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AUTHOR Kim, Myonghee

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ABSTRACT

Historically, in the educational field, numerous efforts have been made to facilitate the complex process of second language (L2) reading comprehension. While computers are increasingly being used for instruction for L2 reading, there is not yet a solid understanding of how this technology can be effectively used in the area of L2 reading instruction. This study examines the effect of the computer on developing L2 reading comprehension. To this end, the study reviews relevant empirical studies conducted both in L1 and L2 contexts. Although some studies reported contradictory findings, previous research has generally supported the notion that computer-assisted reading programs facilitate L2 reading comprehension. Several advantages of using the computer for enhancing reading comprehension have been identified, for example, facilitating automatic word recognition and vocabulary acquisition, providing multimedia glossing, strengthening the benefits of reading strategy training, and stimulating student motivation toward reading. The literature review also points out the need for reading software incorporating sound theoretical principles of the reading process. Reflecting the need, this study establishes practical guidelines for designing and evaluating reading software on the basis of interactive processing theory, which is currently one of the most prevalent reading theories. (Contains 49 references.) (Author)

The Use of the Computer in Developing L2 Reading Comprehension: Literature Review and its Implications

Myonghee Kim
Indiana University

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Abstract

Historically, in the educational field, numerous efforts have been made to facilitate the complex process of L2 reading comprehension. While computers are increasingly being used for instruction for L2 reading, there is not yet a solid understanding of how this technology can be effectively used in the area of L2 reading instruction. The present study examines the effect of the computer on developing L2 reading comprehension. To this end, this study reviews relevant empirical studies conducted both in L1 and L2 contexts. Although some studies reported contradictory findings, previous research has generally supported the notion that computer-assisted reading programs facilitate L2 reading comprehension. Several advantages of using the computer for enhancing reading comprehension have been identified, for example, facilitating automatic word recognition and vocabulary acquisition, providing multimedia glossing, strengthening the benefits of reading strategy training, and stimulating student motivation toward reading. The literature review also points out the need for reading software incorporating sound theoretical principles of the reading process. Reflecting the need, this study establishes practical guidelines for designing and evaluating reading software on the basis of interactive processing theory, which is currently one of the most prevalent reading theories.

The Use of the Computer in Developing L2 Reading Comprehension: Literature Review and its implications

I. Introduction

Research in first language (L1) and second language (L2) reading comprehension has gained impetus over the past three decades and resulted in many valuable insights for understanding the process of reading. In spite of its constant shift in focus throughout the history of reading research, it has been generally agreed that reading is a very complicated process involving a variety of factors that interact with one another. Chun & Plass (1997) claimed that this complexity is further compounded for L2 readers.

Historically, in the educational field, numerous efforts have been made to facilitate the complex process of L2 reading comprehension, incorporating the findings of research in the field. Based on a psycholinguistic model of reading, for example, Clarke and Silberstein (1977) convincingly argued for the need for instruction on reading strategies. In addition, pictures, videos, sound, and diagrams have been valued for their potential aid in the reading comprehension process by activating the schemata relevant to the story being read (Chun & Plass, 1996; Hanley, Herron, & Cole, 1995; Omaggio, 1979). More recently, since the advent of computers, increasing interest has been paid in the use of computers for developing reading comprehension skills. Some writers have even claimed that the incorporation of computer technology into the reading process may bring about a change in reading theory and reading practice (Wilkinson, 1983; Reinking, 1987). While computers are increasingly being used for instruction for L2 reading (Borchardt & Johnson, 1995), however, there is not yet a solid understanding of how this technology can be effectively used in the area of L2 reading instruction.

The purpose of this study is to examine the effect of the computer on developing L2 reading comprehension. For this purpose, two questions have been posed: 1) What studies have been conducted on the use of computers for improving reading comprehension? 2) What considerations should be taken in creating computer reading software? This study will first review relevant empirical studies conducted both in L1 and L2 contexts and then offer practical guidelines for designing and evaluating reading software on the basis of a reading theory and the literature review.

II. Conceptual Framework

Reading research has greatly aided in understanding reading comprehension processes, which in turn can significantly contribute to the actual reading instruction. Understanding an adequate theory of reading comprehension is a prerequisite for the development and improvement of educational practices. In line with this, it is important that computer-based reading programs should also be designed and implemented in such a way that they reflect current knowledge about the reading process in terms of how to teach reading and what to focus on in order to maximize their effectiveness (Singhal, 1998).

This section will describe a current theoretical view of L2 reading comprehension as a conceptual framework for critically evaluating studies and programs that will be reviewed in this study and for presenting practical guidelines for selecting and designing theoretically grounded, empirically validated reading software.

One of the current prevalent views of reading is interactive processing theory (Samuels & Kamil, 1984; Silberstein, 1987; Swaffar, Arens, & Byrnes, 1991). The term, *interactive processing*, refers to two different conceptions. First, it can refer to the

interaction that happens between the reader and the text. In other words, reading is the process in which the reader intelligently interacts with the text to comprehend it. While interacting with the text, the reader builds the text information with the help of the knowledge gained from the text and the background or prior knowledge he or she already has (Barnett, 1989; Carrell & Eisterhold, 1983).

Second, it can also refer to the interaction among many reading component skills. To be more specific, reading is the result of the simultaneous, not sequential, interaction between lower-level, bottom-up processing skills and higher-level, top-down processing skills (Carrell, 1988b, Eskey, 1986, Eskey & Grabe, 1988; Sameuls & Kamil, 1984). Bottom-up processing is primarily concerned with textual decoding and requires such skills as word recognition, vocabulary knowledge, and knowledge of sentence structure. Automaticity in lower-level processing has been shown to contribute importantly to fluent reading. On the other hand, top-down processing is more related to the macro level of comprehension, interpretation and use of prior knowledge. Research has shown that good readers skillfully use higher-level reading strategies which facilitate reading comprehension, such as inferring the meaning of unfamiliar words, phrases, and expressions through the contextual clues, predicting what will come next, and mobilizing background or prior knowledge. Due to its ability to describe how input is processed in a meaningful, convincing way, the interactive processing theory has been widely applied to the area of reading instruction.

Interestingly enough, most L2 researchers stress the first type of interaction between the reader and the text while most cognitive psychologists and education psychologists emphasize the second one, interaction of diverse reading skills. However,

these two perspectives are not mutually exclusive, but complementary (Grabe, 1991). Grabe explained that this division largely results from the difference in emphasis placed on defining how reading processes interact and how the processes can be investigated through research. To sum up, interactive processing theory views reading as interactive in that the reader makes use of information from his/her background knowledge as well as information from the printed page while reading. Reading is also interactive in the sense that many skills work together simultaneously in the process.

III. Literature Review

A vast majority of studies on the use of computers for developing reading comprehension have been conducted in the L1 context. Considering the current situation, this literature review will include the research conducted in L1 environments to offer readers a broader, concrete understanding of what has been accomplished in this field and to aid them in applying valuable insights gained from L1 research to L2 situations. Mostly for the studies conducted in L2 contexts, the literature review will also entail a critical evaluation of the studies in terms of study design and the computer programs used to make a more valid assessment of the effectiveness of the computer as a medium for L2 reading instruction

Using computers for reading instruction dates back to the mid-1960s when broad-scaled projects such as the Stanford Project, which were often supported by U.S. federal grants, were carried out to develop a comprehensive computer-based reading curriculum. For example, the reading curriculum which the Stanford Project produced for kindergarteners through third graders was characterized by utilizing centrally located mainframe computers, eliminating the need for a classroom teacher, and computer-

assisted instruction focused on individual reading skills including word attack skills. With respect to the Stanford project, Spache (1967) raised the issues that it ignored the role of the teacher and overemphasized the mastery of isolated skills in a drill-and-practice format.

Since then, widespread availability of microcomputers has made possible research on the effect of specific computer programs on reading ability. Several studies, for instance, have been conducted to examine the effect of using the computer on developing reading readiness skills. Gore, Morrison, Maas, and Anderson (1989) conducted a study with 14 five-year-old children for five months to determine whether the computer can serve to teach preschoolers pre-reading skills. Analysis of the Metropolitan Readiness pre- and posttest revealed that there were significant differences in the scores in the pre-reading skill areas of rhyming skill related to learning phonics for decoding and school language related to sequencing, organization and word meaning. On the other hand, no differences existed in the areas of letter recognition and visual matching. In spite of the mixed results, the researchers claimed that computers can be used effectively to teach preschoolers some important pre-reading skills.

In the studies of elementary and junior high school students on the effectiveness of computer-assisted instruction, findings have been mixed. In a study undertaken to determine the effect of extended use of computers on reading achievement of the students of low socio-economic status, Arroyo (1992) found significantly higher reading achievement gains on the IOWA Tests of Basic Skills for 30 seventh graders who were exposed to extensive computer instruction for a year compared with nonusers. She suggested that in addition to reading improvement, computer-assisted instruction

enhanced student motivation toward learning. But it is questionable whether the mere exposure to general computer instruction not specifically related to reading instruction could truly contribute to improvement in reading comprehension. On the other hand, a study by Hamilton (1995) of 46 third- through sixth-grade students reported no significant differences between the computer-assisted instruction group and the traditional basal instruction group. But both studies did not provide sufficient information on what specific computer-assisted reading instruction was given to students. Besides, the results have limited generalizability, due to the small sample size.

Serious efforts were made to improve reading comprehension and vocabulary knowledge through the use of computer software and teaching reading strategies in Illinois. After analyzing the possible causes of the problem of declining reading scores among elementary and middle school students, Lange, McCarty, Norman and Upchurch (1999) designed a reading intervention program composed of three major categories: instruction of reading strategies through using graphic organizers and cooperative learning, use of appropriate software matching the strategies, and integration of reading strategies into other subject areas. After receiving reading instruction integrating reading strategies with computer technology for five months, students showed improvement in both overall reading scores and specific reading skills on a standardized test. And the data of interview with teachers and students as well as case studies of four students revealed that learning multiple reading strategies helped students transfer the reading skills to other subject areas. The value of this intervention program used in this study lies in the fact that an attempt was actually made to incorporate the findings of the

research regarding the crucial importance of reading strategies and their training into classroom practices.

As recent developments in computer technologies have led to the appearance of CD-ROM, many studies have involved comparing the effect of electronic CD-ROM storybooks with that of conventional paper storybooks on reading comprehension. In a study designed by Greenlee-Moore and Smith (1994) to determine the effects of interactive CD-ROM software on reading comprehension, an experimental class composed of 14 fourth graders read seven CD-ROM books and a control class composed of 17 students read the same narratives from the actual books over an eight-week period. A comparison of the performance of the two groups on six multiple-choice questions for each book revealed that whereas there were no significant differences between the two groups when they read the short and easy texts, the computer group earned higher scores for the longer and difficult narratives. The researcher claimed that textual manipulations of the interactive CD-ROM software, such as a click of words for pronunciation and explanation, could account for the higher scores for difficult texts. However, a question remains of why the same characteristic is not applicable to reading easy texts. In addition, it is questionable whether only six multiple-choice comprehension questions, two of which are literal, one vocabulary, and three inferential questions, can serve as a true indicator of overall comprehension of the texts.

Another major category of studies was on the effect of computer programs on students with reading difficulties. Due to its great potential for providing reading supports including glossing, visual and audio supports, and speech supports, computer software has been credited as an effective tool for teaching reading to students who suffer

from reading difficulties. And in fact several efficacy studies have reported the positive results for the effectiveness of the computer as a means of developing literacy skills in struggling readers. Reasoning from their previous studies that lack of word recognition skills is a primary factor of the struggling readers' problems, Wise and Olson (1994) conducted a study with 45 struggling readers in second through sixth grade to examine whether or not the talking computer can help them to develop word recognition and phonological decoding skills. Students read stories on the computer for thirty minutes for four to five days per week for 10 weeks, having access to pronunciation of unfamiliar words they encountered in the text through the computer's speech synthesizer. Results in pre- and post tests on word recognition, non-word reading, spelling, reading comprehension, and phonemic awareness revealed that the children's word recognition and phonological decoding abilities improved significantly, compared with similar students who were assigned to regular classroom language arts instruction. This result is consistent with the findings of other studies on the effect of the computer on increasing word recognition skills (McKenna, Reinking, Labbo, and Watkins, 1996). The researchers also reported the students' improved attitude toward reading and enthusiastic responses toward the computer-assisted program. However, no information was included in this study on the results of reading comprehension tests, which makes it possible to determine whether the increased word recognition in fact affected the improvement in reading ability.

The research attempts described thus far were exclusively for L1 reading. Only during the past two decades have studies on the use of computers in the field of teaching L2 reading been increasing (AlKanhtani, & Abalhassan 1999). Included among them are

a couple of studies with ESL learners. In a study conducted to investigate the effects of a computer-assisted instruction program on basic reading skills achievement and attitudes toward it, Saracho (1982) compared the performance of two groups of 256 Spanish-speaking migrant children in third through sixth grade. The control group participated in regular classroom instruction, while the experimental group received computer assisted instruction as well as the regular instruction for five months. Based on the scores on Comprehensive Tests of Basic Skills, Saracho claimed that students in the computer group gained higher achievement than those in the control group. However, this study has serious methodological flaws in that it failed to fully control the variables that might explain the difference between the two groups. That is, the experimental group was administered additional instruction through the computer as well as conventional instruction, whereas the counterpart group received only classroom instruction. In this case, it can be claimed that the improvement in reading performance might result from the additive effects of additional instruction, not from the computer instruction. Stricter control of such a variable would increase the validity of the study.

In an evaluation report of a 3-year project to use computers to improve reading skills of third to sixth grade Lakota Indian students with limited English proficiency, Edeburn and Jacobi (1984) reported that students failed to reach the objective as measured by pre- and post-tests on the Comprehensive Tests of Basic Skills. With regard to the research, Kleinmann (1987) argued that this report was incomplete in that it did not contain sufficient information on the characteristics of the program and materials and how they were used.

Several studies involved actual implementation of computer assisted reading programs in a college reading course. In order to determine whether the introduction of computer software into a college reading course has beneficial effects on reading achievement, Kleinmann (1987) conducted a study with 76 ESL college students enrolled in a basic skills college reading course over a semester. In this study, both experimental groups and control groups received two hours of conventional lectures on reading and one hour of individualized reading instruction in the reading laboratory for fourteen weeks. The only difference was that whereas control groups used traditional reading materials such as reading selections from the humanities and social sciences, ESL materials, and exercises on vocabulary and reading skills in the reading laboratory, experimental groups could get access to not only reading materials available to control groups but also reading software packages for every other week, i.e. six hours all told. The pre- and posttest results found no significant differences in the score gains between the experimental and control groups. Kleinmann attributed the results to the poor software programs used, most of which took a drill-practice format based on a behavioristic theory of language learning. He portrayed them as little more than electronic textbooks. Significantly enough, he strongly argued that it is important to create more innovative reading software programs that foster more interaction between a student and the computer and provide activities for enhancing reading comprehension skills and strategies based on a solid understanding of L2 reading. Regarding the limitations of this study, insufficient treatment time should be mentioned. Merely six hours of exposure to reading software is not long enough to make a valid judgment of its effect. In addition, no information was provided on what kind of software students used

most, what content the software is composed of, and what students actually did with it. At any rate, however, this study succeeded in alerting language educators to the significant role of high quality software designed in harmony of theoretical principles and methodological insights of L2 reading.

Krasilnikov (1989) reported a course developed in Russia to improve reading skills in English through the use of computers. The course integrated nine computer programs designed to offer exercises in specific reading skills including word recognition and word comprehension, recognition of word boundaries and sentence structures, vocabulary development, recognition of the devices used to create textual cohesion, skimming and scanning skills, and reading for global understanding. The activities in the programs addressed both bottom-up (e.g. textual decoding) and top-down reading approaches (e.g. interpretation, comprehension), which largely took an isolated drill and practice format. Unfortunately, however, no information on the actual effects of the programs was provided in this report.

Several studies in the use of computers for reading have been undertaken using languages other than English. For instance, Aweiss (1994) conducted a study to examine the effects of varying types of computer-mediated reading annotations on the reading comprehension of beginning learners of Arabic as a foreign language (AFL). 24 American AFL students were exposed to four conditions for four different experimental electronic texts:1) text only, 2) text with glossary, 3) text with glossary and verb conjugation, and 4) text with glossary, verb conjugation and background information about the text. Analysis of the relationship between the scores of immediate recall protocol and the number and type of reading supports accessed revealed that readers with

access to reading supports showed better performance on the comprehension test than when no reading supports were provided. And the glossary was identified as the most frequently used reading support in the study. However, with regard to the immediate recall protocol test in which subjects were required to write everything they could remember about the text in their first language, it was claimed that recall protocol was like a memory test used simply to recall information rather than reveal global understanding of the text. And use of four different groups for the four conditions instead of using one group for all four conditions would greatly enhance the generalizability of the findings of this study.

A number of more recent studies have attempted to investigate the effects of multimedia annotations on reading comprehension. The studies mostly used computer programs with different types of reading supports such as annotations of individual words, visual supports, and information on the text. Lomicka (1998) undertook a pilot study with 12 college students enrolled in a French course to explore the effect of three different types of multimedia annotations on reading comprehension: no glossing, limited glossing (definitions in French; translations in English), or full glossing (definitions in French; images, questions, pronunciation, and translation in English). Students were asked to think aloud which glosses they were using, why, and what their understanding of each line was while they read text. And a tracker was set up to keep record of the type of glosses used and the amount of time they spent consulting each gloss. Based on the analysis of "think aloud" data and tracker data, Lomicka suggested that computerized reading with full glossing including question glosses and reference glosses promoted a deeper level of text comprehension.

A study by Chun and Plass (1996) produced results consistent with Lomika's. Chun and Plass (1996) conducted three sub-studies with a total of 160 second year university students enrolled in a German course using a multimedia application which incorporated the interactive processing theory of reading. This reading theory views reading as a combination of lower-level, bottom-up processing skills such as word identification and decoding, and higher-level, top-down comprehension skills such as inference and interpretation. The purpose of the study was to examine the effects of a visual advance organizer on the macro level and different modes of multimedia annotations of vocabulary items on the micro level. On the basis of the analysis of the recall protocol completed by students in their first language, the researchers claimed that the visual advance organizer aids in overall reading comprehension by providing background and contextual knowledge for text comprehension. As to the effect of annotation on reading comprehension, the result revealed that words annotated with both text and video help comprehension better than those annotated only in one form or not at all. Chun and Plass claimed that the results supported the dual coding theory (Paivio, 1971, 1986) that two different storage systems for information (a verbal and a nonverbal system) make additive effects possible if information is coded dually. The greatest value of this study lies in the fact that it attempted to investigate the effect of multimedia reading software that reflects a well-accepted current reading theory that stresses the interactive process of reading. In addition to the problem concerning the use of recall protocol as in Aweiss' study, however, this study has a couple of limitations. First, the absence of a control group weakened the research findings. That is, a comparison of an experimental group who used the reading software and a control group working with the

printed text with the similar reading supports would strengthen the findings of the study. Second, insufficient information was given on to what extent students accessed the annotations, which is necessary to determine the effectiveness of the annotations accessible.

Lyman-Hager, Davis, and Chennault (1993) investigated the relationship between student glossing choices and vocabulary acquisition with intermediate level students studying French with the multimedia program designed for an excerpt from a French story. The rationale behind this study is that vocabulary knowledge is critical for successful reading comprehension. Based on a written recall protocol and vocabulary quiz, the researchers claimed that students who had access to multimedia annotations in computerized text learned more vocabulary words than students who could consult the same glosses in printed text. In view of the current reading theory, this study appeared to have overemphasized the role of vocabulary knowledge in reading comprehension, with a focus on the bottom-up approach. Regarding the rationale, it can be claimed that though the reader succeeded in recalling words, he or she may not understand the text globally.

Davis and Lyman-Hager (1997) undertook a study with 42 college students of French to examine how they interact with a computerized L2 reading glossing and to determine the relationship between the use of glossing and reading comprehension. While interactive reading theory was integrated into the multimedia reading software developed by Chun and Plass for their study, Davis and Lyman-Hager used Bernhardt's reading model to design a computer reading program that provided appropriate multimedia annotations for six factors that Bernhardt claimed constitute the L2 reading process: 1) word definitions (word recognition), 2) pronunciation (phonemic/graphic

errors), 3) grammatical explanation (grammar), 4) explanation of linking statements and ideas (intratextual perception), 5) cultural information (cultural references), and 6) built-in tracker device for gathering information on students' strategy use (metacognition). In the study, students first briefly read a short French story in a printed form, then read a computerized version with multimedia annotations and finally completed a recall protocol and a multiple-choice test. Results indicated that there were no observable relationships between the number of times reading supports were accessed and reading comprehension. Besides, it was found that students consulted the English definitions category most frequently, though different types of annotations were available to students, which is in agreement with the findings of the study by Aweiss. But the results of exit interviews showed that students showed a unanimously positive attitude toward the effectiveness of the computer reading program. Like the study by Chun and Plass, this study has a great value in that it attempted to carefully apply one of the prevalent theoretical views of the reading process to a computer instructional program. However, the fact that students primarily turned to the reading support of word definition in spite of the availability of other supports implies that additional efforts should be made to make students fully utilize the other choices to maximize reading comprehension. This study has a weakness in its design concerning the absence of a control group. A meaningful answer to the research questions posed would require a comparison of an experimental group and a control group who read a story in the printed form or a computerized story without any annotations.

In a study on the effect of individual learning preferences such as visualizer vs. verbalizer preference on L2 reading comprehension in multimedia environments, Plass,

Chun, Mayer, and Leutner (1998) found a significant interaction among learning preferences, annotation type, and text comprehension. On the basis of an analysis of learning preferences for visual and verbal information in multimedia learning settings, 103 college students enrolled in German language courses were classified as visualizers that prefer to learn from the visual modes of the presented material, as verbalizers that prefer to learn from verbal options, and as showing no strong preferences. In two 50-min class periods on 2 consecutive days, the students had access to a multimedia program presenting a German short story in which for 82 words a translation with pronunciation was available to them along with its corresponding picture or the video. On the vocabulary test, the students were asked to report which annotation type of the three came to their mind first when they saw the vocabulary word as well. And for the comprehension test, they were instructed to write a summary of the story in English. The result of the study demonstrated that visualizers performed better when both verbal and visual information was available, whereas verbalizers benefited more from verbal information. Thus the researchers concluded that multimedia reading programs that can offer readers chances to select their preferred mode from both options have a great potential to address individual differences in visual and verbal preferences. They tried to provide a rationale for the effectiveness of multimedia reading programs by saying that they skillfully address individual learning differences.

Most studies on the effects of multimedia annotations on L2 reading comprehension have produced positive results as shown by higher score gains in reading comprehension tests. However, the gains in reading achievement can be explained by the immediate availability of annotations for the text being read. Obviously multimedia

annotations provided for a text can facilitate the comprehension of the given text, but it is not certain whether students have in fact received any benefits from the use of annotations in relation to reading skills which can be applied to different reading contexts.

IV. Summary of Literature Review

It is clear from the literature review that various studies have been conducted to assess the effectiveness of the use of computers for improving reading comprehension. Although some studies reported contradictory findings, previous research has generally supported the notion that computer-assisted reading programs facilitate L2 reading comprehension. Several advantages of using the computer for enhancing reading comprehension have been identified. For example, multimedia glossing offered in reading software aids readers in acquiring vocabulary and comprehending the text more effectively, especially through addressing individual learning preferences. Use of reading software can enhance automaticity in word recognition and reinforce the benefits of reading skill instruction. In addition, it can stimulate student motivation and encourage a more positive attitude toward reading. However, partly due to the limitations of many studies such as small sample size, insufficient treatment time, absence of a control group, and use of immediate recall protocol as a measurement tool, caution is needed in measuring the truly reliable pedagogical value of using computers for developing L2 reading comprehension until more convincing research findings in this area are available.

With respect to computer software programs, it is worthwhile to mention that not many computer programs used in the reviewed studies incorporated well-founded

theoretical principles of reading and appropriate practices in reading skills. And it is a fact that much reading software has been criticized for its poor quality due to lack of theoretical foundations (Balajthy, 1995; Reinking, 1989). Considering the importance of theoretical principles as a guide to educational practices, it is important that reading software be designed based on knowledge of reading process. This claim can be strengthened by the critical role of the software in the success of computer-assisted reading instruction.

The following section of this study will offer a set of guidelines for creating and evaluating computer reading software on the basis of reading theory. For establishing guidelines, the interactive processing theory of reading is employed as a conceptual framework. In addition to the reading theory, careful consideration will be taken of research findings for devising more valid, effective guidelines.

V. Guidelines for Creating Reading Software

As described earlier, the interactive processing theory of reading adopted as the conceptual framework for this study views reading as interactive in that the reader intelligently interacts with the text to make sense out of it and also in that many reading component skills involved in bottom-up and top-down processing interact with one another simultaneously while the reader is reading the text.

In order to cover the full range of the reading theory, this study establishes two main frameworks reflecting the two types of interaction specified by the theory: interaction between the reader and the text, and interaction between bottom-up processing and top-down processing. And individual, specific guidelines relevant to either framework are built and presented in detail along with an example of exercises. Based on

the major claims of the theory and empirical findings, these guidelines put an emphasis on promoting interaction between the reader and the computer, integrating decoding skills and comprehension skills, and providing relevant activities as a means of developing reading skills.

1. Interaction between the reader and the computer

One of the potential benefits of the computer for reading is the opportunity for increased interaction between the reader and the text on the computer. Interactive capabilities of the computer have been recognized as an effective tool to make reading less frustrating and more enjoyable (McKenna et al., 1996). In order to maximize reading achievement in computer-assisted reading environments, these capabilities must be taken full advantage of in developing software programs.

a) Provides individual supports such as multimedia annotations:

Reading software can provide useful glossing, such as definitions of key words in both visual and verbal forms, their pronunciation, and grammar explanation. Easy availability of glossing can help readers move through the text when they face comprehension problems and explore the supporting materials at an individualized pace.

b) Presents open-ended questions as well as well-designed true/false questions:

In order for the interaction between the reader and the text to be meaningful, computer reading programs should contain open-ended questions instead of heavily relying on true/false or multiple-choice questions. Open-ended questions entail more interaction by responding to reader's answers in an individual way. For both types of questions, software can provide the reader with hints or clues to work with to help them to get the correct answer before the correct answer is given.

c) Provides immediate and adequate feedback on reader's responses:

Reading software should provide immediate feedback on answers the reader gives in response to the questions presented by the computer. Feedback should be relevant to the responses and provided in such a way that promotes interactivity and refines the reader's comprehension of the text.

d) Keeps record of individual students' performance and progress:

Recent technological developments make it possible to build a tracker system in reading software to keep record of the type and frequency of the access the reader has to glosses and the performances. By looking at the records kept by the computer, both the reader and the teacher can assess the student's current level of L2 reading, diagnose his or her problems in reading and take proper steps toward enhancing L2 reading comprehension.

e) Provides a timed reading option:

Through the option of timed reading, the reader selects the speed with which he or she wants to read. The reader can increase or decrease the speed depending on the current competence and comfort level. Timed reading is also a good means of furthering the interaction between the reader and the text on the computer.

2. Interaction between bottom-up processing and top-down processing

Considering the fact that the reader is simultaneously engaged in bottom-up and top-down processing for reading comprehension, reading software programs should be focused on simultaneously addressing decoding skills and comprehension skills in order to teach both types of skills. To this end, software programs should provide the reader with opportunities for practice in reading skills and strategies that are critical for

successful reading comprehension. Provision of a variety of relevant activities embedded in reading texts is recommendable.

a) Enhances word recognition skills:

As described earlier, interactive processing theory postulates that textual decoding constitutes a major part of the information processing involved in reading. And textual decoding requires automatic word identification which is widely recognized as one of the crucial components of reading. With respect to the role of word recognition skill in reading, much research shows that fluent readers have fully developed automaticity in word recognition, whereas unskilled readers lack this skill. Reflecting the obvious need for developing the word recognition skill, reading software programs should offer exercises designed for this purpose. For example, word recognition exercises can engage the reader in reading several words that are similar in shape and marking the same word as the first one as quickly as possible (e.g. word: work, worm, world, word, ward). Or the reader can be asked to draw a line between the boundaries of a nonsense word composed of several words without any interval (e.g. aboyiswalkingtowardtheschool).

b) Promotes sentence-decoding skills:

Knowledge of sentence or language structure also plays a significant role in reading processes. Many studies support the effect of knowledge of structure on fluent reading (Garnham, 1985; Perfetti, 1989; Rayner, 1990). Considering the role of knowledge of sentence structure, reading software should present sentence-decoding activities. Sentence-decoding exercises can involve the reader in reading a sentence in meaningful units. To be more specific, computer programs should be designed to model reading in meaningful groups and ask the reader to divide a sentence into meaningful units quickly

while reading. These exercises help the reader not only to enhance sentence-decoding skills but also to overcome the tendency toward word-by-word reading.

c) Promotes vocabulary development:

Almost every L2 reading researcher agrees that vocabulary knowledge is a critical element of reading comprehension (Grabe, 1991). Vocabulary building activities should be set within the context of a reading passage. Contextualized vocabulary exercises facilitate word acquisition and retention more effectively.

d) Builds background knowledge about the text:

A large number of research findings support the significant role of background knowledge in reading. To facilitate reading comprehension, reading software should aid in building background knowledge about the topic of the text prior to reading. Pre-reading activities designed to create background knowledge include looking at or reading an advance organizer in the form of video or short reading abstracts. Questions can also be used to activate the reader's prior knowledge of the text during reading.

e) Prompts students to guess, inference, and predict while reading:

Successful reading requires the knowledge and implementation of higher-level, reading skills such as guessing, inferring, and prediction and thus computer programs must be designed in a way that addresses them. Studies have shown that training in reading strategies including the skills described can contribute to enhancing reading comprehension (Jimenez & Gamez, 1996; Kern, 1989). Exercises should be designed to offer students opportunities to practice drawing inferences or making predictions based on clues, hints, and contextual information. Such activities can take the form of problem-solving games, simulations, cloze exercises or text reconstruction exercises.

f) Encourages readers to read for main ideas:

Reading an L2 text requires going beyond understanding an individual word or sentence to constructing main ideas from the text. Activities can include reading instructions on getting general meaning of the text and answering questions presented by the computer.

VI. Conclusion

This study aimed to investigate the effect of the computer on developing L2 reading comprehension. A review of relevant literature revealed that the use of the computer has a beneficial effect on enhancing L2 reading particularly by facilitating automatic word recognition, and vocabulary acquisition, providing multimedia glossing, strengthening the benefits of reading strategy training, and stimulating student motivation toward reading. On the other hand, the literature review also pointed out the need for designing reading software incorporating sound theoretical principles of the reading process. Reflecting on the need, this study attempted to establish guidelines for creating and evaluating computer reading software programs using the interactive processing theory of reading as a conceptual framework and also empirical findings. These guidelines, however, are not comprehensive in that they were devised only from the perspective of interactive processing theory. It is true that there are other considerations in evaluating reading software, such as text style, fonts, graphic features, and ease of use, which is beyond the scope of this paper. It is hoped that the guidelines will assist language instructors and software developers in developing an awareness of the need for theoretically grounded and empirically validated reading software.

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