Using the Think Aloud Method to Observe Students' Help-seeking Behavior in Math Tutoring Software

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***Abstract*—This qualitative study presented high school students' help-seeking behavior and how they interacted with hints while they solved math problems on an intelligent tutoring system for math.**

Keywords: think aloud method; help-seeking behavior; intelligent tutoring system; math education

I. INTRODUCTION

With continued rapid development of technology, intelligent tutoring systems (ITS) provide interactive learning environments (ILEs) for education. One of the characteristics of ILEs is their on-demand help feature. Hints, hyperlinks and glossaries can be provided in computer learning environments, and be sought for whenever necessary to support learning. Human tutors can facilitate and decide when, how, and what level of assistance to provide to students depending on cues of the human-to-human interaction. However, in human-to-computer interaction learning environments, learners may take an active role to seek help. They control when, how, and to what extent they need help during learning. This ability and action of help seeking relies on learners' "metacognition" [9]. Hence, learners' help-seeking behavior [9] plays an important role in ILEs, and affects learning.

II. MODELS OF HELP-SEEKING BEHAVIOR

A. Models of Help-seeking Behavior in other studies

In Aleven, Stahl, Schworm, Fisher, and Wallace's review [3], they pointed out that help-seeking has not really been studied in the context of computer learning environments. The model of help seeking was presented originally by Nelson-LeGall [7] in the classroom, the social context. Aleven, McLaren, Roll and Koedinger [1] designed a model of help-seeking behavior with The Geometry Cognitive Tutor. In their model, the ideal help-seeking behavior of students should spend time to think about steps of solving a problem. If they feel it is familiar, they should try to solve the problem. If they don't seem familiar with it, they should ask a hint from the tutor. Students should spend time to read a hint and decide if they need more hints to help them solving the problem. They should check Glossary for help if they don't have sense of what to do. If the Glossary is helpful, they should try to solve the problem. If it does not help, they should ask for more help. After students tried the above steps to answer the question, the tutor will then tell students if the answer was correct. If the answer is not accurate, they should try to solve the problem again.

We believe that different software with different designs of help functions may lead students to have slightly different steps when they seek help in the interactive computer learning environment. Therefore, the model of help-seeking could be altered depending on a specific tutor.

B. A Model of Ideal Help-seeking Behavior for Wayang

We applied the model by Aleven et al. [1] in this study to observe students' help-seeking behavior in Wayang Outpost, an intelligent math tutoring software. This tutor-dependent model of help-seeking behavior was based on Aleven [2]; however, it was revised to fit the Wayang math tutoring software (see Figure 1).

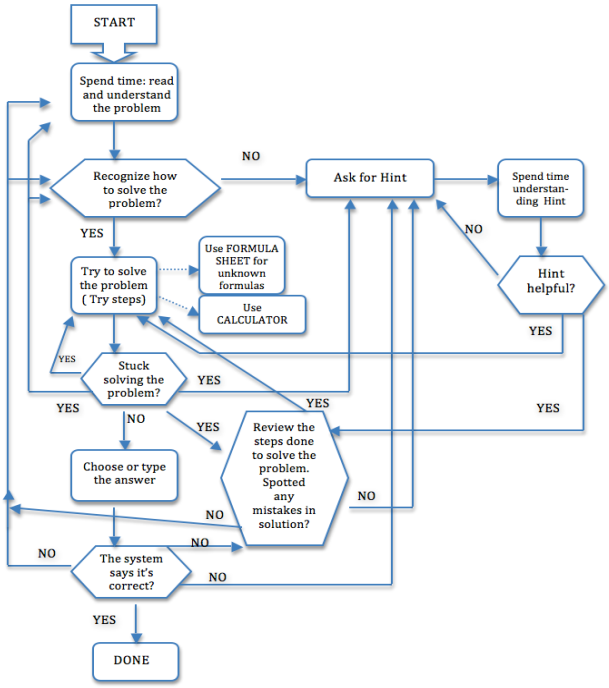

Figure 1: A model of ideal help-seeking behavior in the Wayang Math Tutor, revised from Aleven and colleagues [2]

Students with ideal help-seeking behavior, according to the model would behave as follow: they would 1) spend time to read and understand the problem; 2) recognize if

they know how to solve the problem; 3) ask for help from Hint button when they don't know; 4) spend time to understand hints; 4) if a hint is helpful, students should try to solve the problem; 5) if a hint is not helpful, and students are still not clear about how to solve the problem, they should ask more hints for solving the problem; 6) during the time this ideal student solves the problem, he/she would use the formula sheet and calculator if it is needed.

III. THE USER STUDY

We ran a study using think-aloud methods to observe students' help-seeking behavior during the use of Wayang Outpost, in order to understand proper and improper uses of the software and the help features. We investigated: a) What are the participants' help-seeking behaviors when solving math problems in Wayang Outpost? b) What happens during "the moment" when participants interact with help features?

A. The testbed tutoring system: WAYANG OUTPOST

We examined high school students' help-seeking behavior within the interactive computer-learning environment, Wayang Outpost. In this system, students practice math problems in the "Learning Hut". Each problem provides detailed multimedia hints about how to solve the problem. Students can click the "Help" button to receive hints. Students can continue to click on the Help button to get more hints until they know how to solve the problem, or see all hints to get full animated processes that show a solution to the problem.

B. Participants

The participants in this study were eight students in a suburban high school in western Massachusetts. They were randomly selected from around 1,000 students in ten math classes, which these ten classes participated in Wayang research studies. The average of their age was sixteen years old, three girls and five boys. One male and one female student had IEPs (students with Individualized Education Plans).

C. Data collection and data analysis

The participants were asked to think aloud as they tried to solve math problems. Before starting, we explained that we were interested in getting to know the thoughts that come into participants' minds as they carry out the task of solving math problems. We showed participants a video demonstrating how to do a think-aloud. We only prompted participants when it was necessary by just saying: "Keep talking" [8] when participants were silent or stopped talking at all. The participants were audiotaped while they thought aloud. The think aloud task time period was between fifteen minutes to thirty-seven minutes. They were not given the same amount of time to finish this think aloud task because each participant took different amount of time to solve problems. Also, they were not asked to solve the same amount of problems in Learning Hut. The participants might see easy problems and solve problems correctly without using Help button during the think aloud task. (see TABLE I.)

The data from the computer logs in the Wayang Outpost system was gathered to help interpret student behavior along with the protocol data. The computer logs showed participants' detailed actions on computer when they solved problems, such as Hints seen in each problem, incorrect attempts per problem, seconds to solve and seconds to first attempt for each problem.

The analysis of content in raw protocols was in terms of the model of help-seeking behavior. Every step or process in the model of help-seeking behavior was labeled as a coding scheme. Steps or processes that were not covered by the model of help-seeking behavior were categorized in order to analyze the unexpected help-seeking behavior. The coded protocol of each math problem presented a unique theme of a student's help-seeking behavior.

TABLE I. THEMES OF PARTICIPANTS ACTUAL HELP-SEEKING BEHAVIOR AND NUMBERS OF PROBLEMS

Participants	Solved the problem correctly without using Hints.	Solved the problem correctly by the help from Hints.	Using some Hints for help, but still can't solve the problem correctly.	Using all Hints during problem solving process, but still fail to solve the problem correctly.	Using all Hints, but No problem solving steps.	Can't solve the problem correctly and did not use Hint either	Guessing	Memory	Other	Total
1	6	1	0	2	0	0	1	0	1	**11**
2	10	2	0	0	4	0	0	0	0	**16**
3	9	3	0	0	0	0	4	0	0	**16**
4	12	2	0	2	2	0	6	1	0	**25**
5	9	1	1	2	0	3	0	0	0	**16**
6	7	3	0	0	1	0	0	0	0	**11**
7	6	3	1	0	1	0	0	0	0	**11**
8	15	3	1	0	0	1	14	0	0	**34**
Total	**74**	**18**	**3**	**6**	**8**	**4**	**25**	**1**	**1**	**140**
%	**53%**	**13%**	**2%**	**4%**	**6%**	**3%**	**18%**	**<1%**	**<1%**	**100 %**

IV. RESULTS

Coded Think- aloud protocols of each math problem from all participants have been categorizing to nine themes. TABLE I shows the analysis of participants' actual help-seeking behavior and the number of problems and percentage that each participant saw.

A. What are participants' help-seeking behaviors when solving math problems while using Wayang Outpost?

a) Solved problem correctly without using Hints. (53%)

74 out of 140 problems fell into this first category based on the coded think aloud protocol.

b) Solved problem correctly by using hints (13%)

This theme included participants that were able to solve the problem correctly after asking help from hints. Participants in this theme demonstrated the ideal help-seeking behavior that we expected.

c) Using some hints, but still can't solve problem (2%)

Not being able to solve the problem after receiving hints included 3 problems. Participants did not see all hints, but just saw a couple of hints. They stopped asking for further hints, and finally failed to solve problems or got the correct answer by luck.

d) Using all hints, but still failed to solve problem (4%)

Six problems were categorized in this theme. They tried the steps to solve problems, but still failed to solve it.

e) Using all hints, but no focus on problem solving(6%)

This theme, in which participants use all hints but no problem solving steps, is different from the previous theme. Participants tried to understand what each hint told them, but did not attempt to solve problems or they might just click through all hints quickly. Participants got the correct answer because the last hint contained the answer. There were 8 problems categorized in this theme.

f) Can't solve the problem, but did not use hints (3%)

Five problems were categorized in this theme including two participants rejected asking for hints and were not able to solve the problem correctly.

g) Guessing (18%)

Twenty-five problems were categorized as guessing. Four participants (1, 3, 4 and 8) guessed when they tried to solve problems until they got the correct one. The protocols suggested reasons for guessing was that, after clicking on help a couple of times, those hints did not really help them or gave enough information for solving problems. For example, after participant 8 saw 1 hint, and she said, "*I think it's B or C… I am just gonna go with a guess of C, and I am… B… and B came out to be right*." In another case, participants did not even want to ask help. They just tried wrong steps to make up numbers, which would sound like they were generating an answer, or they randomly guessed.

h) Memory (<1%).

Only one problem categorized in this theme, that is, participant 4 saw the same problem twice. In his second time seeing the problem, he used the memory strategy.

i) Other (<1%) One problem categorized in this theme was from participant 1. The participant was able to solve the problem correct at the beginning. The correct answer that the computer system gave was"48-9π." However, she could not find the answer from options that matched her own answer, which was "20." She then tried to do it again and asked help from hints as well. She was confused by hints, and failed to solve it. She finally chose the correct answer from the last hint.

B. What happened at "the moment" when participants interacted with hints?

We found participants solved the problem right by chance. From participants 5 and 8 protocols, we saw that both of them had asked for hints and yet they both used the wrong steps to solve problems without asking more hints and then got the correct answer by luck. The protocol suggested that students might not be clear what the problem was actually asking. Besides, the protocol also showed that students might lack or not be clear about certain math knowledge, or they misunderstand certain math rules. Thus, they misused it, and solved the problem correctly with luck.

We also found that when hints were not helpful for participants, they felt frustrated and not confident. They finally gave up solving the problem. For example, participant 7 saw 3 hints on a problem and made one incorrect attempt. He was frustrated and said, "*ok…I have no idea*" He did not check the last hint and commented that "*math is not my best subject*." Participant 4's protocols showed that he did not really understand hints he had seen: "*Oh… I am not sure if that's gonna help me or not.*" Or the hint did not give him enough information to solve problems but showed him the correct answer too soon: "*Choose A???!!! That was a hell of a hint.*

Another situation we observed from the protocol was that students did "bottom out" because they did not like certain problems. They chose to let hints show them how to solve the problem and they tried to understand it instead of trying steps.

V. CONCLUSION

This study showed an analysis of how students interact with help in a tutoring software environment, in a qualitative way. We concluded that Guessing (18%) was the main behavior that was not expected in the ideal help-seeking behavior with the Wayang Outpost system. We suggest that the last hint should not be accessible through the "HELP" button and should be reached by another button in the system. In this way, the function of "HELP" button only has the function to show hints and provide help. It can avoid students "clicking through" hints and only waiting for the answer. It can also "motivate" students to try to use their own steps to solve the problem after they had seen all hints.

A quantitative analysis should be conducted in the future to link students' pre test and post-test performance with their hint use behavior in the Learning Hut. The future we would like to ask how to motivate proper help-seeking behavior in order to enhance learning.

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