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Identifying and Comparing Elementary Students' Problem-Solving Behavior Patterns Using Lag Sequential Analysis

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Abstract: This paper investigates the elementary students' problem-solving behavior patterns using the lag sequential analysis. 90 students in grade 5 were required to develop their own solution to the task in an online assessment system and all their interactive behaviors were recorded and then coded for sequential analysis. Comparing the analysis results between the higher-score and lower-score students shows that regardless of the prior knowledge and school exam performance, their differences in the problem-solving behavior pattern led to the discrepancy in task performance.

Keywords: problem solving, assessment task, behavioral pattern, lag sequential analysis

1. Introduction

Problem solving refers to the process of discovering a proper method of reaching a goal from an initial state. While educated adults may show equally good performance in their skills to solve problems, teenager students normally have different competence levels in using strategies to solve problems (Findings, 2014).

In recent years, some scholars have concentrated on assessing problem solving. Distlehorst et al. (2005) assessed students' problem solving by checking their performance in information acquisition, self-regulation and collaborative study in problem-based learning (PBL). Johnson et al. (2007) argued how students value the information could be evaluated through their information-accessing behaviors. Schweizer et al. (2013) developed MicroDYN to evaluate students' determining variable dependencies through manipulating the variables and observing the effects.

Scholars also investigated different factors influencing problem-solving performance. Kalyuga et al. (2010) and Greiff et al. (2015) argued that cognitive elements, such as exploring the problem, representing knowledge, and planning and evaluating the solution affect problem-solving skills. Sabourin et al. (2012) discovered that information gathering could improve problem-solving efficiency. OECD (2012) found that non-cognitive factors such as belief and motivation have a direct impact on the problem-solving process in the 2012 PISA results. Gyöngyvér et al. (2018) concluded that deductive and inductive ability and fluid intelligence level are significantly associated with problem solving.

In recent years, both hardware and software are competent to collect real-time behavioral data and scholars employed lag sequential analysis (Sackett & Richard, 1979; Bakeman & Gottman, 1986) to analyze the data. Lan et al. (2012) used lag sequential analysis to identify the behavior pattern of students' knowledge construction. Hou (2013) analyzed the differences in behavior between students in an online role-playing game. Yang et al. (2015) investigated the behavioral pattern and group interactive network in online English-to-Chinese translation. Malmberg et al. (2017) examined temporal sequences of regulated learning activities by lag sequential analysis of video data. Shukor et al. (2014) explored students' knowledge construction behaviors using lag sequential analysis.

In this paper, we aim to find and interpret the difference in students' behavioral pattern during the problem-solving process by using lag sequential analysis.

2. Assessment System

A general framework for the assessment task is provided in the assessment system and all the interactions between the respondent and system will be automatically recorded into log files for further analysis.

The system offers some general functionalities, as Figure 1 illustrates. For instance, a tip button is to the upper left of the task window and a small popup window showing the guideline and tips about this task will be displayed after clicking it. In addition, the restart and give up buttons are to the lower left and right of the task window, respectively. The restart button can be used to restart the task from the beginning and the give up button can be used to abort the task with zero score obtained.

Figure 1. General Functionalities of the Assessment System

We carried out our experiment and data analysis by using one of our assessment tasks where tent allocation in outdoor camping is used as the background setting. Respondents need to allocate tents to people by dragging women, girls, men or boys into the big, medium and small tents. Different tents can accommodate different numbers of people and two essential requirements for completing this task can only be found in the tip popup. The solution to the task can be submitted only when the following two requirements are satisfied: only people of the same gender can use the same tent and each tent must have at least one adult in it. Besides, the dragging action in this task can never be undone and the only way of clearing a false move is to click the restart button and do the task again.

3. Experiment Design and Analysis Method

In this experiment, respondents would independently finish the task within 10 minutes. In total, 90 elementary students in grade five participated.

We used lag sequential analysis to analyze the students' behavior sequences in two scale ranges: first all the behaviors in the whole problem-solving process were used and then only their dragging choices of people and tents in each new attempt after a restart were manipulated.

For the whole problem-solving process, all important behaviors including clicking the tip, dragging people into the tent, clicking the restart button, reading reference information, using the give up button and finally submitting the solution were used. Of these behaviors, clicking the tip is a little bit special since just clicking the button could never guarantee students' reading and understanding the information. As the assessment system would also automatically record the duration of the behavior, only those lasted for over 6 seconds when reading the tip of 30 Chinese characters would be recognized as effective reading and then used.

For the allocating choice, every first dragging behavior both when the task began and each time after they restarted the task by clicking the restart button was used and dragging different people (man, woman, boy and girl) into different tents (big, medium and small ones) was treated as different behaviors. Since the solution to the task will be submitted and graded only when the two essential requirements are satisfied and no false move can be undone in the task, the restart button may be frequently clicked by students and whether and how students would change their dragging strategies in the next new turn based on their previous errors can show their problem-solving strategy.

The above-mentioned behaviors were obtained and directly coded for subsequent analysis, as Table 1 and 2 shows, respectively.

Table 1

The Coding Scheme for All the Behaviors in the Whole Problem-solving Process

Code	Behavior	Description
TP1	Read the tip	Read the tip at the beginning of the task
TP2	Click the tip	Read the tip during the problem-solving process
DR	Drag people	Drag people into the tents in allocation of tents
RE	Click restart	Click the restart button to clear and reload the current task
DA	Use reference	Click the "Information Center" to read reference
GU1	Click give up	Click the "Give up" button and the popup menu appears
GU2	Confirm give up	Confirm aborting the task with zero score obtained
CT	Click continue	Click the "Continue" button and return back to the task
SU	Click submit	Click the submit button to submit the solution

Table 2

The Coding Scheme for the First Dragging Behavior in Each New Attempt

Code	Behavior	Description
WB	Woman-big tent	Drag a woman into the big tent
WM	Woman-medium tent	Drag a woman into the medium tent
WS	Woman-small tent	Drag a woman into the small tent
GB	Girl-big tent	Drag a girl into the big tent
GM	Girl-medium tent	Drag a girl into the medium tent
GS	Girl-small tent	Drag a girl into the small tent
MB	Man-big tent	Drag a man into the big tent
MM	Man-medium tent	Drag a man into the medium tent
MS	Man-small tent	Drag a man into the small tent
BB	Boy-big tent	Drag a boy into the big tent
BM	Boy-medium tent	Drag a boy into the medium tent
BS	Boy-small tent	Drag a boy into the small tent

4. Results

4.1 Correlation Results

During our experiment, we also collected the Chinese and Math scores of the students in the last final exam. Then Pearson correlation coefficients were calculated and the results showed that different exam scores did not lead to significant differences in task performance.

Table 3

Correlation Between the Exam Scores and Task Performance

	Chinese score	Math score	
Pearson correlation	0.13	0.05	Task performance

P-value	0.2827	0.6465	Task performance

4.2 *Results of the Lag Sequential Analysis*

Since our assessment task requires no prior knowledge and students' performance was also independent of their school scores, we assumed that the possible determining factor might be their problem-solving behaviors and strategies during the task process.

The full mark of the task is 100 and the average score is 56.3. In all the 85 students from whom valid behavioral data was obtained, 49 obtained higher scores than the average while 36 got lower scores. As a result, lag sequential analysis was conducted for higher-score and lower-score groups, respectively and the results are as follows.

4.2.1 First Analysis Using All the Task Behaviors

The behavioral transition of the significant sequences (with z-scores greater than 1.96) is illustrated for the two groups in Figure 2 and 3, respectively.

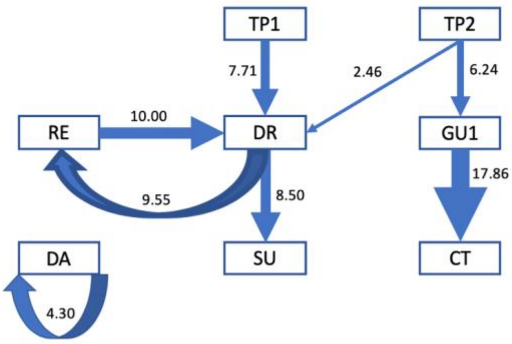

Figure 2. Behavioral Transition Diagram of All the Problem-Solving Behaviors for the Higher-Score Group

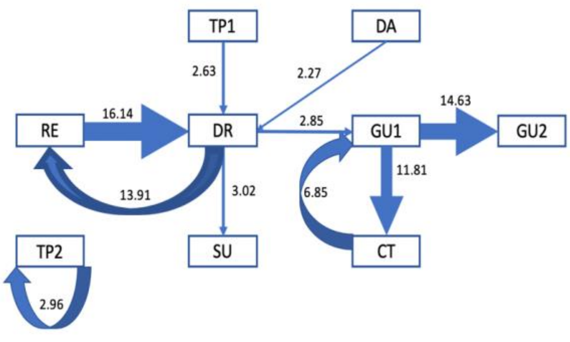

Figure 3. Behavioral Transition Diagram of All the Problem-Solving Behaviors for the Lower-Score Group

According to the above figures, the higher-score and lower-score groups share some significant behavior sequences such as GU1 → CT, DR → RE, DR → SU, RE → DR, and TP1 → DR. However, TP2 → GU1, DA → DA and TP2 → DR are only significant for the higher-score group while GU1 → GU2, CT → GU1, TP2 → TP2, DR → GU1 and DA → DR are only significant for the lower-score group.

4.2.2 Second Analysis Using First Dragging Behaviors

The behavioral transition of the significant sequences is illustrated in Figure 4 and 5.

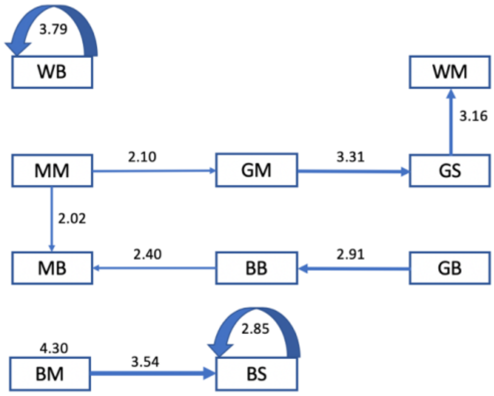

Figure 4. Behavioral Transition Diagram of the First Dragging Behaviors for the Higher-Score Group

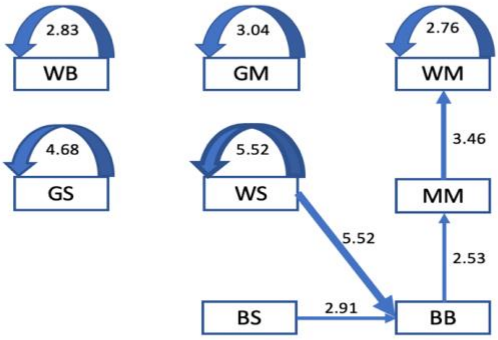

Figure 5. Behavioral Transition Diagram of the First Dragging Behaviors for the Lower-Score Group

According to the results, the two groups share a significant behavior sequence WB → WB. However, other significant sequences are quite different between the two groups.

5. Discussion and Conclusion

We could draw several implications from the results:

First, in the second sequential analysis, it is obvious that for the higher-score students, various combinations of people and tents were used at the new attempts with only two repeated sequences while their lower-score peers also did comparatively well but tended to repeat their choices in different new attempts. This difference might help result in their different task performance.

Second, in the first sequential analysis, the GU1 → GU2 sequence ranked as the second most significant sequence for the lower-score group while for the higher-score group, the GU1 → CT sequence appeared as the most significant one and no sequence including GU2 showed significance. This indicated that among all the task behaviors, the higher-score students may click the give up button but they tended to return to the task whereas their lower-score peers could really give up. In addition, the CT → GU1 sequence shown by the lower-score group implied that they could repeat clicking the give up button after they cancelled it whereas no similar sequence initiated by CT for the higher-score students indicated that they tended not to try giving up again after a previous cancelation.

Moreover, in the first sequential analysis, both groups had the TP1 → DR sequence that indicated they all read the tip at the task beginning and then began dragging. However, the TP2 → DR for the higher-score group suggested that they also turned to the tip during the task and then started dragging again. Since the information of the tip is essential to obtaining the proper solution, naturally we can assume that the helpful tip might be used to instruct their dragging behaviors. On the contrary, the TP2 → TP2 sequence appeared significant in the lower-score group and it indicated these students would just repeat reading the tip but without the TP2 → DR sequence, the tip might not make a difference to reaching their task goals. It seemed that the higher-score students were more target-oriented and their lower-score peers distracted by the tip information to some extent.

All the above differences are related the behavioral strategies representing students' positive character and attitude. This is supported by studies conducted by other scholars. O'Connell (2000), Jonassen (2000), Au et al. (2003), and Erdemir (2009) argued about the importance of positive character and attitude in problem-solving ability from different aspects in their individual research.

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