Being an Opportunist or a Hard Worker: Comparison of Computer-based Input Types for Arithmetical Word Problems

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Abstract: The digital content has been considered as a core part of classroom learning. The way to input answers may influence student learning behaviors. This paper focuses on three computer-based input types—choice buttons, drag-and-drop, and text boxes—that are used frequently in arithmetical word problems of elementary schools. The experiment was conducted to examine how students input answers in computers and how they are engaged in learning. The results showed that the students had high accuracy when they had to type their answers; they were willing to spend time on studying the questions and creating the answers. When students were allowed to choosing or dragging-and-dropping, some of students would guess the answer by the “advantage” of computers—instant feedbacks. This paper suggests that the interface should facilitate a student to be a hard worker rather than an opportunist.

Keywords: Digital content, computer based input types, arithmetical word problems

Introduction

When adopting technology-enhanced learning in the real world practice, teachers mainly care the learning materials more than the functionalities of computers [1]. When the digital learning materials are developed and implemented, content providers tend to graft the paper-based learning materials onto computers. For example, multiple choice questions, which have been used in education for a long time, become choosing answers from several buttons of options. Content providers perhaps have an assumption that these old learning materials work well in computer-based environments. However, when the learning environments change, student behaviors necessarily change, so do the way to interact with the learning material.

Therefore, it is a challenge that how to integrate the existing learning materials into the digital environments in classrooms. Previous research showed that students tended to use surface learning approaches when the test was multiple choice questions [8], suggesting that input types may influence student learning behaviors. The objective of this study is to examine the learning outcomes of three computer-based input types—choice buttons, drag-and-drop, and text boxes—for learning word problems in elementary mathematical classrooms. Although perhaps these input types are not the best or mature ways of interaction, this study can still give implications as to designing an effective interface in learning.
1. Interfaces for Word Problems

The cognitive process of solving mathematical problem is consisted of two main phases: problem representation and problem solution [6]. Furthermore, problem representation includes translating the problem into a mental model and integrating different pieces of information in the problem; and problem solution involves formulating a plan for solving the problem and then executing it. Previous studies showed that students had particular difficulty in generating a set of solvable mathematical equations from problem texts [2] [5].

For learning word problems, three major input types are used in many systems. The first one is choice buttons, which originate from multiple choice questions on paper. Students have to choose one or more answers from several options by mouse (or stylus on tablet PC). As an assessment tool, multiple choice questions are powerful to diagnose students’ weaknesses if well designed. Multiple choice questions based exams are reliable only because they are time-efficient and a short exam still allows breadth of sampling of any topic. Other written examination formats are slower to complete and hence cannot realistically sample as widely unless the test is several hours long [7].

The second input type is drag-and-drop, which allows students to move an answer to a target by mouse (or stylus). For example, MONSAKUN system [3] asked students to construct word problems in order to satisfying a certain expression (e.g. “5+3”) by drag-and-drop. The candidate answers were five statements and the targets of the word problem was a question consisted of three statements. That is, students had to choose three statements from five statements as well as to decide their sequence.

The third kind of input types is text box. Students should have the ability to type in the answers by keyboard. For example, QPPA system [9] allowed students to create the entire word problem in text boxes and then asked them to review one another’s works. With text boxes, students are urged to contribute their knowledge and ideas. However, the ability to type is a threshold of using such systems. Students who are not familiar typing will feel difficult to create word problems. This paper focuses on comparing the effects of these three input types on learning.

2. System Design

A system was designed as a content container to deliver the math word problems to be practiced. It incorporates the DCE (Digital Classroom Environment) system as a framework. The DCE system facilitates the exchanging of messages among students’ and the teacher’s devices in a classroom and is responsible for collecting log data which can be analyzed later. The content container is designed as a carrier of word problems to be practiced by students. Depending on the ways of user interface manipulation, there are 3 types of templates designed for this study, namely: choice button, drag-and-drop, text box.

2.1 Choice Buttons

Questions of choice buttons are basically multiple choice questions. As shown in Figure 1(a), each question in this study has four candidate answers on four choice buttons. When a student interacts with a word problem of choice buttons, he may click the button representing the correct answer in his mind and then click the “OK” button to check the answer. If the answer is wrong, the system colors the frame of the button red immediately. The probability of guessing the correct one at the first time is 0.25.
2.2 Drag-and-drop

A question of drag-and-drop in this study is consisted of an arithmetic expression, a word problem with two blanks, and four candidate answers (Figure 1(b)). The blanks are designed to construct the most important parts in the word problem for fitting the expression. By reasoning the relationship between the expression and the context given, a student may drag the appropriate candidate answer out of the four into the blanks of the problem. Generally, students in elementary schools are not familiar with this type of practice, which facilitates understanding the structures of a word problem. After clicking the “OK” button, correctness feedback is given immediately. Similarly to choice buttons, the system colors the frame of the blank red. The probability of guessing the correct answers and their sequence at the first time is about 0.08.

2.3 Text Boxes

Compared with choice buttons and drag-and-drop, text boxes are more straightforward. As shown in Figure 1(c), after a student comprehends the word problem given, he then keys in appropriate numbers into the text boxes to complete the math expression as a solution to the problem. Besides the ability to understand the word problems, this type of word problems is also dependent on the students’ fluency of keyboard operations. When the answers are wrong, the system colors the frame of the text boxes red immediately. It is impossible to guess the answers without reading the questions.

3. Method

The objective of the experiment was to investigate the student behaviors of interacting with the three kinds of input types: choice buttons, drag-and-drop, and text boxes.

3.1 Participants & Environment

The participants of this experiment were 52 (26 boys and 26 girls) grade 4 students in an elementary school. The students aged from 9 to 10 years. Each student used a notebook (small portable laptop computer) to practice the math word problems about multiplication. A classroom server was set up in order to collect the log data of the students’ practice.

3.2 Procedure

The experiment is with-subject design. It was consisted of three class sessions. Each session was forty-minute long. In the first session, text boxes were used. Students needed to fill in the multipliers and multiplicands into scaffolded multiplication expressions. Choice buttons were used in the second round. Each question had four candidate answers of which are the four basic math operations. The questions are not always related to multiplication. Instead, in order to prevent the students from guessing answers according
to the operation sign, the word problems of using operation signs other than multiplication were mixed into the material. Specifically, three quarters of all the problems were multiplication problems. In the third session, drag-and-drop was adopted. The students’ task was to drag two candidate answers out of four into correct blanks of the problems.

3.3 Data Analysis

In order to examine the effect of input types on accuracy and response time, one-way analyses of variance (ANOVA) were carried out with input types (choice buttons, drag-and-drop, and text boxes) as the within-subject variables. Alpha was set at .05 for all statistical tests. All these analyses were done with the Statistical Package for the Social Science (SPSS Windows V. 13).

4. Results

4.1 Accuracy and Response Time

Figure 2(a) illustrates the average accuracies of the three input types. A one-way ANOVA showed that there was a significant difference among the input types ($F_{(2, 102)}=87.724, \text{MSE}=.013, p<.05$). Furthermore, posteriori comparisons indicated that the accuracy of text boxes was significantly higher than choice buttons ($t_{(51)}=10.727, \text{SE}=.022, p<.05$) and drag-and-drop ($t_{(51)}=10.680, \text{SE}=.025, p<.05$), but there was no difference between choice buttons and drag-and-drop. The reason of low accuracies of choice buttons and drag-and-drop was that the two input types both had candidate answers so that students could choose; when they faced the two kinds of input types, some of them adopted the strategy to try every candidate answer. In the condition of drag-and-drop, besides trying candidate answers, they also had to try the sequence of answers. The result suggested that when there was no candidate answer like text boxes, students were forced to read the problem more carefully.

![Figure 2(a): Accuracy](image)

Figure 2. The average accuracy and response time

Figure 2(b) showed the response times in the three conditions. One-way ANOVA on the response time indicated that there was a significant difference among the three input types ($F_{(2, 102)}=38.494, \text{MSE}=17.717, p<.05$). Posteriori comparison showed that students spent significantly more time on drag-and-drop than on choice buttons ($t_{(51)}=7.938, \text{SE}=.910, p<.05$) and text boxes ($t_{(51)}=5.489, \text{SE}=.741, p<.05$). Additionally, students spent significantly more time on text boxes than choice buttons ($t_{(51)}=3.864, \text{SE}=.817, p<.05$). The results showed the usability of the three input types. That is, it is easier for students to use choice buttons, but it took longer time to input answer by keyboard and drag-and-drop. However, it also implied the appropriateness for learning—usability is not always the first
concern when designers develop the digital learning environment. Although clicking choice buttons is faster than the others, students may select answers without thinking.

(d) Choice Buttons     (e) Drag-and-Drop     (f) Text Boxes
Figure 3. The student distribution on the dimensions of accuracy and response time.

Figure 3 illustrates the student distribution on the dimensions of accuracy and response time in the three conditions. The pattern in choice buttons is similar to that in drag-and-drop: there were a small group of students whose accuracy and response time were both at a low level. However, in the condition of text boxes, although the students spent more time in typing, most of them reached a high level of accuracy.

4.2 Observation

In the condition of choice buttons, it was observed that when a question was shown, some of students clicked the buttons randomly without reading the question first. Similarly, in the condition of drag-and-drop, they just picked one of the candidate answers and put it in an arbitrary box. They quickly click the “OK” button to check their answers. In most cases, they were wrong. And then they tried to figure out which candidate answers were not possible. Eliminating the impossible ones, they usually could find the correct answers and sequence. Compared with these two input types, in the condition of text boxes, students had no clues to guess answers. They only had the strategy to read the question first. If they did it wrong, they would either rethink the question more carefully again or recheck their answers in order to find out which steps were wrong. Text boxes provided a chance to reflect.

The results illustrated the common characteristics of choice buttons and drag-and-drop: candidate answers. With candidate answers, students do not need to create answers by themselves. Rather, they only need to distinguish which candidate answers were correct, clicking or dragging it to the destination. Furthermore, some of students also took the advantage of computers, instant feedbacks, to check the answers quickly. In other words, in a learning environment where choices are limited and feedbacks are prompt, students likely learn nothing. However, the result did not imply multiple choice questions and matching question on papers were not appropriate. Instead, it is suggested that the paper-based learning materials should not be directly grafted to digital environments. In some cases, digital environments weaken the strengths of learning materials, which should be designed more carefully.

5. Discussion

It was found that some of students abused the advantage of computer-based environment—instant feedbacks. When solving multiple choice questions on test papers, students do not have a chance to try the answers. They have to wait the results until their
teacher marks the test papers. They thus value the multiple-choice questions, reading the questions and checking the answers carefully. However, when multiple choice questions are changed into a digital environment, where all feedbacks are immediate and confirmable, there are no reasons for respecting the learning method. When answering becomes a quick click, learning becomes meaningless.

Although drag-and-drop took more time in this experiment, it resulted in a low accuracy, similarly to choice buttons. In essence, drag-and-drop is a variation of choice buttons. That is, drag-and-drop is also consisted of several candidate answers. Yet, its difficulty is higher than that of choice buttons. Students have to decide the sequence of correct answers when using drag-and-drop, which theoretically takes more time than when using choice buttons. In the conditions of both drag-and-drop and choice buttons, it was observed that students guessed the answers at the start of solving a question. They behaved opportunistically because there was nothing to lose as an opportunist.

Text boxes, however, require students to key in answers. Without candidate answers, students perceive that it costs more time. Even if the instant feedbacks tell they were wrong, they still have no chances to guess. They eventually realize that if they do it wrong, they have to key in the answers again. Although a text box is not a user-friendly and time-consuming input type like choice buttons or drag-and-drop, it makes students pay more efforts to share their thoughts. Even if the thoughts are not quite right, it provides a chance to reflect and to improve.

6. Conclusion

The objective of this research is to evaluate which input types are suited for pupils in learning arithmetical word problem. The authors designed three kinds of input types—choice buttons, drag-and-drop, and text boxes—which are incorporated in DCE system with the learning materials about multiplication of integers in the third grade. It was found that students got high accuracy in the condition of text boxes; but for choice buttons and drag-and-drop, instant feedbacks, one advantage of computers, give students chances to guess the answer. Although good interfaces cannot promise meaningful learning, bad interfaces definitely result in failed learning. It is suggested that the interaction of learning environments should provide students with more learning opportunities to express themselves. But they do not need to become an opportunist by abusing the interface of digital learning environments. Instead, they have to become a hard worker willing to invest efforts in learning.

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References


