

## A Computer System of Referential Resolution to Assess Students' Reading Comprehension

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### ABSTRACT

The major purpose of this study is to assist college students in constructing mental representation of referential resolution in a computer system. Ninety students were asked to draw mental maps indicating the relationships between references, take reading comprehension tests, and fill out open-ended questionnaire. Results showed that the correlation between referential resolution and reading comprehension ranged from 61% to 75% in three reading tasks. The more students practiced in referential resolution, the higher average score they obtained in the reading comprehension test. Students also requested fewer feedbacks when they progressed to better comprehend the final online text. That is, they became more independent and relied less on the system's feedback in their reading development. Although seventy-six students expressed that they learned from building connections of related words and made progressed in reading comprehension, fourteen students revealed that they still had difficulties after using the online system. This deserved more investigation in the future.

### Keywords

Referential resolution, Reading comprehension, Referring strategy, Mental representation, and Metacognition

### Introduction

College students who learn English as a Foreign Language (EFL) in Taiwan were found to experience great difficulty in resolving references (Chen, 2001; Yu, 1993; Chen & Dai, 2003). Results of Bensoussan and Laufer's study (1984) indicated that the major reading difficulty that ESL or EFL college students encountered was their failure to recognize the interrelationship between sentences in a text. In addition, Chu, Swaffar, and Charney (2002) mentioned that most Taiwanese EFL students were found to be less aware of how to use cohesive devices to integrate textual information. Wang and Ding (1998) further claimed that Taiwanese students' lack of skills in cohesive ties was sure to hinder them from comprehending texts.

Five cohesive ties were proposed by Halliday and Hasan (1976) and these ties were considered the keys to help readers integrate the meanings of the sentences in a text; they were reference, substitution, ellipsis, conjunction, and lexical cohesion. Among these five cohesive ties, reference accounted for 59% of variance in L1 readers' comprehension (Demel, 1990) and 75% of EFL students' statistical text comprehension (Huang, 2005). Three types of references, personal, demonstrative, and locative pronouns were considered in this study since they appeared more frequently in texts (e.g., Fortane, 2004; Kennison, 2003). Personal references refer to individuals or objects by specifying their functions or roles in the speech situation (Halliday & Hasan, 1976), such as "I", "me", and "you." Demonstrative references substitute nouns when the nouns can be understood from the context. They also indicate whether they are replacing singular or plural words. Examples include "this," "these," "that," "more," "neither," etc. Locative references are used to indicate locations. Examples include "here" and "there."

Once a reader received trainings in cohesive ties, he was supposed to identify the critical links in integrating successive sentences and forming a coherent discourse representation (Tea & Lee, 2004; Potelle & Rouet, 2003). This representation illustrated the reader's cognitive process of understanding a text. The reader might later use the

mental representation to summarize, analyze, discuss, and evaluate the information in a text (Guerrero, 2003). In Sharp's review (2003), different kinds of mental maps were built by the reader to organize knowledge and represent his/her cognitive structure, such as semantic networks, roundhouse diagrams, compare/contrast matrix, continuum/scale, and concept maps. According to Gardner (2004), mental maps provided students with alternative paths leading to the comprehension of a text. Reading the linear structure of a text was no longer the only way to comprehend a specific content. Instead, students were allowed to understand the content through the radial structure of diagrams represented in their mental maps. These mental maps not only displayed specific relationships among ideas but also enabled the reader to generate elaborative inferences about the text (Cuevas, Fiore, Bowers, & Salas, 2004).

The mental map could be viewed as the mental product of text comprehension for it helped the reader remove lexical or syntactic ambiguities, determine anaphoric antecedents or improve subsequent recall of information in long texts (Payne & Reader, 2006). In presenting students' mental maps, Greene and Azevedo (2007) suggested that self-regulated learning (SRL) processes accounted for qualitative shifts in students' mental maps from pretest to posttest in hypermedia learning environments (HLEs). In their study, the results indicated that students who exhibited a qualitative shift employed different processes, including metacognitive monitoring activities and learning strategies. They further claimed that "future research should focus on the best means of inculcating effective SRL behaviors through on-line methods, so that HLEs can teach both content and the actual process of learning" (p. 141). This led to substantive recommendation for the use of trace logs and scaffolding to promote self-regulated learning.

In Schacter, Herl, Chung, Dennis, and O'Neil's study (1999), four computational tools were designed to support assessment of students' problem-solving performance: (1) CRESST's Java Mapper; (2) a simulated World Wide Web environment; (3) a bookmarking applet; and (4) outcome feedback. In the feedback module, students could access real-time outcome feedback regarding their performance while searching for information and constructing their concept maps. Outcome feedback presented students with information describing whether concept-link-concept propositions in their concepts maps were correct and where additional work was needed. Feedback was based on comparing a student's concept map to that of an expert.

Chang, Sung and Chen's study (2002) addressed that graphic strategies, such as graphic organizers and knowledge maps, had proved useful for text comprehension. In their study, they tested the learning effects of a concept-mapping strategy. Three concept-mapping approaches were designed—map correction, scaffold fading, and map generation—to enhance students' text comprehension and summarization abilities. The experimental results showed that the map-correction method enhanced text comprehension and summarization abilities and that the scaffold-fading method facilitated summarization ability. In addition, Vakilifard, Armand & Baron (2006) examined whether concept maps enhance the second language students' reading comprehension in the first language context. Their result showed that the early presentation of concept maps before reading texts led students in experimental group to understand the texts effectively. Positive results of using concept maps in various subject areas could also be found in Hazzan's (2004), Kwon and Cifuentes' (2007), Ruiz-Primo, Schultz, Li, and Shavelson's (2001) studies.

From the literature and system reviewed, it was found that several problems existed in the studies of mental maps. First, there was a controversial issue regarding the activity using graphic strategies. On one hand, several studies indicated that graphic strategies demanded effort and usually resulted in cognitive overload and negatively affective learning outcomes (e.g., Katayama & Robinson, 2000). Novice students tended to be frustrated in the constructive process of mental maps and unwilling to use this strategy (Fisher, Faletti, Patterson, Thornton, Lipson, & Spring, 1990; Reader & Hammond, 1994). On the other hand, some studies revealed that mental maps served as tools for the reader to build his/her own understanding of a text (Cuevas, Fiore, Bowers, & Salas, 2004; Guerrero, 2003; Payne & Reader, 2006; Tea & Lee, 2004). Readers' construction of a graphic presentation might foster deeper processing. Second, the criteria of evaluating students' mental maps were not clearly revealed in the previous studies. In reading a text, each individual might have very different ways in generating his own concepts. This resulted in the difficulty of comparing experts' "concept maps" with those of students. It also made the evaluation of concept maps questionable.

Third, most findings were based on comparisons of evaluation results obtained immediately after the training was finished (Moore & Readence, 1984). This approach might be good for examining the immediate influences of graphic strategies on text comprehension, but it said little about what happened afterward. Further explorations using longer training duration and more extensive reading materials along with participants of different levels of reading

abilities are worth considering in order to examine the relative effectiveness of different concept-mapping methods. Finally, although some studies have reported performance outcome (e. g. Chang, Sung, & Chen, 2001; Folkesson & Swalander, 2007; Glenberg, Brown, Levin, 2007; Schater et al., 1999), they do not present students' thinking process. A model that demonstrates the relative effects of these processes on outcome performance is needed to answer questions such as: What role does the use of feedback play on subsequent searching and finding relevant textual information?

This study reports on our design of a computer system which assists EFL college students in constructing mental maps of referential resolution in reading texts. In order to reduce the cognitive overload on students, our system offers a list of references for students to select, instead of asking them to figure out the key words or concepts everywhere in a text. The system also provides students with three candidate references as a scaffold when they encounter difficulties in finding out the relationship between two references in drawing their mental maps. Paas (1992) stated that a good way to avoid possible overload on students was to provide scaffolding when they were learning. In addition, the evaluation of students' mental maps in our system is based on referential resolution. Referential resolution provides a clear criterion for the comparisons between experts' maps and those of students. For example, in a short text "I have a sister. Her name is Mary. She is a junior high school student." The mental map of referential resolution is shown in Figure 1.

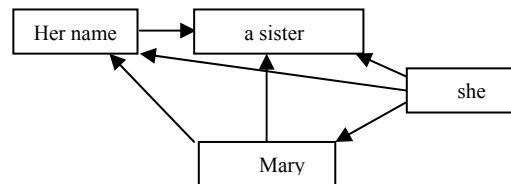


Figure 1. An example of mental map in referential resolution

Furthermore, the examination of three different reading proficiency groups' mental maps of referential resolution also provides a guideline for the teacher to identify individual student's strengths and weaknesses and to plan and design the follow-up remedial courses. Finally, the system records every single reading action that students take in the system and reports these process data back to students and the teacher.

In this study, referential resolution is defined as a reading strategy applied by the reader to interpret the references that have the same meanings as other elements in the text. This operational definition is similar to Paterson, Sanford, Moxey, and Dawydiak's (1998) and Walsh and Johnson-Laird's definition (2004) of co-reference. According to Paterson et al., a major task in reading is to decide whether people or objects appearing in different parts of a text refer to the same entity. While resolving the references, the reader is actually engaged in metacognition which he/she monitors, regulates, and evaluates his/her own reading process (Hartman, 2001). Evaluating one's own reading process involves an assessment of the current progress. This evaluation can assist readers to develop the necessary skills and strategies. Revising one's own reading process refers to modifying previous strategies related to reading goals and other possible learning approaches (Brown, 1987). All these evaluation and revision of one's own reading process are helpful for the meaning construction of text comprehension (Paris & Winograd, 1990).

Coined from the definition of referential resolution, mental representation is identified as the mental map that demonstrates the reader's cognitive structures for establishing the relationships among the references in different parts of a text. In the mental map, references are represented as nodes and connected by lines, which represent the relationships among the references. These lines make the mental map more meaningful by showing how the reader relates references to each other in their cognitive structure. The mental map, thus, is viewed as an external mirror of the internal structure and the process of the reader's thinking (Potelle & Rouet, 2003).

Based on the purpose of assisting EFL college students to practice and construct mental representations of referential resolution in reading, two research questions are addressed: (1) How do the mental maps that students construct in our system help them read and understand the text better? (2) What are the effects of the feedback tool in our system on students' performance of referential resolution?

## System Development

The system built for this study includes three modules, *user interface*, *recording module*, and *feedback module*. The relationships among these three modules are shown in Figure 2. A teacher uses a management interface to save into a database the texts to be read by students. The teacher also prepares the expert's maps that provide the correct reference answers for the texts and must enter the expert maps into the system with the management interface. A student uses a reading interface to work on the exercises by picking references from the texts and construct maps to connect the references. When a student asks for a hint on referential resolution, the system uses the expert's map to provide the student with choices of two distracters and one correct reference. Moreover, every action a student makes in the system is saved into the database by the recording module. The action data provide rich resources from which the teacher can observe many aspects of student behavior during the exercises. Based on the architecture of the system, the interfaces and the modules of referential resolution are shown in Figure 2.

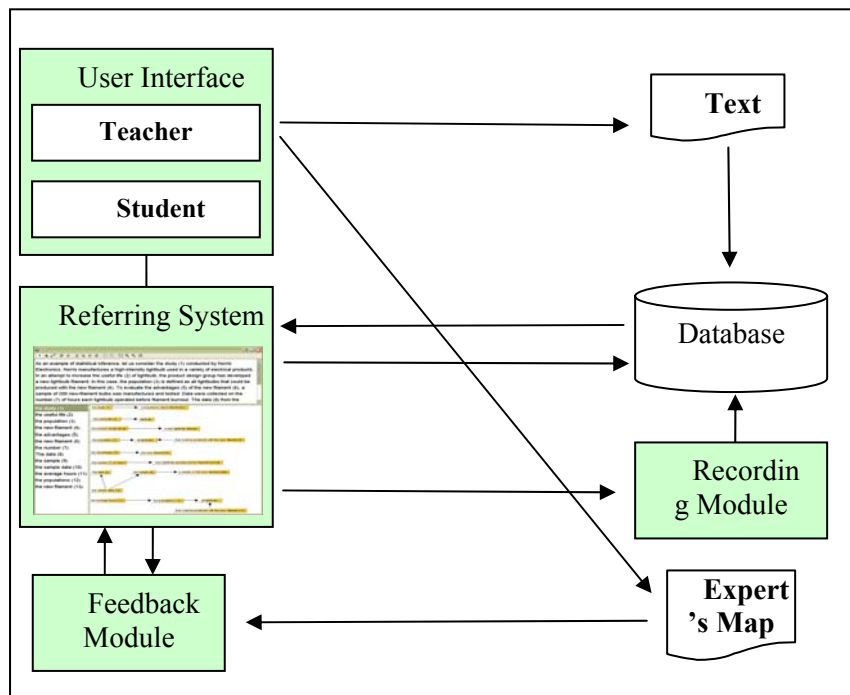


Figure 2. The system architecture

Elements of the student interface are shown in Figure 3. Section A of Figure 3 is a toolbar which includes many graphic tools. *Connection tool* can establish meaningful relations between referential devices. *Feedback tool* compares students' initial map with that of the expert. It then informs students what have been done incorrectly and provides students with three candidate references to correct their previous incorrect selection. Other tools are *cut*, *copy*, *paste*, *erase*, *group*, *ungroup*, *zoom in*, *zoom out*, *undo*, and *redo*. As shown in section B, this area is used to display the text. Students can select a word or a phrase as a text element and then drag into the canvas directly. When a sentence is selected, it will be highlighted.

All referential devices are listed in section C of Figure 3. Students have to understand what these referential devices refer to, then drag and drop them to the canvas. When a referential device in the list is selected, the referential device will also be highlighted in the *text field*. Section D of Figure 3 is a feedback frame. This will inform students what have been done correctly and incorrectly in the referring practice. In addition, the feedback will provide three candidate references when the student has difficulties identifying the link between two words. Students can decide whether they want to activate this frame. Finally, section E is a canvas. On this canvas, students can add links to indicate the relationships between references. They can *add*, *erase*, *drag*, and *drop* elements on the canvas.

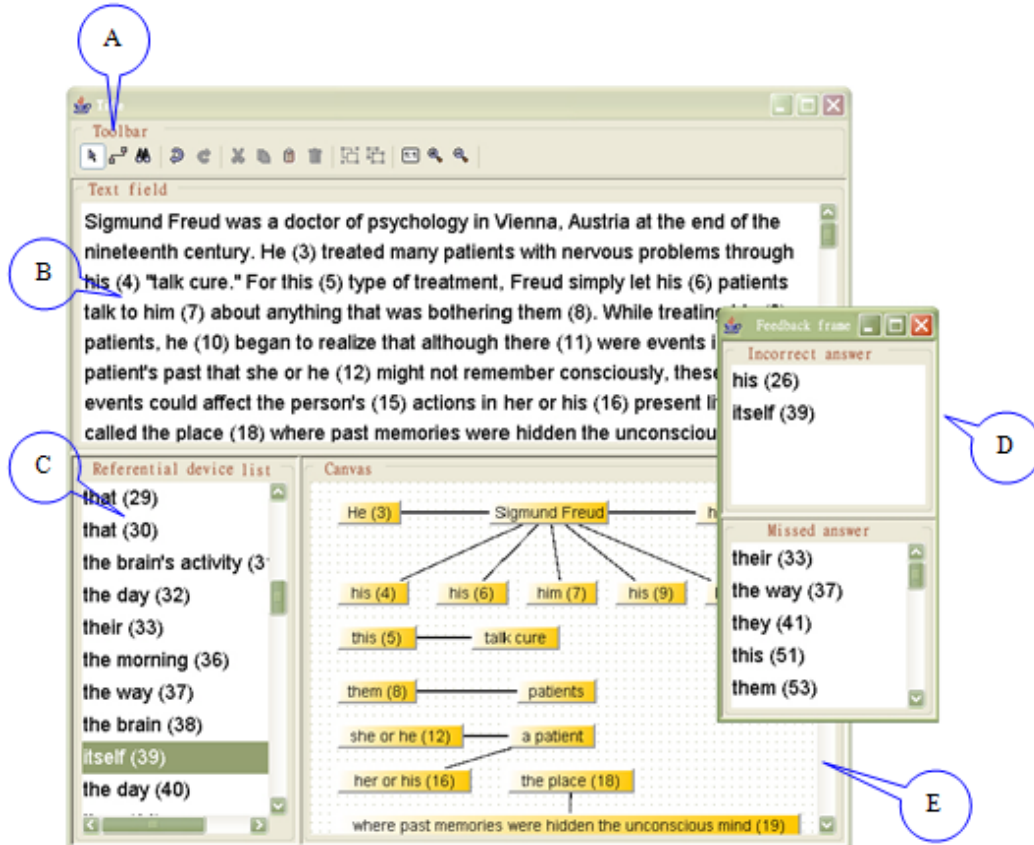


Figure 3. The interface and module of referential resolution

## User Interface

The *user interface* includes a *teacher interface* and a *student interface*. The *teacher interface* helps the teacher manage course data, provide texts which students should read, and observe students' reading process and behavior data. The *student interface* provides a student space to draw a map indicating the relationships between references, take the reading comprehension test, and fill out a questionnaire.

## Recording Module

The system uses a *recording module* to trace students' reading process. From the data, the teacher can identify the difficulties they encounter and check their performance. The records are helpful for the teacher to modify his/her instruction according to students' strengths and weaknesses. The module uses some predicates to record students' behavioral data. Table 1 shows some of the recording predicates.

Table 1. Some of the recording predicates

Predicates	Description
Read a sentence: [T]	Select a sentence T which the student is reading in the text field
Add a cell: [X]	Add an element X on the canvas
Erase a cell: [X]	Erase an element X from the canvas
Add a connection: [X][Y]	Add a meaningful relation between X and Y
Cut a connection: [X][Y]	Cut a relation between X and Y
Get feedback count: [N]	Request the feedback for N times
Get feedback of: [X]	Request the feedback for the reference X

In Table 1, the recording module shows the predicate “read a sentence” when a sentence is selected by a student to read. The predicate “add a connection” is used when the student figures out the relationship between two references and draws a line between these two references. These predicates indicate every single pre-defined action that the student takes in the system. The sequence of these actions then represents the process of referential resolution that the student has gone through in reading a text. An example of *trace result* is shown in Figure 4.

- 
1. Read a sentence: [The young man (22) was hunting with his (23) dogs, and Echo was struck by his (24) perfect figure, beautiful face, and long flowing hair.]
  - ...
  11. Get feedback count :[26]
  12. Cut a cell :[ the image (51) he (52) saw]
  13. Cut a connect :[the image (51)] connect to [null]
  14. Cut a cell :[his (49) own refection ]
  15. Add a cell: [refection]
  - ...
  25. Get feedback count :[40]
- 

Figure 4. Records of a student’s reading process

### Feedback Module

While students encounter difficulties in constructing their initial maps, they can request feedback (see Figure 5). In the example, the student refers “them (8)” to “Sigmund Freud.” He is not sure whether the referential resolution is correct so that he asks for feedback. The system provides the correct reference “patients” and two distracters “that” and “his (9)” and requires the student to pick an answer from the three given choices (see Figure 6).

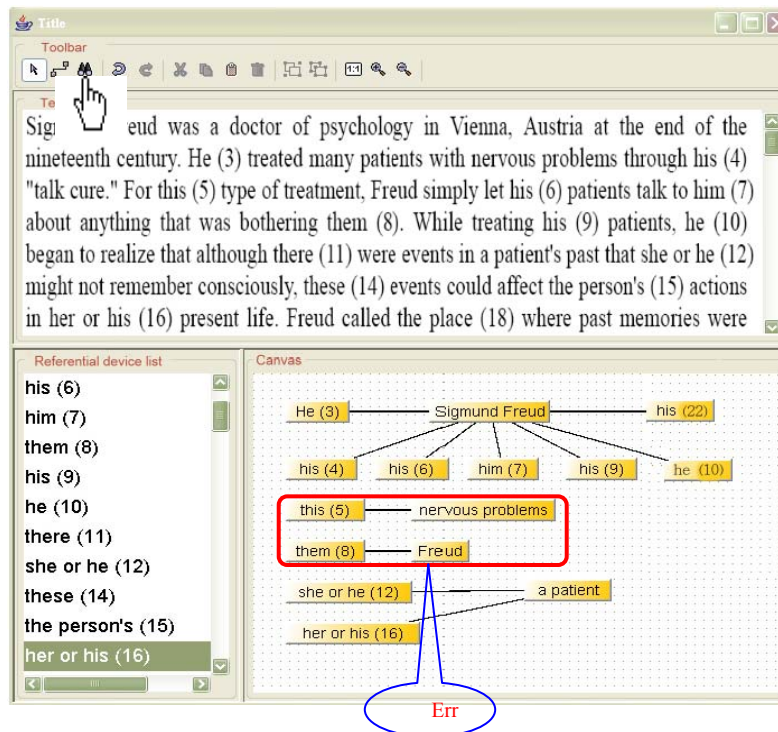


Figure 5. The student asks for a feedback

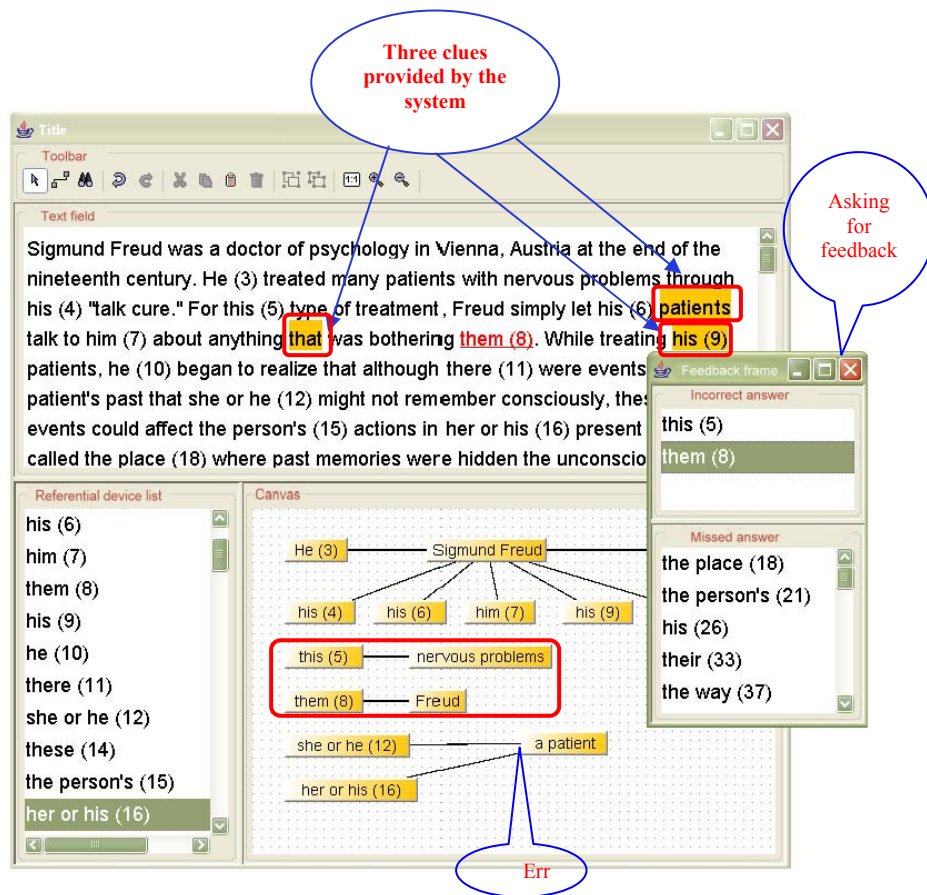


Figure 6. The feedback to a student

A student's answer is compared to the expert's referential resolution in the following way. First, the module transforms the correct map and the student's map into predicates. Second, the module finds all references from students' predicates and then compares them with the correct ones. If students' references do not match the correct ones, they are incorrect. Then the module will provide one correct reference and two distracters as clues back to the student. Table 2 shows the comparison between a student's map and the expert's map in the system. The *feedback module* compares a student's map with that of the expert and finds out that the resolution of the referential device A is incorrect in the student's map. The module will then offer the correct reference B and two distracters D and E as choices for the student.

Table 2. Comparison between a student's map and an expert's map

Student's Map		Expert's Map	
Map	Predicates	Map	Predicates
	Add a cell: [A] Add a cell: [C] Referring: [A][C]		Add a cell: [A] Add a cell: [B] Referring: [A][B]

## Method

### Participants

A total of 90 junior and senior college students were recruited from two reading classes in a technological university in central Taiwan. Their language proficiency levels were defined by their reading scores in a simulated online exam *Testing of English for International Communication* (TOEIC) with a reliability of 0.87. The full score in the online exam was 200.

The frequency distribution of all the participants' score was used to divide the participants into three groups of readers. It was found that the highest frequencies fell in two score intervals, 81-90 (8 students) and 131-140 (8 students). These two intervals were used to identify a less proficient reader group (31-90) and a more proficient reader group (131-200). Participants with scores in the range 91-130 were excluded from the study. The frequency distribution of the participants recruited in the current study is shown in Figure 7.

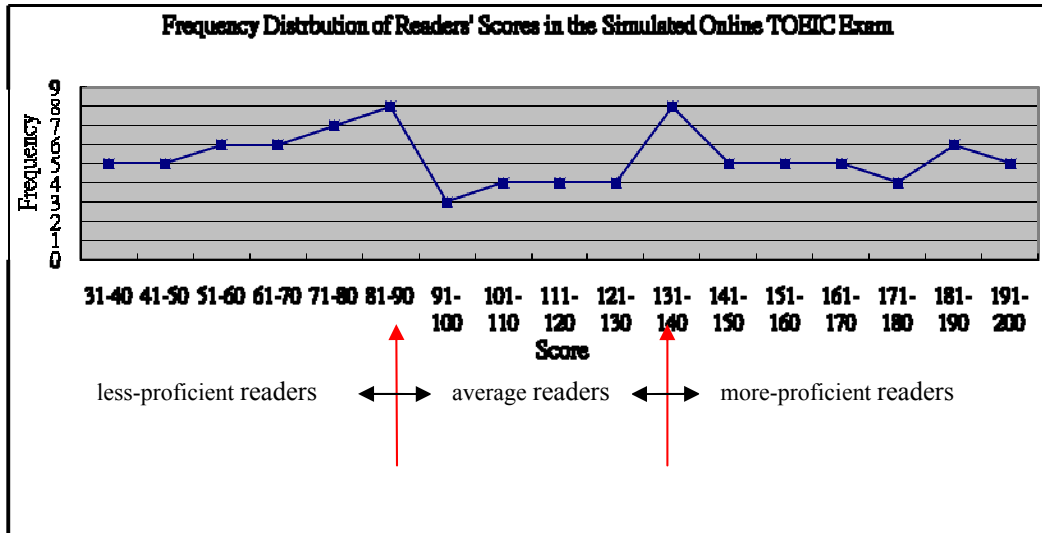


Figure 7. The frequency distribution of the participants' score

Thus, 38 more-proficient readers and 37 less-proficient readers were identified in this study. The mean score of the more-proficient readers was 157.89 with a standard deviation of 18.37. The mean score of the less-proficient readers was 57.84 with a standard deviation of 14.70.

## Material

The online referential resolution practice used three texts to examine the participants' reading comprehension. The three texts were selected from *College Reading Workshop* (Malarcher, 2005) based on the following four criteria: abundance of references for reading practice, similar length, similar readability level, texts written for EFL college students. The three texts were presented in sequence in the textbook and they are text 1---*Freud and the Meaning of Dreams* (number of words: 708; number of referring phrases: 38), text 2---*The Tragedy of Echo and Narcissus* (number of words: 692; number of referring phrases: 62), and text 3---*Commerce through the Internet* (number of words: 651; number of referring phrases: 21). Table 3 shows the readability of these three texts. According to the Flesch reading ease test (Farr, Jenkins, and Paterson, 1951), higher scores indicate material that is easier to read and lower numbers mark harder-to-read passages. The formula for the Flesch reading ease test is shown as follows.

$$206.835 - 1.1015 \left( \frac{\text{total words}}{\text{total sentences}} \right) - 84.6 \left( \frac{\text{total syllables}}{\text{total words}} \right)$$

Scores of 90 to 100 are easily understandable by native speakers of English at an average 11-year old students and scores of 60-70 are considered easily understandable by 13- to 15-year old students. Passages with results of 0-30 are best understood by college graduates. In addition, Flesch-Kincaid grade level is calculated with the following formula (Flesch, 1948; Kincaid, Fishburne, Rogers, Chissom, 1975).

$$0.39 \left( \frac{\text{total words}}{\text{total sentences}} \right) + 11.8 \left( \frac{\text{total syllables}}{\text{total words}} \right) - 15.59$$

Among the three texts, text 1 has the most words, 708. Text 2 has the most sentences, 46, and paragraphs, 8. Text 3 is the most difficult with Flesch-Kincaid grade level at 11.5.



Table 3. The readability of text 1 to 3

	Text 1	Text 2	Text 3
Number of words	708	692	651
Number of sentences	35	46	35
Number of paragraphs	7	8	6
Flesch reading ease	53.6	66	44.5
Flesch-Kincaid grade Level	10.6	7.6	11.5

### Procedures of Data Collection

The present study was conducted between April 24<sup>th</sup>, 2006 and June 10<sup>th</sup>, 2006. The 90 college students were asked to complete the online referential resolution practice on the website <http://140.125.32.148/reading> in class. The participants' reading behavior and performance were automatically recorded by trace results in the system.

For each online text, the participants were provided instruction on the definition and types of references followed by examples. They were also asked to practice the referential resolution in the trial section by drawing the relationships between two phrases. After the trials, they were requested to complete a formal referential resolution practice by selecting referential phrases and drawing the relationships between these phrases on the canvas. After drawing the mental maps, they were required to take a reading comprehension test. Each comprehension test contained 8 multiple-choice items. At the end, the participants were requested to fill out an open-ended questionnaire. The online system graded the participants' referential resolution practice by giving one point to each correct connection between two referential words. This was similar to the scoring in the reading comprehension test. Each test item was assigned one point and the full score was 8. The reading comprehension test was specific to each text and an example was shown in the appendix.

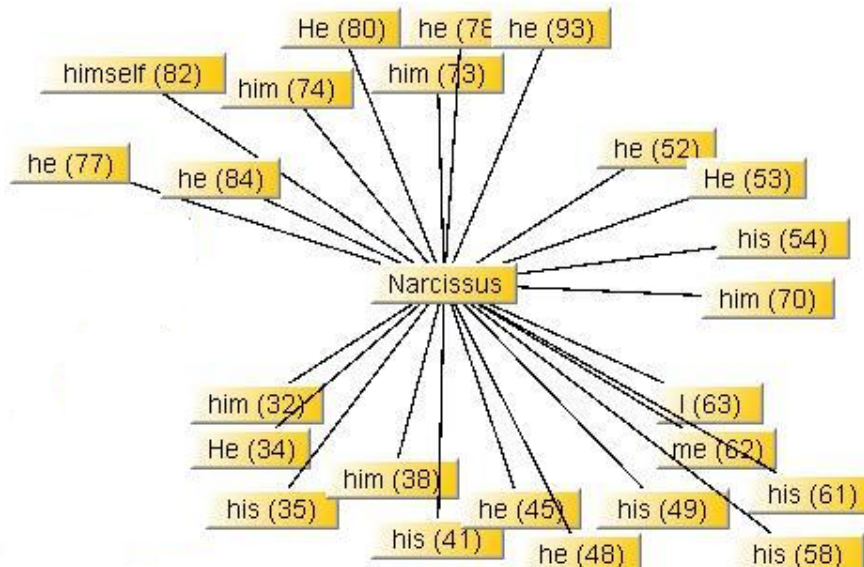


Figure 8. An example of the more-proficient participants' mental map in personal references

### Procedures of Data Analysis

Based on the research questions, the data were categorized into three types: reading process, reading product, and perception towards the referential resolution practice and the online system. Reading process refers to the mental maps of the participants' referential resolution and the trace results of their reading behavior. Reading product includes the participants' scores of referential resolution, scores of reading comprehension test, and frequency of feedback. Finally, students' perception towards the resolution task and the online system will be described.

## Result

### Reading Process

In this study, data from the reading process include the mental maps of the more- and less-proficient participants' referential resolution and the trace results of their reading behavior. An example of the more-proficient reader's mental maps in the text *The Tragedy of Echo and Narcissus* is shown in Figure 8.

As shown in Figure 8, the more-proficient participant was able to integrate personal references in different parts of the text to form a coherent network. The more-proficient participant could refer "his", "him," "himself", and "he" to "Narcissus." He used references from No. 32 to 84. This simple task for the more-proficient participant became a big challenge for a less-proficient participant. The less-proficient participant could not relate references toward the same subject as well as the more-proficient participant did. Figure 9 illustrates an example of the less-proficient participants' mental maps in personal reference. He could only used references from No. 53 to 63. This implies that he could not understand the full text.

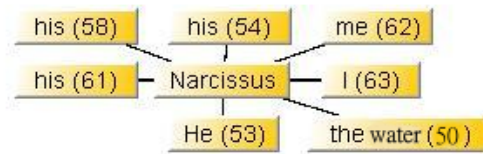


Figure 9. An example of the less-proficient participants' mental map

	1. Add a cell: [Echo]
	...
	26. Add a connection: [she (37) connect to [Echo]
	27. Add a connection:[I (39) connect to [Echo]
	...
	74. Get feedback count :[2]
	75. Cut a connect :[his (23)] connect to [null]
	76. Cut a connect :[his (24)] connect to [null]
	77. Get feedback count :[3]
	78. Cut a connect :[he (26)] connect to [null]
	79. Get feedback count :[4]
	...
	86. Get feedback count :[6]
	87. Get feedback count :[7]
	88. Get feedback count :[8]
rereading	89. Read a sentence: [The young man (22) was hunting with his (23) dogs, and Echo was struck by his (24) perfect figure, beautiful face, and long flowing hair.]
	90. Read a sentence: [The young man (22) was hunting with his (23) dogs, and Echo was struck by his (24) perfect figure, beautiful face, and long flowing hair.]
	...
Self-correction	168. Get feedback count :[26]
	169. Cut a cell :[ the image (51) he (52) saw]
	170. Cut a connect :[the image (51)] connect to [null]
	171. Cut a cell :[his (49) own refection ]
	172. Add a cell: [refection]
	...
Frequency of asking for feedback	259. Get feedback count :[40]
	260. Cut a connect :[the water] connect to [the image (51)]
	261. Cut a cell :[the image (51)]

Figure 10. Trace result of a more-proficient participant's reading process

As shown in Figure 9, the less-proficient participant's referential resolution was more inconsistent than that of the more-proficient participant. Even though he tried hard to resolve the references, his/her answers were incorrect. For example, the less-proficient participant referred "the water" to an incorrect personal reference "Narcissus" in Figure 9.

In addition to the mental maps, the participants' reading process was recorded in the trace results of the online system. Figure 10 is an example of the more-proficient participant's trace results with the text *The Tragedy of Echo and Narcissus*.

The *trace result* showed that the more-proficient participant paid more attention to their reading. He often read and reread the sentence to make sure he really understood or not (e.g., lines 89 and 90). He also used the feedback tool 40 times to help him comprehend the text. After receiving the feedback, he was engaged in comprehension monitoring for self-correction, such as adding or cutting a text element (e.g., lines 169 to line 172). In contrast, the less-proficient participant usually skipped the sentence that he/she did not understand instead of asking for feedback. An example of the less-proficient participants' trace results was shown in Figure 11.

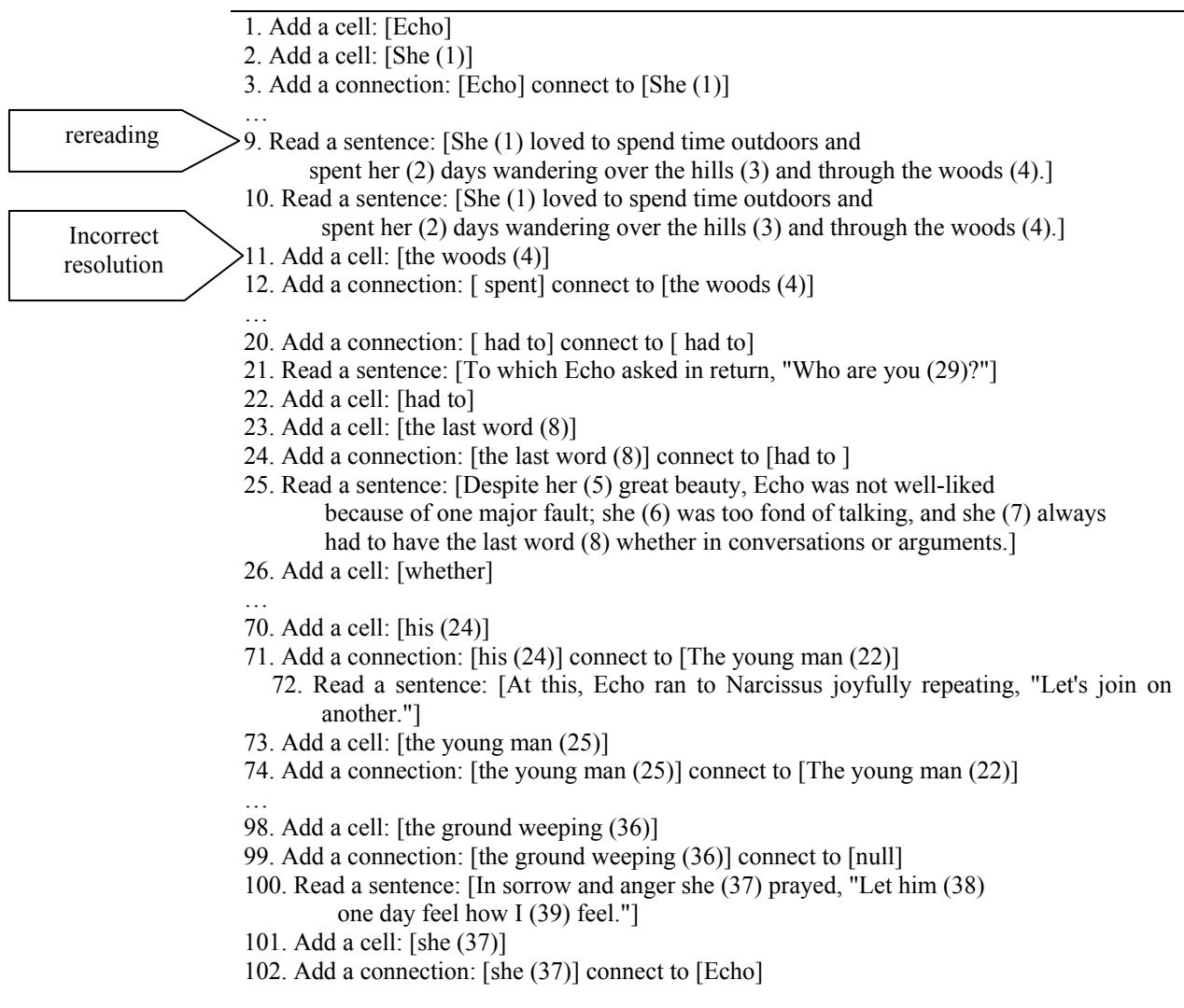


Figure 11. Trace result of a less-proficient participant

Comparing with the more-proficient participant's trace result shown in Figure 10, the less-proficient participant seldom asked for feedback. Although he did self-correction, he did not appropriately revise the incorrect referential resolution. After he read and reread the sentence (e.g., lines 9 and 10), he made a connection between "the woods"

and “spent” (e.g., lines 11 and 12). The difference between the two participants in their comprehension monitoring was that the more-proficient student went through the process of evaluation and revision successfully while the less-proficient student got stuck in these processes.

### Reading Product

The 90 participants’ correct percentage in referential resolution practice and reading comprehension test were shown in Figure 12. The full score of referential resolution practice in text 1 (*Freud and the Meaning of Dreams*) was 38; that of text 2 (*The Tragedy of Echo and Narcissus*) was 62; and that of text 3 (*Commerce Through the Internet*) was 21. As shown in Figure 12, students made progress in the practice of referential resolution as the percentages of correct resolution (the number of correct referential resolution/the total number of references) were 55 % (20.71/38), 70 % (43.42/62), and 69 % (14.47/21) in the three reading tasks. This was similar to their progress in reading comprehension tests as the percentage increased from 61 % (4.85/8) to 82 % (6.55/8) in three texts.

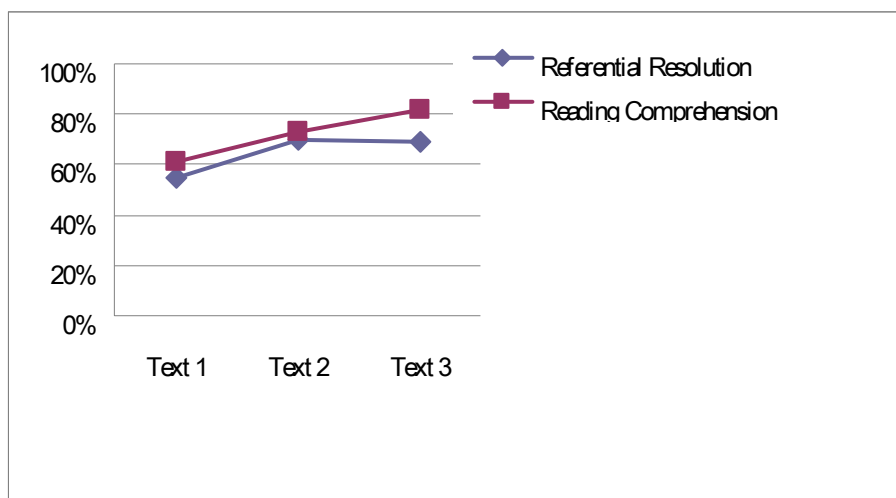


Figure 12. Students’ performance in referential resolution practice and reading comprehension test

As students made progress in referential resolution practice and reading comprehension test, they requested fewer feedbacks as the frequency of feedback dropped from 17.90 in text1, 13.61 in text2, to 7.67 in the final text. This suggested that students became more familiar with the task and more independent in resolving references.

Table 4 presents the result of the Pearson product-moment correlation coefficient between the referential resolution practice and the reading comprehension test.

Table 4. The correlation between referential resolution score and reading comprehension score

Number of participants	Pearson’s correlation		
	Text 1	Text 2	Text 3
90	.61	.67	.75

As shown in Table 4, the referential resolution score and the reading comprehension score had a positive correlation. When the participants got higher scores in referential resolution practice, their scores on reading comprehension test were also higher.

Thirty-eight more-proficient and thirty-seven less-proficient participants’ reading scores in referential resolution practice, frequency of feedback, and reading comprehension test are further shown in Table 5 with mean scores of the more-proficient readers on the left of the slash.

Table 5. The mean scores and standard deviation of the more- and less-proficient participants in referring, feedback, and reading comprehension test

	Text 1		Text 2		Text 3	
	mean	SD	mean	SD	mean	SD
Referring	22.30/16	8.39/ 8.45	46.6/32	10.90/ 17.94	16.14/4	3.82/ 3.46
Feedback	16.22/17.63	8.90/ 25.24	14.43/ 10	12.96/ 9.19	7.68/ 2.33	8.44/ .58
Reading Comprehension	5.86/ 2.63	1.01/ 1.60	6.57/ 4.20	1.21/ 2.17	7.14/ 2.33	1.55/ .58

According to Table 5, the more-proficient readers outperformed the less-proficient ones in referential resolution practice. Generally, the more-proficient students asked for more feedbacks than the less-proficient students. Both groups decreased their frequency in asking for feedback in three texts. Even though they decreased asking for feedback, they made progress in reading comprehension. That is, students became more independent and less relied on the feedback tool in three sequential reading tasks.

A *t*-Test was further conducted to examine whether there were significant differences between the more-proficient and the less-proficient readers in referential resolution, reading comprehension test, and frequency of feedback. The result showed that  $t(73) = 5.30, p < .05$  for the referential resolution practice between two groups. This result was similar to that of frequency of feedback and reading comprehension test. That is, the more- and less-proficient readers' mean scores in the referential resolution practice, frequency of feedback, and reading comprehension test were significantly different.

In addition, the performance of the two groups of participants in referential resolution practice and feedback was evaluated. Table 6 shows the correlation between feedback frequency and the number of errors and between feedback frequency and the number of missed references.

Table 6. The correlation between the number of errors and feedback frequency and the correlation between missed referents and feedback frequency

Readers	Text 1		Text 2		Text 3	
	Feedback/ Error	Feedback/ Missed	Feedback/ Error	Feedback/ Missed	Feedback/ Error	Feedback/ Missed
More-proficient readers	-.43	-.38	-.87	-.76	-.50	-.86
Less-proficient readers	.19	-.81	.14	-.62	.36	-.82

According to Table 6, the correlation between feedback frequency and the number of errors was negative for the more-proficient readers. That is, when they asked for more feedbacks, they made fewer errors. This was also true for the relationship between feedback frequency and the number of missed references. In contrast, the correlation between feedback frequency and the number of errors was positive for the less-proficient readers. The feedback tool was not very helpful for the less-proficient students. They did not actively ask for feedback and did not select the correct answers when the feedback provided clues.

## Discussion

The two research questions asked in the introduction section could be answered by the results of this study. First, in the mental representation of referential resolution practice, the more-proficient students were able to construct and integrate references in different parts of the text to form a coherent network while the less-proficient students often referred the references to incorrect or unrelated subjects. The more-proficient students paid more attention to the text elements they read. They often read and reread a sentence to make sure they really understood the sentence. They also used the feedback tool for help. After receiving the feedback, they were engaged in comprehension monitoring for self-correction, such as adding or cutting a text element. In contrast, the less-proficient students usually skipped

the sentence that they did not understand instead of asking for feedback. By examining students' mental representation of textual information and the records of their reading process, the reading teacher can further design appropriate lesson plans and classroom activities to assist the struggling students to overcome their difficulties and compensate their weaknesses. In other words, the mental maps and the *trace results* serve as guides for the reading teacher to design and plan follow-up remedial courses.

Second, students made progress in the online practice of referential resolution as the correctness of resolution increased from 55% to about 69% in three reading tasks. This was similar to their performance in reading comprehension tests as the correctness rate increased from 61% to 82% in the three texts. Further analysis indicated that the correlation between referential resolution and reading comprehension ranged from 61% to 75% in the texts. From these results, it was suggested that referential resolution was one of the essential skills to the enhancement of students' reading comprehension. This online reading system offered students abundant opportunities to practice referential resolution when they tried to understand the text. That is, the online practice of referential resolution could enhance students' reading comprehension. Without referential resolution, students might misunderstand a text to a greater extent.

Third, the *feedback tool* served as a scaffold for students when they encountered difficulties in establishing the relationships between words. It was only provided when the students requested them actively. Since text 1, text 2, and text 3 were presented to students sequentially, a comparison on the feedback frequencies for the three texts could show whether the students relied more, or less on the scaffolding tools as they worked on the texts. The results of this study showed that students gradually asked fewer feedbacks from text 1 to 3 as the mean of feedback frequency decreased from 17.90 to 7.67. In other words, students became more independent and relied less on the feedback in the three reading tasks. This implied that students could use "referential resolution" strategy in the follow-up reading activities.

In an open-ended questionnaire, fifty-one students, 22 more-proficient and 29 less-proficient students, expressed that the referential resolution task was more difficult in text 3 than it was in text 1 and 2. This confirmed the measurement of Flesch-Kincaid grade level of text 3 at the most difficult one, 11.5, among the three texts (see Table 3). In addition to the text difficulty, fourteen students revealed that they still had difficulties in figuring out the relationship between references after using the online system. This deserved more investigation in future study.

The result also indicated that the correlation between the number of errors and feedback frequency was negative for the more-proficient readers. That is, when they asked for more feedback, they made fewer errors. This was also true for the relationship between the number of missed references and feedback frequency. In contrast, the correlation between the number of errors and feedback frequency was positive for the less-proficient readers. They did not actively ask for feedback and seldom selected the correct answer when the feedback provided candidate references. The less-proficient students should be encouraged to ask for feedback when confronting difficulties in referential resolution.

Some limitations were found in this study. First, *trace result* could not reveal all details of the reading process that a reader went through in a text as he might read a sentence without clicking the mouse to select a sentence. This possibly made the process data incomplete in this study. Second, referential resolution could not indicate students' full comprehension of a text. In this study, students' reading comprehension was correlated to their performance on the referential resolution task. Other cohesive ties, such as lexical cohesion, conjunction, substitution, and ellipsis should be used to get a better understanding of students' text comprehension. Finally, the teacher's perception toward students' development of referential resolution should be further explored. An interview could be conducted in the future to investigate the teacher's perception of the impact of the system on students.

Some new help functions could be added to the system. First, after students have completed the referential resolution practice, the system should not only provide the results of grading but also the expert's mental map. This will help students compare their initial mental map with that of the expert. It will also assist them to reflect on their own reading process. The precision rate of the students' mental map should also be provided, so that the students' mental maps in referential resolution can be further analyzed by the students themselves. Through the analysis, students could learn from building connections of related words and make progress in reading comprehension.

Second, the sequential number of references should be removed from the texts and shown in students' mental maps of referential resolution only. This will help students concentrate on reading instead of tracking the numbers of references. Third, the three candidate references that the system provided should be categorized into personal, demonstrative, and locative references. This will help students identify the related references in figuring out their relationships. Finally, the reader-adapted check-points could be taken into consideration for the next implementation of the system. Students could be given more freedom in terms of the type and the number of texts they intend to read based on their specific needs. A reader's self-selected materials could also be adopted in the system that allows readers to set up their reading plan for a whole semester. Another consideration is to use the system for bonus credit purposes to motivate low achievers to use the system, rather than requiring the whole class to complete the same tasks. Individual learning styles and strategies should also be taken into consideration.

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## Appendix

Test items in an online reading comprehension test (text 2)

- 1) According to the passage, which is not Echo's characteristics?
  - (A) Talkative
  - (B) Beautiful
  - (C) Indifferent**
  - (D) Sensitive
- 2) Which of the following sentences is true?
  - (A) Narcissus was distracted by many women.
  - (B) Narcissus eventually fell in love with Echo.
  - (C) Narcissus loved Hera before.
  - (D) Narcissus eventually fell in love with himself.**
- 3) Why was Echo attracted to Narcissus?
  - (A) He has charming appearance.**
  - (B) He has a warm heart.
  - (C) He has mighty power.
  - (D) He has special odor.
- 4) How did Narcissus recognize his figure?
  - (A) through water**
  - (B) through a glass
  - (C) through many women's words
  - (D) through Echo's description
- 5) The word **consumed** in the passage has the closest meaning to
  - (A) earned
  - (B) learnt
  - (C) provided
  - (D) spent**
- 6) What will be the best title for this article?
  - (A) The honeymoon of Echo and Narcissus
  - (B) The tragedy of Echo and Narcissus**
  - (C) The competition of Hera and Echo
  - (D) The origin of Narcissus
- 7) The word withered away in the passage has the closest meaning to
  - (A) fade**
  - (B) bloomed
  - (C) made
  - (D) increased
- 8) According to the passage, the story is
  - (A) heroic
  - (B) martial
  - (C) grievous**
  - (D) joyous