving the understanding of learners generally. Because of the different degrees of learner's understanding, learners should be given different feedback in the same way as the different correctness which is given the feedback differently. Furthermore, the adaptive feedback regarding confidence information aims to ensure the confidence of learners who have an accurate understanding but lack confidence for encouraging the retaining of their understanding. The adaptive feedback also aims to reduce the confidence of learners who are confident in their misunderstanding, then correct the misunderstanding.

In this paper, we propose a mechanism to provide individual feedback based on the correctness and confidence information as an adaptive feedback of the Kit-Build concept map with confidence tagging (KB map-CT). The Kit-Build concept map (KB map) is a digital tool for supporting the concept maps strategy [9]. The instructor-built map is called a goal map, illustrating a learning goal, and the goal map will also be used as criteria for identifying the correctness. The goal map is decomposed into a list of concepts and linking words (called the "kit"), while the learner-built map, which is called a learner map, is used to represent the understanding of learner. The structuring task of the KB map-CT is to gather learning evidence that consists of the learner map and the confidence of the learner. Learners can construct learner maps as the learning evidence by connecting the kit to form the propositions [10]. A completed proposition, which can be tagged with the confidence of the learner, comprises one connected linking word between two concepts. The confidence of the learning evidence is simplified in the form of confidence- or unconfidence-value, which the learner can assign to every complete proposition. Hence, the KB map-CT can elicit learning evidence that includes the understanding of learners and the degree of the understanding in the gathering process. The adaptive feedback based on the correctness and confidence information is provided for learners in a reflection task for improving their understanding individually. The mechanism of the adaptive feedback is to provide different interactions as different feedback for encouraging the learners to reconsider their current understanding according to the correctness and confidence information of each proposition. For instance, the evidence identification task requests the learners to identify the evidence of all their confident propositions for ensuring the confidence of correct propositions by themselves and for reducing the confidence of incorrect propositions before correcting the misunderstanding. The related content of the material and the correct proposition of the goal map will be visualized along with the proposition of learners to promote the learners to reconsider their incorrect propositions. Therefore, we present an experiment of the adaptive feedback of the KB map-CT in a reading situation for illustrating the effectiveness of the feedback.

This paper is structured as follows: Section 2 mentions to related works of the concept mapping tools and its feedback. An introduction of the KB map and the KB map-CT are also described in this section. Section 3 presents the adaptive feedback of the

KB map-CT based on the correctness and confidence information and the description of the experiment. The results section, outlined in Section 4 presents the learning achievements and the proposition revising after the learners received feedback with a discussion about the effectiveness of the adaptive feedback. The discussion of the feedback implementation with confidence information is mentioned in Section 5, and Section 6 is the conclusion of this study.

2 Background

2.1 Concept Mapping Tools and Its Individual Feedback

Concept maps are graphical tools that are used to represent and organize knowledge [11]. A proposition is constructed by connecting two concepts via a relation with a linking word to represent a unit of meaning. The propositions are a core component of measuring a map score. The concept maps strategy is utilized to represent and assess the knowledge of learners in classes as the learning evidence. An instructor can gain information to utilize in various situations, such as using individual or group discussions to contribute a self-awareness of learners [12]. The concept maps strategy is simple to use, effective, satisfactory for problem-solving, and compared to lectures, significantly improves the learning achievements of learners. It is also more effective than traditional lectures in encouraging meaningful learning [13-16].

The correctness information of the concept map is primarily used as feedback. Several concept mapping tools provide the correctness for each component to learners based on the criteria map, such as COMPASS [17-19], ICMLS [20], KAS [21, 22], and CMfl [23]. Some special assessment methodologies were used for scoring the map, such as the weight of the important components of ICMLS and KAS, and the modified pathfinder of CMfl. Although different mapping tools have different details of their systems, the common methodology is a criterion-referenced assessment with the benefit of automatic assessment. The systems can identify the correctness of each component of the learner's map compared to the criteria map. The results of the comparison are provided for the learners as the system feedback for informing their performance, and the display of the related material content is general feedback for correcting the misunderstandings of learners regarding their incorrect propositions.

2.2 KB map-CT and Its Experiment in Classes

The KB map framework is a digital tool for supporting the concept maps strategy, which is realized as an automatic diagnosis of the concept maps in propositional level exact matching for identifying the correctness information automatically in the form of the diagnosis results [9]. An instructor constructs the traditional concept map to indicate a learning goal of the class as a goal map, while the learning evidence is constructed by the learners by connecting the provided components. The provided components are a list of concepts and linking words that are decomposed components of the goal map as a kit. Additionally, the figure of the KB map framework is shown in

[9], due to the page limitation. The diagnosis results of the KB map were utilized by the instructor for recognizing the current learning situation. The instructors used the diagnosis results to design and provide feedback to improve the learning achievements in the lecture classes effectively [24-26]. In addition, the propositional level exact matching of the KB map can attain almost the same validity as the well-known manual method [27, 28].

To gather learning evidence and identify the degree of the learner's understanding, the KB map-CT was developed to elicit learning evidence and associate the correctness and confidence information. Then, the KB map-CT has been experimentally used in classrooms conducted by teachers in elementary schools, and the results have been reported in [10]. The system allows learners to indicate their confidence as "sure" or "not sure" on all complete propositions. Accordingly, the system can generate diagnosis results based on the correctness and confidence information automatically. An example of a learner map on the structuring task with the confidence tagging is displayed in Figure 1. The correctness and confidence information can be used to classify the propositions into the four following types: (1) A correct proposition with confidence (COR-CON), (2) A correct proposition with unconfidence (COR-UNC), (3) An incorrect proposition with confidence (INC-CON), and (4) An incorrect proposition with unconfidence (INC-UNC).

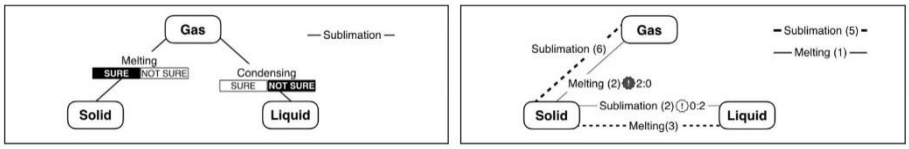

Fig. 1. An example of a learner map on the structuring task and a group-goal difference map

The diagnosis results of the KB map-CT consist of four different visualized maps following an individual overlay map, an individual-goal difference map, a group map, and a group-goal difference map. For instance, Figure 1 shows an example of a group-goal difference map where the correctness and confidence information is reported to the instructor. The other figures of the diagnosis results are illustrated in [10]. The group-goal difference map is a visualization of the mistake of learners in the form of three types of error link, and the linking word of correct propositions are disappeared in this map. The three types of error link consist of excessive links, leaving links, and lacking links. The excessive link (solid line) indicates the incorrect answer, and the lacking link (dashed line) represents the correct information. The leaving link is the link that is not connected to any concept. A badge is added to the linking word to indicate the confidence of the learners on the link. The colon is a punctuation mark for separating the number of learners. The number of learners who indicated "sure" is displayed on the left-hand side of the mark, while the right-hand side number displays the number of learners who indicated "not sure." In the experiment, the correctness and confidence information of learners were utilized to design and provide the instructor's feedback in the lecture classes. The results suggest that the instructors ac-

cepted the confidence information of learners as valuable information for recognizing the learning situation [10].

Table 1 illustrates the revision rate of each proposition type from 2,067 complete propositions in the uses of the KB map-CT in classrooms. The instructors provided feedback to improve the understanding of learners based on the diagnosis results of the KB map-CT. The results of the experiment demonstrate that the propositions without confidence are easier to be changed than the confident propositions. Although the instructor's feedback can improve the understanding of the learners, the correction rate of the incorrect propositions is different, depending on the learner's confidence. The results suggest that adequate feedback should be different, depending on the confidence of learners.

Table 1. The revision rate of each proposition type in the experiment of KB map-CT

Proposition Type	**INC-CON**	**INC-UNC**	**COR-CON**	**COR-UNC**
Revision Rate	66.66%	84.72%	5.93%	71.27%

In this paper, we propose the correctness- and confidence-based adaptive feedback that promotes improving the understanding and ensuring the confidence of an individual learner. A goal map structuring task for an instructor and a reflection task for learners were developed to support the automatic adaptive feedback. The goal map structuring task facilitates building a goal map for the instructor and linking each component of the goal map with the content of the material. The reflection task facilitates accessing personalized feedback and revising their learner maps for the learners. Accordingly, the system has adequate information for providing individual feedback according to each learner's characteristics. The adaptive feedback was designed for emphasizing the correctness and confidence information for each proposition type, which the instructor's feedback cannot deal with a large number of learners.

3 Methodology

3.1 Goal Map Structuring Task

The traditional concept map is constructed by an instructor to represent the learning goal. The instructor must type keywords to create labels of concepts or linking words. In this study, the goal map construction tool of the KB map-CT facilitates displaying the learning material in the form of a sentence by sentence for the instructor. The instructor can easily select keywords from the learning material instead of typing, can choose between concepts and linking words to create the components of the goal map. Then the instructor can connect them to each other. The goal map structuring task encourages a clear learning goal because all of the words that appear in the goal map also appear in the learning material. Moreover, the system can track the relationship between the content of the material and each component of the goal map as a related sentence. That means the system can link between each component of the goal map

and the content of the material. The related sentences are utilized in the adaptive feedback that is described in the next section.

3.2 Reflection Task

The reflection task is provided for learners after they completed learner maps, where the adaptive feedback is available. The learners will receive the information for recognizing their performance that includes a learner map score and an overlay map between their map and the goal map. The four different proposition types are distinguished using the different displayed line, while the confidence tagging also appears to determine the confidence in each proposition. The adaptive feedback is promptly provided for the learners according to each proposition type. The system allows learners to revise their map and change their confidence freely. Figure 2 demonstrates the system architecture of the KB map-CT and its adaptive feedback.

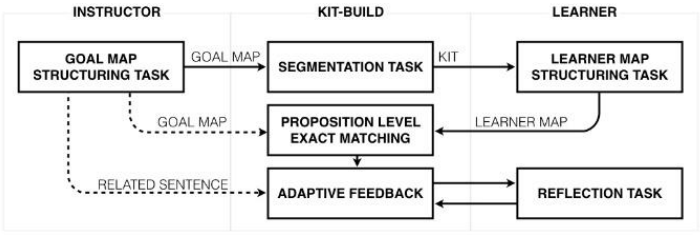

Fig. 2. The system architecture of the KB map-CT and its adaptive feedback

3.3 Adaptive Feedback

The adaptive feedback of the KB map-CT was designed to deal with both the correctness and confidence information of learners. The objective was defined based on four types of the propositions to encourage a positive change of the learning achievements. The primary objective is to correct the misunderstandings of learners in both INC-CON and INC-UNC, while increasing the confidence in COR-UNC. For the remaining proposition type, COR-CON, the aim is to encourage the learners to retain both the correctness and confidence. In other words, the adaptive feedback should correct the misunderstandings of learners and give more confidence to learners regarding the understanding appropriately. Accordingly, the adaptive feedback of the KB map-CT consists of four layers following:

Error Identification Layer.
The error identifying layer visualizes the correctness and confidence information of the learner map in three different lines. Solid lines present COR-CON and dashed lines represent INC-CON. COR-UNC and INC-UNC are displayed as a dotted line. An example of the error identification layer is displayed in Figure 3.

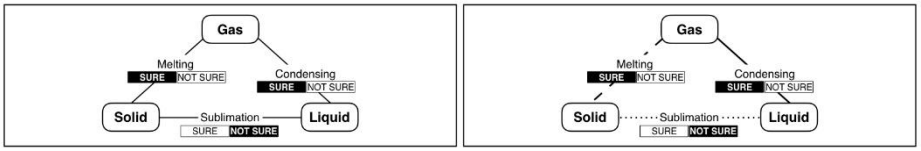

Fig. 3. An example of a learner map and the error identification layer

Evidence Identification Layer.
The evidence identification layer emphasizes learners who have the confidence in their propositions by promoting them to identify the evidence for each confident proposition. Its procedure contains a sentence selection and a sentence suggestion. The sentence selection requests learners who have the confidence to select a sentence of the material as a selected sentence for tracking the source of their understanding. The objective is to ensure the confidence of learners who can construct COR-CON and can select the sentence accurately. On the other hand, the sentence selection aims to reduce the confidence of learners who constructed INC-CON. The sentence suggestion provides the related sentence regarding the linking word of the unconfident proposition to the learners who do not have confidence. The objective is to increase the confidence on COR-UNC and to correct the misunderstandings on INC-UNC.

Explanation Layer.
The explanation layer emphasizes the proposition revision. Its procedure contains a proposition suggestion and a proposition selection. The proposition suggestion provides the proposition of the goal map to learners as the affirmation of learner's understanding on COR-UNC. The proposition selection aims to change the misunderstanding of learners who constructed INC-CON and INC-UNC. The feedback requests the learners to select an appropriate proposition of the selected sentence (INC-CON) or the provided related sentence (INC-UNC) between their incorrect proposition and the proposition of the goal map.

Guidance Layer.
The guidance layer is an instruction suggestion of the next actions regarding the previous activities of learners. For instance, the confirmation message is displayed when the learners selected the appropriate sentence in the same way as the related sentence of the goal map for ensuring the confidence of COR-CON.

Figure 4 represents scenarios of the adaptive feedback based on the correctness and confidence information that demonstrates the provided different feedback for each proposition type. The different scenarios create different feedback, which aspires to provide adequate feedback based on each combination of correctness and confidence information. The confidence information is utilized in the evidence identification layer to separate the learners into two cases. The learners who have confidence in their understanding have to indicate the source of the confidence in the sentence selection task. This task leads learners to reconsider their proposition and the material

content thoroughly. For the learners who have no confidence, they are necessary to receive the accurate source of the material in the sentence suggestion task.

The correctness information is utilized in the explanation layer for correcting the misunderstanding of learners. Despite only visualizing the correct proposition, it may directly guide how to revise their incorrect proposition. The adaptive feedback requests learners to determine the proper proposition according to the related sentence in case of the incorrect proposition. The proposition suggestion is to affirm the understanding of learners by presenting the related sentence of the material according to the correct proposition for ensuring the confidence.

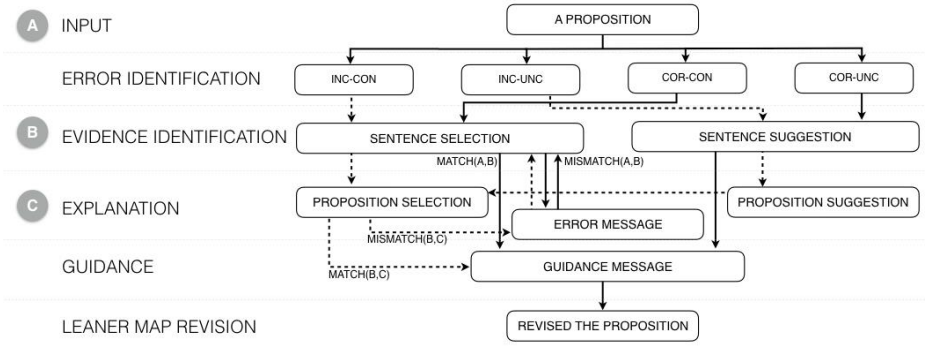

Fig. 4. The scenarios of the adaptive feedback for each proposition type

Figure 5 illustrates an example of the adaptive feedback on INC-CON, in which the proposition is incorrect with confidence of the learner. The system will provide the sentence selection to request learners to identify their evidence as a selected sentence and then will provide the proposition selection for adjusting the misunderstanding according to the selected sentence. Even if the learner can select the correct proposition in the proposition selection task, they have to revise their learner map by themselves after this process.

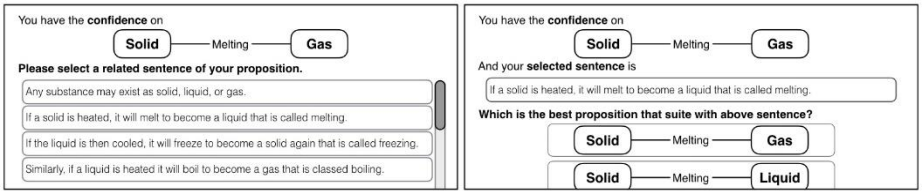

Fig. 5. An example of the adaptive feedback on the incorrect proposition with confidence

3.4 Experiment Procedure

The experiment was conducted to investigate whether the adaptive feedback encourages the learners to correct the misunderstanding and increase their confidence. The goal map was constructed via the goal map structuring task to create a learning goal,

generate a kit, and pair the related sentence of each proposition. The goal map consists of eight propositions from eight linking words and seven concepts. The participants are 24 university students who read a 104-word article in five minutes and constructed a learner map in five minutes to represent their understanding as a formative map. The reflection task is provided for learners who uploaded the formative map. The learners have ten minutes to receive feedback and revise their map as a reflective map. Lastly, the learners have to construct the learner map again one week later as a delay map to evaluate the retention of the understanding. Hence, there are three learner maps for each learner: the formative map, the reflective map, and the delay map.

In this paper, the investigation emphasizes on the proposition changing from the formative map to the reflective map to observe the direct effect of the adaptive feedback on the learning achievements. Moreover, the correctness and confidence of each proposition type were analyzed to demonstrate the effectiveness of the adaptive feedback. Using the adaptive feedback, we expected that (1) INC-CON and INC-UNC would be changed to correct propositions, (2) COR-UNC would be changed to COR-CON, and (3) COR-CON would be retained as the same proposition type.

4 Results

4.1 Learner Map Score

The learner map is used to estimate the understanding of learner, and the average learner map score represents an overview of the learning achievements. Table 2 presents the average score of each map in the experiment. The formative map score shows the first understanding of learners after they read the material. The reflective map score presents the understanding of learners after they received feedback. The delay map score represents the understanding of learners one week later.

Accordingly, the average score demonstrates that the adaptive feedback can encourage the learners to improve their map score, which the average score of the reflective map is higher than the formative map. There were also significant differences between the formative map scores and the reflective map scores, and between the formative map scores and the delay map scores according to the t-test with Bonferroni correction. Their effective sizes were large by Cohen's d criteria. These results suggest that the adaptive feedback can effectively encourage learners to improve their map score.

Table 2. The average scores and *p*-value of the formative-, the reflective-, and the delay-map

Variables	**Formative Map**	**Reflective Map**	**Delay Map**
Average score: full mark is 1.00	0.69 (*SD* = 0.21)	0.90 (*SD* = 0.14)	0.84 (*SD* = 0.16)
p-value from t-test with Bonferroni correction (Cohen's *d*)	*p = 0.00* (*d* = 1.15)		*p* = 0.70 (*d* = 0.35)
	p = 0.02 (d = 0.83)		

4.2 Proposition Transitions

The different feedback was provided for learners according to the correctness and confidence information of each proposition. The changing of the proposition type from the incorrect propositions to the correct propositions after the learners received the adaptive feedback produced the significant improvement in the learner map score. Figure 6 demonstrates the forward transition of the propositions from the formative map to the delay map. Although a few INC-CONs are unchanged to the other proposition types, the learners revised all of those propositions after receiving feedback. The revised propositions mean the learners changed at least one component of the two concepts and one linking word. The results suggest that the adaptive feedback promotes the revising INC-CON and feedback is possible to reduce the confidence of learners and encourage them to correct their misunderstanding.

Moreover, the previous study of the KB map-CT [10] demonstrated that the propositions without confidence tend to change more easily than the propositions with confidence when the learners received the instructor's feedback. The results suggest that the INC-CON should be the most difficult to overcome in the classroom situation. However, the adaptive feedback is possible to reduce the number of INC-CON similar to that of the INC-UNC on the reflective map. The forward proposition transition suggests that the adaptive feedback is adequate for correcting the misunderstanding of learners, even those learners who have the confidence in that misunderstanding. The learners can change the INC-CON to the correct proposition, similar to INC-UNC.

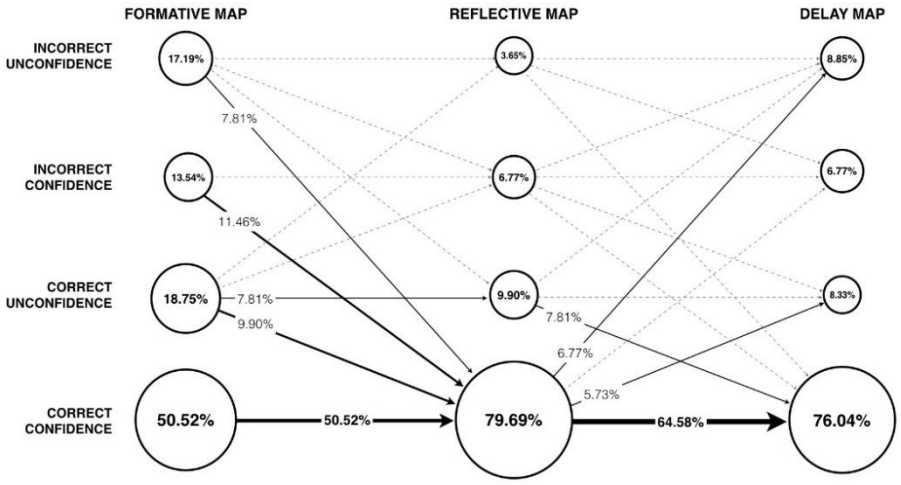

Fig. 6. The forward transition[1] of the propositions from the formative map to the delay map

The retaining of COR-CON is one of the objectives of the adaptive feedback. The forward proposition transition illustrates that the learners can keep all COR-CON from the formative map to the reflective map. The transition suggests that the adap-

[1] The dashed line represents the proportions transitions that less than or equal to five percent.

tive feedback did not disturb the learners from maintaining confidence in their accurate understanding. On the other hand, ensuring confidence is another objective of the adaptive feedback for COR-UNC. The most revised COR-UNC were changed to COR-CON following the objective. There are some COR-UNC that retained the same type, and a few propositions were changed to INC-UNC and INC-CON. Moreover, the results of the experiment demonstrate that the learners can keep COR-CON of the formative map 46.88% from 50.52% through the delay map. The average score of the delay test is 84.28% correct propositions with and without confidence, which comprise 53.10% of the first understanding, 19.63% from the improvement between the formative map and the reflective map, and 11.55% are undescriptive.

Discrimination and Certainty of the Understanding

The discrimination value (d_r) represents the recognition of the difference between what they know and what they do not know [2]. The value is measured based on COR-CON and INC-UNC against all of the complete propositions in the learner map. A perfect score indicates that the learners are able to discriminate their understanding according to the appropriate confidence. Table 3 shows the improvement of the discrimination value after the learners received feedback. The results suggest that the adaptive feedback encourages the learners to discriminate progressively between the different understandings based on correctness and confidence. Moreover, the hit rate (*HR*) represents the consistency with the interpretation that, if a correct response is covertly selected, then its execution helps the learner to confirm its correctness [2]. The value is measured based on COR-CON against the number of correct propositions in the learner map. The hit rate of the experiment is displayed in Table 3. The results suggest that the adaptive feedback encourages the learners to present consistency with the interpretation of the correct proposition more accurately.

Table 3. The discrimination value (d_r) and hit rate (*HR*)

Variables	Formative Map	Reflective Map	Delay Map
Discrimination of the understanding (d_r)	0.68	0.83	0.85
Certainty of the understanding (*HR*)	0.73	0.89	0.90

5 Discussion

The general feedback aims to correct the misunderstanding of learners based on the correctness of learning evidence. The automatic assessment of the concept maps creates an opportunity to provide individual feedback, such as visualization of the discrepancies of learner map against the goal map. The related content of the material can be part of individual feedback with some preparation. Only incorrect answers of learners are regularly treated with one kind of feedback, while the correct answer is interpreted as accurate understanding without treatment, which indicates that even if the learners have a different degree of the misunderstanding, they will receive the same feedback. Moreover, it is necessary to ensure the accurate understanding of the

learners who are unsure in their understanding. However, it is impossible to identify the degree of the learner's understanding with only the correctness information.

The confidence information of learning evidence demonstrates the difference in the same correctness of the evidence, which is used to represent the degree of learner's understanding. Correspondingly, the association of correctness and confidence information can describe the learning situation. The different correctness information is treated with different approaches, the different confidence also requires different approaches. Thus, the combination of correctness and confidence information should be treated appropriately. The adaptive feedback of the KB map-CT represents the utilization of correctness and confidence information to reduce or ensure the confidence, correct the misunderstanding, and confirm the accurate understanding of learners, which is the effect of confidence information on automatic individual feedback implementation. The results of the experiment present the improvement of learning achievements and retention of the understanding of learners. The forward transition of the propositions demonstrates that the learners can change INC-CON in the same way as INC-UNC, which is different from the previous experiment in the classrooms in which all learners received the same feedback from the instructor. Moreover, the learners who received the adaptive feedback are also able to associate the appropriate confidence in their understanding more accurately.

6 Conclusion and Future Work

The correctness and confidence information is valuable for recognizing the understanding of learners and identifying the degree of learner's understanding. Thus, the adaptive feedback of KB map-CT utilized both correctness and confidence information to correct the misunderstandings of learners and ensure the confidence of learners. The goal map structuring task and the reflection task were developed to support the automatic adaptive feedback. The experiment in the reading situation was conducted to demonstrate the effectiveness of the adaptive feedback. The results suggest that the adaptive feedback based on the correctness and confidence information can significantly improve the learning achievements. Moreover, the adaptive feedback encourages the ability of learners to discriminate the different understandings based on the correctness and confidence, and encourages the learners to promote their confidence in the correct propositions accurately. For future work, increasing the number of participants and comparing with the other feedback should be considered to contextualize the effectiveness of the adaptive feedback.

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