An Individualized e-Reading System Developed Based on Multi-representations Approach

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ABSTRACT

Students with disabilities encounter many difficulties in learning activities, especially in reading. To help them participate in reading activities more effectively, this study proposed an integrated reading support system based on the principle of multiple representations. An integrated e-reading support system provides physical, sensory, and cognitive support to learners. This system also served as the convenient interface for material developers and instructors. The results of usability evaluation also demonstrated the interface of learner to be friendly and efficient. Thirty fifth- and sixth-grade students with learning disabilities in Taiwan participated in the experiment to explore if this e-reading system could help them to understand natural-science articles. All students read the articles on the e-reading system, with and without cognitive support. The results indicated better comprehension performance when the participants read with cognitive support.

Keywords

Reading difficulties, Cognitive support, Multiple representations, Individualized reading system, Students with disabilities

Introduction

Reading skill is essential to a successful learning activity. However, without any help, it is difficult for learners with special needs to read effectively due to their limitations or disabilities, such as dyslexia, intellectual disability, visual impairment, visual perception difficulties, or palsy. Such disabilities prevent these students from meeting the challenge of the general curriculum (Bender, 2004; Lerner, 2006; Mastropieri & Scruggs, 2002). Therefore, remediating the deficiencies of reading and improving the reading skills, including word recognition and reading comprehension, has been one of the major services provided by schools. Recent studies have supported various effective strategies, such as word-recognition instruction methods (Browder, Spooner, Wakeman, Trela, & Baker, 2006; Hung & Huang, 2006; Van der Bijl, Alant, & Lloyd, 2006), reciprocal teaching (Ledere, 2000; Palinscar & Brown, 1984), and drawing concept maps (Chang, Sung, & Chen, 2002; Guastello, Beasley, & Sinatra, 2000). Though effective, these strategies, however, remain inadequate for certain disabled users. Therefore, researchers explored alternative solutions that would allow users to bypass their disabilities or augment their residual capabilities (Lewis, 1993).

To help special needs students access the reading material, typical assistive technology devices are provided, for example, e-readers, screen-magnifying software, and adaptive computer devices. Popular e-readers, e.g. WYNN Literacy Software Solution and Kurzweil 3000, could read the text for the poor readers. Screen-magnifying software can help people with low vision read electronic texts by enlarging the characters. A switch equipped with a scanning program allows people with severe motor impairment to read the electronic texts (Alliance for Technology Access, 2004). However effective these methods may be, they are of little use for the cognitively challenged, especially for those lacking lexical knowledge. Therefore, these students need extra cognitive support to comprehend the articles (Rose & Meyer, 2002). Extra support should include the following: presenting important concepts with pictures, audios, and videos; or teaching students to read concept maps instead of drawing.

In addition to accessible support, such as adjustable font size and color and having someone read the text aloud to them, individuals facing reading difficulties need extra cognitive support. Bottom-up and top-down are two approaches for providing cognitive support based on the reading models (Rose & Meyer, 2002). The bottom-up approach provides supports to the specific word in order to compensate readers’ limitations in decoding and accessing lexical meaning; the top-down approach provides holistic maps and enhances understanding of the text. The supports of the bottom-up approach include pictures, speeches, texts, and videos for key words; adjusting attribution of text; and supplying alternative representations for the text. Earlier studies demonstrated the effect of
narration, speech, and animation on minimizing the difficulties of decoding and concentrating on the meaning of the text for the learners (Matthew, 1997; Miller, Blackstock, & Miller, 1994).

The top-down approach provides concept maps, text summarization, and background knowledge. Potelle and Rouet (2003) compared different types of content representation devices in comprehending an expository hypertext in French for 47 undergraduates. The study indicated that the hierarchical map improved comprehension for low-knowledge participants. The summarization improves comprehension by allowing readers to quickly grasp a document or preview its content (Foulds & Camacho, 2003).

Reading activity is not only a cognitive process, but also a process of motor control and visual perception. In fact, a learner should overcome three major barriers — physical, sensory and cognitive — barriers to participate in reading activities (Cook & Polgar, 2008). Thus, besides cognitive support, a learner with special needs also needs physical and sensory support. The belief description is below:

**Physical Access.** People with poor postural position and motor control need devices to help them maintain their body in a proper posture so that they can manipulate items appropriately. In addition, they need to be equipped with supporting devices, such as arm and wrist support systems, and have alternative access solutions, such as a mouse equipped with switches or joysticks or an infrared mouse, to navigate electronic texts and to interact with computers. While users equipped with adaptive computer devices interact with computers, they usually have to make some adjustments to the interface, such as larger icons and navigation bars, longer intervals between double clicks, and larger spaces between words and lines.

**Sensory Access.** The following adjustments are essential to reducing the impact of sensory difficulties for visually impaired learners: flexible interface design; enlarged font size; a font color that contrasts with the background; refreshable Braille display or a screen reader that can transfer text on demand; suitable typesetting with the adjusted space between characters, words, and paragraphs; and foreground and background colors (LoPresti, Mihailidis, & Kirsch, 2004).

**Cognitive Access.** Cognitive access is the core process of reading. Past experiments presented some useful strategies: marking the keywords or important ideas in the articles; reading selected text aloud; and providing an electronic dictionary, a picture symbols assistant, and a concept map (LoPresti et al., 2004). Since pictures could sometimes represent concepts more concretely than text would, they are a good assistant to reading comprehension, even for the readers with cognitive disabilities (Chen, Wu, Lin, Tasi, & Chen, 2009). Concept mapping is a kind of visualized learning strategy that could help the readers understand what they read by extracting and visualizing the key concepts from the text (Chang et al., 2002).

Though the above-mentioned strategies were proven effective by past studies, existing assistive reading software could only offer separate strategies (Chu, Li, & Chen, 2002; LoPresti et al., 2004). There has been no integrated system that can simultaneously provide physical, sensory, and cognitive access and none has especially focused on Mandarin learners with cognitive disabilities.

Four important aspects must be considered when developing a flexible, accessible, and supportive reading environment:

1. removing the three major reading barriers: physical, sensory, and cognitive.
2. providing support suited to individual needs. For example, text description of a key concept is necessary for a reader with good decoding capability but without concept knowledge; however, such support can’t help a dyslexic reader.
3. keeping learning material challenging while providing support. For instance, although reading the text aloud is useful for a reader with comprehension difficulties, it will diminish the original purpose of a remedy reading program.
4. reducing professionals’ workload. Although the e-learning environment allows variety in the representation of text and flexibility of the cognitive support (LoPresti et al., 2004; Rose & Meyer, 2002), certain cognitive support, such as concept maps and précis, still need to be developed by curriculum professionals. Accommodations on a case-by-case and lesson-by-lesson basis often overwhelm professionals. It would greatly ease their workload if a system in which individualized supports provided across lessons were to be developed.
Interestingly, the Universal Design for Learning (UDL), advocated by Center for Applied Special Technology (CAST), could offer thoughts that address the above-mentioned considerations. UDL consists of three principles: multi-representations, multi-engagements, and multi-expressions (Rose & Meyer, 2002). The principle of multi-representations emphasizes that learning material should be displayed in multiple representations and provide flexible cognitive supports responding to users’ needs. The principle of multi-engagements stresses that learners should participate in learning activities and interact with the material their own way. The principle of multi-expressions emphasizes that learners demonstrate their learning outcomes through multiple methods. In addition, CAST believes that affectivity has great impact on learners’ engagement. Past studies indicate that giving choices to learners can encourage and motivate them to participate in learning activities (Kim & Wei, 2010). Because accessible and supportive learning material is the keystone of creating UDL, it is noted that only when the material is displayed with multiple representations can learners properly interact with the learning material based on their needs and preferences. Therefore, among these three principles, developing material in multiple representations is regarded as the initial step to assisting students.

Focusing on UDL, the authors considered UDL a vital approach to creating learning material not only for special needs students but for all learners. More importantly, learning with multiple-representation material requires collaboration between material developers and instructors. Material developers must create appropriate cognitive support in advance. Then instructors can customize a reading environment for their students; moreover, learners can set up proper environments by themselves. However, no study in the past has focused on exploring the relationship among material developers, instructors, and learners, nor has a system been developed to integrate the needs of material developers, instructors, and learners.

Based on the above research and observations, this study was set to develop an individualized e-reading environment that can provide not only essential support for Mandarin readers but also a convenient interface that allows material developers to create adjustable material. In addition, an experiment was also conducted to explore the effectiveness of the system on reading comprehension for students with learning disabilities.

### System development

Adopting the principle of multi-representations, this study aimed to develop an integrated, web-based e-reading system called the “TriAccess system,” which would not only provide individualized physical, sensory, and cognitive access for special needs learners but also attend to the needs of instructors and material developers.

#### Accessibility supports

Based on previous studies, the authors proposed 16 potential supports to address special needs learners’ potential difficulties deriving from their physical, sensory, and cognitive problems. Bottom-up and top-down supports were included. Seventeen professionals in the fields of curriculum design, special education, and instruction, who were familiar with interventions for individuals with special needs, were invited to participate in a modified Delphi survey to validate these supports. They were asked to rate the importance of the 16 potential strategies. Two rounds of survey disclosed 14 items as important or very important strategies (Chen, Cko, Chen, & Chiang, 2007). As shown in Table 1, all supports except one were embedded into the system.

<table>
<thead>
<tr>
<th>Accessibilities</th>
<th>Possible difficulties</th>
<th>Proposed supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical access</td>
<td>• Postural position</td>
<td>• Adjustable interface</td>
</tr>
<tr>
<td></td>
<td>• Motor control of upper limbs</td>
<td>• Location of icons (1)</td>
</tr>
<tr>
<td></td>
<td>• Gross motor</td>
<td>• Size of icons (2)</td>
</tr>
<tr>
<td></td>
<td>• Fine motor</td>
<td>• Interval between icons (3)</td>
</tr>
<tr>
<td></td>
<td>• Lacking upper limbs</td>
<td></td>
</tr>
<tr>
<td>Sensory access</td>
<td>• Low vision</td>
<td>• Magnifying size of text (4)</td>
</tr>
<tr>
<td></td>
<td>• Difficulty discriminating between foreground and background</td>
<td>• Contrasting the color of text with background (5)</td>
</tr>
<tr>
<td></td>
<td>• Blind</td>
<td>• Increasing spacing between words and lines (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Having just one sentence per line (7)</td>
</tr>
</tbody>
</table>
Reading aloud on demand (8)

Critical access

- Attention & perception
- Word recognition
- Comprehension
  - Syntax
  - Concept of keyword
  - Background knowledge
  - Working memory
- Reading aloud on demand (8)
- Marking keywords or key concepts (9)
- Explaining keywords in various representations (10)
  - Text, voice, picture, and video
- Providing background knowledge (11)
- Providing graphic symbols as alternatives to text (12) *
- Assisting holistic understanding
  - Précis (13)
  - Concept maps (14)

Note: *The support was not available in the current study

TriAccess system overview

Based on the multi-user management mechanism and the multiple-representation principle, the TriAccess system is implemented through a three-tier model (client/application server/database server). Figure 1 shows the framework and the database used to store the curriculum materials and users’ profiles, including specific configurations for individual learners’ reading environment. The elements of an article — texts, pictures, and video clips of key concepts, summaries, and concept maps — are stored separately in the specific database. To integrate speech synthesis systems into the TriAccess system, Microsoft Agent, Visual Basic ActiveX, and Character MP3 (a popular speech-synthesized program in Taiwan) are used. The TriAccess system can “speak” the text marked by the reader. In addition, the TriAccess system adopts streaming media techniques to display video. A profile for each learner is used to manage which supports are required. The elements are assembled and displayed based on the user’s profile.

Focusing on multiple-representation design, the TriAccess system consists of three user interfaces, targeting the material developer, instructor, and learner. The users’ responsibilities and the functions of these interfaces are described in the following.

**Material developer.** Developing curriculum material requires teamwork of professionals in instruction, curriculum development, and psychology. They should prepare in advance the related cognitive supports, namely, multi-representations for explaining the key concepts, précis and background knowledge of the article, and the concept map. Then, an authorized person uploads the required cognitive supports separately using the developer’s interface. The system works by organizing these supports automatically and storing them in the database. The remaining supports, including physical, sensory, and cognitive access supports, are also generated automatically. Therefore, since the above-mentioned supports are already provided by the TriAccess system, the developers need to create only the text and the required cognitive supports that they system cannot generate. The system organizes them and displays the material in response to the learners’ individualized requirements, thus requiring less information-technology literacy of the instructional material developers.

**Instructor.** The major responsibility of authorized instructors is to set up individualized, appropriate reading environments for their students. First, students’ profiles are created and then particular reading subjects are assigned. An individualized reading environment is provided by configuring proper physical and sensory access and by selecting cognitive supports based on the student’s abilities, limitations, and preference. Unless the student profile is reset, the setting remains consistent in all reading material; in this way, the workload of preparing the individualized learning material can be reduced.

**Learner.** Learners access the specific subjects in individualized reading environment. Based on age, disabilities, cognitive capability, and computer experience, learners are placed into three categories as independent, dependent, or blind users. Users classified as independent can set up the accessibility items by themselves after logging in. Dependent users can read only in the specific environment set by the instructor. For blind users, the TriAccess system can read aloud both the article and the explanation of keywords, allowing users to access the article and the text explanation of keywords via voice by pressing hotkeys even when the computer is not equipped with a screen reader.
Figure 1. Framework of the TriAccess system

Figure 2. Four snapshots of the learner’s interface, with different supports
The following demonstrates how users try to select a specific lesson after logging in to a customized environment. Some snapshots for learners without blindness are shown in Figure 2. As Figure 2 indicates, the articles are identical but displayed in different conditions and shown in four frames. The upper left frame reveals a video support of a key concept, a larger font size of text, and larger icons in the control panel. The upper right frame displays a picture support of a key concept and larger space between icons in the control panel. The lower right frame displays a concept map of the article, and the lower left frame shows that the menu bar and cognitive-support display area are disabled and that Merlin (a pedagogical agent) is activated. Friendly interface aside, pedagogical agents have high potential to better motivate learners (Dowling, 2002). The agents encourage the learner with disabilities to interact with the material actively when other visual supports are disabled.

The control panel allows learners to choose the essential support. Then they move the cursor to an underlined word. Related support would be displayed in the description area. In read-aloud assistance mode, users can mark a specific Chinese character, word, sentence, or paragraph and activate the text-to-speech program by clicking the mouth icon. Then, the computer would read out the selected text.

**Usability evaluation**

A preliminary usability evaluation was conducted to explore potential users’ TriAccess experience (Chen et al., 2007). Thirty volunteer evaluators, consisting of five faculty members in universities, four experienced school teachers in elementary schools, thirteen special education student teachers, and eight elementary school special needs pupils, participated in the evaluation. Two versions of the five-point Likert scale regarding TriAccess system usability were developed: the special educator version and the student version. Evaluations of 22 participating educators demonstrated their positive user experience toward all the three different interfaces: material developer, instructor, and learner. Meanwhile, all eight students also expressed their satisfaction with the system.

Since the participants in the previous study (Chen et al., 2007) rated the interface after a few trials, they might not have been familiar with the system. This paper invited 40 evaluators, 30 students with learning disabilities, and 10 special education teachers to read the articles with the system, and then evaluate the usability of the of interface of learner.

Revised versions of the questionnaire conducted in the previous study (Chen et al., 2007) were used. The questions in the teacher’s version focused on satisfaction, remembrance, efficiency, recognizability, and learnability. Items of satisfaction rated user satisfaction with the interface design; items of remembrance examined the user could, even after they did not use the system for a period of time, still remember how to operate the system; items of efficiency tested user productivity with the system; items of recognizability tested whether the function of the system could be identified easily; and items of learnability tested whether the user could learn how to operate the system quickly. The version for students evaluated four dimensions in terms of satisfaction and learnability in addition to user preference and assistance. Items of user preference tested whether the user liked to use the interface; items of assistance examined whether users felt the system benefited them when they read the article. All the questionnaire participants rated the items on a scale of 5 to 1, with 5 meaning strongly agree and 1 meaning strongly disagree. The student version was read to student participants, who answered orally.

The results of the evaluation by both the 10 special education teachers and the 30 students demonstrated positive opinions on the usability of the reader interface. In the five-point Likert-scale questionnaire, the average score of the five dimensions for teachers — satisfaction ($M = 4.40, SD = .53, t = 2.39, p = .04$), remembrance ($M = 4.67, SD = .38, t = 5.48, p = .00$), efficiency ($M = 4.35, SD = .41, t = 2.69, p = .03$), recognizability ($M = 4.50, SD = .67, t = 2.37, p = .04$), learnability ($M = 4.60, SD = .32, t = 6.00, p = .00$) — were all significantly higher than 4.0. For students, the average score of the four dimensions — preference ($M = 4.56, SD = .77, t = 3.95, p = .00$), learnability ($M = 4.78, SD = .43, t = 9.87, p = .00$), satisfaction ($M = 4.63, SD = .55, t = 6.28, p = .00$), assistance ($M = 4.60, SD = .60, t = 5.45, p = .00$), were also significantly higher than 4.0. The results indicate that these participants thought that the system was user-friendly, making it easy for users to familiarize themselves with the system, could assist with comprehension, and satisfy users’ need for assistance in reading.
Experiment

This experiment aimed to explore whether the cognitive support features in the TriAccess system could assist students with learning disabilities in comprehending articles. The experiment extended the authors’ preliminary study (Chen, Chiang, & Ko, 2008). A two-factor within-subject experiment was conducted. The concrete research questions were as follows:

1. Is there an interaction effect between reading conditions and reading sequence?
2. Is the performance different between two reading conditions if the interaction effect is not significant?

Method

Participants. The participants were identified by the local education agent in southern Taiwan as students with learning disabilities who also had difficulty reading. Thirty students (20 boys and 10 girls) in the fifth and sixth grade participated in the experiment after acquiring their parents’ consent. Their intelligence quotient (WISC-III) ranged from 70 to 109 ($M = 84.27$, $SD = 8.79$). All of them had reading difficulties and received special education service in their schools. None of them reported difficulty in vision, hearing, or motor control.

Based on the requirement of the curriculum standard in Taiwan, the students had formally begun computer and information-technology education in the third grade. Therefore, participants in the experiment had at least two years’ experience using computers and the Internet. To ensure that all of them would be familiar with the TriAccess system, they were individually taught to operate the TriAccess system prior to the experiment.

Material. To exclude the effect of learning experience and demonstrate the effect of “reading for learning,” the authors used the proper text developed for the authors’ preliminary study (Chen et al., 2008). A panel of three experts in natural-science education assisted in developing, reviewing, and approving the experimental material — seven articles related to endemic species in Taiwan. One of them was used to familiarize the participants with TriAccess; the other six served as experimental materials. In each article, the text, keywords, or key concepts were decided first. Then, the concept map and the summary were edited. The narration, pictures, and short film were created to serve as cognitive supports for each keyword.

The six articles consisted of an average of 552 Chinese characters, ranging from 539 characters to 584 characters. The mean length of a sentence ranged from 10.9 Chinese characters to 13.8 Chinese characters, 11.8 characters on average. The structure of the six articles was consistent: all texts sequentially described creatures’ living environment, characteristics, habits, and threats.

Each article was accompanied by a reading comprehension test of ten multiple-choice questions focusing on comprehension. The score ranged from 0 to 10. The higher score, the better performance. Fifty students (26 fifth grade and 24 sixth grade) without special education needs participated in evaluating the difficulty of the text by reading the article without multiple representations before they took the comprehension test. The resulting difficulty index of each comprehension test, from .65 to .85, indicated that the six tests were considered easy. Also, the Pearson’s product correlation coefficient of the scores revealed a significant relationship between the scores ($p < .01$) (Chen et al., 2008).

Experiment design. A within-subjects, repeated-measures design was employed. Independent variables were reading conditions (without and with cognitive supports) and reading sequence (first, second, and third reading). Reading conditions were manipulated by randomly assigning the articles with and without cognitive supports to the participants. In order to control the impact of the related factors on reading, all articles were displayed on TriAccess system with the participants’ preferred font size, color, and type. The only difference was the existence or non-existence of the cognitive supports. The articles were displayed in text mode when they were assigned without cognitive supports. On the other hand, when the articles were assigned with cognitive supports, the functions of reading aloud on demand, keywords, explaining the keywords with various representations, summary, and the concept map were enabled. Participants could use these supports during the reading process if they activated them. The authors also considered the impact of the reading sequence in this study, for the learning curve and novelty effects potentially influence the performance when children use a new system (Zhang & Zhou, 2003). Using the TriAccess system was novel for the participants. Therefore, this study aimed to explore the effect of interaction
between reading conditions and the reading sequence. However, the authors wanted to examine the main effect of the reading conditions only if the interaction effect was not significant, because the main effect of the reading sequence was not the focus of this experiment. The dependent variable was the score on the reading comprehension test.

In addition, the authors controlled the impact of experiment material on reading comprehension. As mentioned, the six articles were developed systematically to make them similar; however, they were of different content. The authors intended for each article to be read in both reading conditions to reduce the impact of experiment material. First, three pairs of the material were randomly assigned to three experiment sessions. The participants were randomly grouped into two groups. In each experiment session, first, the participants of Group One read an article without cognitive supports and those in Group Two first read the same article with cognitive supports. Then Group One read the article with multiple representations while the Group Two read the article without multiple representations. Thus, each article was read in “cognitive supports” and “text” mode randomly.

Apparatus and setting. This experiment used a laptop with a 15-inch monitor and an optical mouse to interact with the system. Chinese Character MP3 v2.0 (http://www.iqchinese.com), a text-to-speech software, was also installed. The participant was equipped with a headphone to enable participants to listen to the article. Due to various school locations and class schedules of the participants, the experiment was conducted individually. Students read the articles and took the tests on the TriAccess system in a quiet room in their own schools.

Experiment procedure. The authors interviewed each participant before the experiment to gather demographic information and computer experience. The second author then read the purpose of the experiment to the participant, and demonstrated how to interact with the TriAccess system. The participants practised using the system to become familiar with the reading environment. In the training sessions, the second author also helped each participant set up his/her favorite reading environment, including font size, character spacing, row spacing, and speed of reading by the text-to-speech program. These setting parameters were stored, and they served as the individual reading profile for the following experiment, for both reading conditions. Each participant needed to pass a prerequisite computer skills test in this session. Twenty nine participants passed the first time and one passed the second time.

There were three sessions in the formal experiment period. Each participant needed to read the above-mentioned six articles, three without cognitive supports and three with cognitive supports, without instruction. In a session, the participants were required to read one article with cognitive supports and the other one without cognitive supports in random sequence. When they read the text with cognitive supports, they were encouraged to use all the supports they liked and could operate the specific support as many times as they needed. Participants were also encouraged to read the article aloud when they read it without cognitive support. There was no time limit for reading the article in both reading conditions. Participants were required to take the test in which questions would be read aloud by the text-to-speech program on the TriAccess system. Their response to each question was recorded by the system. A three-minute break was given between two reading conditions.

Data analysis. SPSS 12.0 for Windows was used to analyze the data. A two-way repeated-measures ANOVA was conducted to analyze the interaction of reading conditions and reading sequence on reading comprehension. The main effect of the reading conditions was examined when the interaction of reading conditions and reading sequence on reading comprehension was not significant. The main effect of reading sequence was not examined, because the effect combined the scores from two reading conditions.

Results

The mean of test scores and standard deviations of the reading comprehension tests appear in Table 2. For these 30 participants, there was no interaction effect \( F = 0.08, \ p = .93 \) on comprehension test scores. The main effect of reading conditions \( F = 92.18, \ df = 29, \ p = .00 \) was significant. The mean of the two reading conditions demonstrated that the participants performed better when reading with cognitive supports \( M = 6.15, \ SD = 1.13 \) for cognitive-support mode; \( M = 4.30, \ SD = 1.20 \) for non-cognitive-support mode. The practice significance was also huge \( \eta^2 = .76 \). Therefore, the main effect of reading supports was confirmed.
Table 2. Descriptive statistics for two reading conditions

<table>
<thead>
<tr>
<th>Reading sequence</th>
<th>Reading conditions</th>
<th>With cognitive supports</th>
<th>Without cognitive supports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>First session</td>
<td>6.03</td>
<td>1.88</td>
<td>4.10</td>
</tr>
<tr>
<td>Second session</td>
<td>6.60</td>
<td>1.59</td>
<td>4.87</td>
</tr>
<tr>
<td>Third session</td>
<td>5.77</td>
<td>1.61</td>
<td>3.93</td>
</tr>
</tbody>
</table>

Discussion and conclusions

Based on the principle of multi-representations, this paper developed an individualized and convenient e-reading system for Mandarin students with special learning needs and for curriculum professionals and teachers. The authors also examined the effectiveness of the TriAccess system on reading comprehension and explored the users’ subjective perception of interacting with the TriAccess system.

In a web-based learning environment, the TriAccess system provides learners with individualized physical, sensory, and/or cognitive supports adapted to their needs. It also promises convenient and simple interfaces for material developers to prepare learning content and for the instructors to set up an individualized reading environment for their own students. The usability evaluation indicated all three interfaces were easy to use. In particular, the efficiency of the system gained the highest score. It reflected that the evaluators agreed that the TriAccess system could increase efficiency for all groups.

Effectiveness-wise, this experiment result indicated better reading performance when the students employed cognitive supports. Furthermore, this paper illustrated the effects of the cognitive supports instead of the effects of using TriAccess system on displaying digital material. In both reading conditions, the articles were displayed based on the participants’ specific preferences of font size, color, and row space of the text with TriAccess system. The results demonstrated the real effectiveness of cognitive supports. However, though the study observed that the use of cognitive supports varied among participants, it didn’t explore the effect of specific cognitive supports on specific individuals. Future study should further examine this aspect.

The participants’ subjective attitudes also revealed a preference for the TriAccess system. Participants regarded it as a user-friendly, supportive, and interesting reading environment compared to traditional textbooks. It was observed that the TriAccess system seemed to motivate them better and, as they became more actively engaged in the learning activities, they gained better reading comprehension. However, the affective issue was not explored in this study.

In conclusion, although the result of this experiment discloses greater reading comprehension when the participants read with the supportive multiple representations, some related questions have not yet been investigated. Future studies should continue exploring the issues that have not been addressed in this paper.

First, which supports will benefit the particular reader with specific disabilities needs to be explored. Teachers would like to know what specific kinds of supports might be useful for readers with certain limitations so that they can help their students to select supports accordingly. Likewise, this knowledge will help learners with disabilities identify appropriate or preferred supports and environments with less trial and error.

Second, the affective issue in reading activities should be investigated. The reasons behind their high motivation in using e-reading systems were not explored. Future study should investigate whether the reading media, selecting supports autonomously, or providing specific supports improve individuals’ motivation in reading activities.

Third, the effect of integrating the teaching reading strategy with e-reading systems on reading comprehension merits further exploration. Though this paper demonstrated the effectiveness of the cognitive supports on reading comprehension, the mean score of students with disabilities on the comprehension tests was 6.15, which was not as high as the scores of the students without disabilities. The result revealed that the participants with learning disabilities still could not learn effectively by themselves through reading with cognitive supports. These learners usually lack useful reading comprehension strategies. They can’t organize what they read, even though the system provides bottom-up and top-down assistance. Thus, some instruction in reading strategies may be necessary to help these students with their organization ability. For example, students may need to learn to read the concept map or to...
review the key concepts of the content. Therefore, future study should integrate reading strategy into the design and explore the effect of strategy instruction, such as reading aloud after the speech is generated by text-to-speech software, or reviewing the key concepts.

Fourth, the experimental design tries to control the extraneous variables to demonstrate the effect of treatment. The design might not represent the actual situation in school, especially for exploring the reading activity. Since reading is a complex phenomenon, it is hard to control the extraneous variables and examine a single factor. That being said, the future study should adopt other research methods to explore in depth the questions for individuals with specific disabilities when reading. For example, qualitative research might be a good approach to investigate the process of improving motivation when learners read with an e-reading system, while single-subject research might be suitable for exploring the effect of integrating reading strategies and e-reading systems on reading comprehension for the individuals with disabilities.

Last but not least, the features of this e-reading system should also be enhanced in the future, at least in the following ways. First, the new version of the e-reading system should record user behavior automatically. Monitoring conditions where the supports are used by the students during the learning processes could help the learner and the teacher to determine the proper supports based on objective information. Second, it should integrate the strategies of remedy and compensation into a system to assist learners in learning reading skills and participating in reading activities through software. Many past studies demonstrated the effectiveness of software for teaching reading skills, such as concept mapping, marking key concepts, and taking notes. However, these software programs do not integrate with assisted reading features. The authors believe that an ideal supportive environment should provide both the necessary supports and essential reading strategies during reading activities.

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