Identifying student difficulty in problem solving process via the framework of the House Model (HM)

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Abstract. Recently, many students have been losing their interest in physics. One of the essential reasons why students look away from physics is the fact that they face difficulty in solving physics problems. Since mechanics is a fundamental subject in physics, many researchers have studied how students learn mechanics and solve problems related to mechanics. However, there is little research on the students' specific difficulties in the process of problem solving. This study investigated degree of students' difficulties in process and the core sources of these difficulties. 24 university students who majored in physics education participated in this study. We have developed a framework, House Model (HM), for helping and analyzing students' problem solving. We found that students felt greater difficulty in planning and executing steps than in visualizing, knowing and finding steps. As the problems grew in difficulty, this pattern became more distinct. We also found the sources of the students' difficulties and discussed the educational implications of these results.

Keywords: problem solving, student difficulty, mechanics, House Model (HM)
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INTRODUCTION

Students often say, "Physics is too difficult to study." This is one of the essential reasons why students look away from physics [1]. Whether students are majoring in physics or not, they have difficulties in solving physics problems. In many cases, despite having the knowledge to solve a problem, students can not apply this knowledge and they fail to solve the problem [2].

For helping students solving problem, many studies supposed a problem solving process. Polya introduced the four-step problem solving process in his paper, 'How to solve it?' According to Polya, these four processes in solving mathematical problems are the understanding of the problem, devising a plan, carrying out the plan, and looking back [3]. In the case of physics, Larkin maintained a four-step process: describing the problem, planning a solution, implementation, and checking the result [4]. Mechanics is a fundamental subject in physics. The importance of mechanics is the reason that a large number of researchers have investigated the issue of solving problems in mechanics. Recently, Heller illustrated five stages in problem solving: focus on the problem, describe the physics, plan the solution, execute the plan, and evaluate the answer [5]. Reif suggested three steps in solving mechanics problems: analyzing the problem, constructing a solution, and checking [6].

Comparing experts with novices and solving mathematical problems represent the large majority of the research related to solving mechanics problems. Many studies depend on interviews and thinking aloud to identify the problem solving process. These methods are appropriate for determining individual characteristics, but are limited in their ability to illustrate entire learners' processes.

We defined 'student difficulty' as the psychological condition aroused by students' perceived gap between the present level and the expected level of content, teacher, context and evaluation in a class [7]. Although studies on 'student difficulty' are more generalized than before, little research exists on student difficulty in the problem solving process. We have developed a special framework, the House Model (HM), for analyzing student difficulty when solving mechanics problems. We try to determine student specific difficulties in a given step when they solve mechanics problems, and investigate the reasons why students feel difficulties in this step. We also try to determine if any change in patterns of student difficulty exist between easy and challenging problems.

RESEARCH CONTEXT

Methodology

24 university students majoring in physics education and enrolled in an upper-level mechanics class during Semester 1 in 2008 took part in this study. They consisted of 11 sophomores taking the course for the first time and 13 juniors or seniors who had taken the course at least two times. The textbook was Symon Mechanics [8]. The class had two lectures (75min) a week with the professor, and one recitation (60min) a week with three teaching assistants. Student had to submit a weekly report [9] as a homework assignment and solved 4~5 problems every week. Homework problems included the exercise problems in the textbook [8], calculus-based introductory physics problems, and new problems created by the instructors.

Homework problems were composed of 2~3 traditional problems, one House Model (HM) problem, and one group problem. Students were also required to submit an Exercise Self Report as homework. We investigated the degree of difficulty in solving problems from the Exercise Self Reports; next we call 'overall score of difficulty'. Every week, we proposed a fresh problem created by the instructors or a difficult exercise problem from the textbook as a HM problem. When students solved a HM problem, they were required to check the degree of student difficulty at each step. During the semester, the total number of HM problems was ten. We analyzed 10~20 students' HM reports (see Fig.1) every week. From analyzing the HM reports, we identified the student difficulties in the problem solving process. We had originally intended to analyze the students' responses related to the checking step, but lacked sufficient data to do so as many of the students did not rank their level of difficulty for this step.

We wanted to answer the question, 'When a student solves a mechanics problem, which step is difficult?' To obtain the answer to this question, we utilized the HM and analyzed ten HM problems (122 answers) by ANOVA. Then, we operated Tukey's test for post hoc comparison. Thus, to find out the change of pattern between easy and challenging problems, we divided the problems into two groups by overall score of difficulty, one consisting of the two easiest problems and other consisting of the two most difficult problems among the ten HM problems. Finally, to know the source of student difficulty, we analyzed weekly reports and Exercise Self Reports. In addition, we interviewed three students (Peter, Kevin, James; these are fictitious names) enrolled in this mechanics class.

House Model (HM)

The House Model (HM) is a new method of physics problem solving that we developed in 2004 [10]. The HM has two purposes: (1) to help students solve problems, as a good problem solving model; (2) to help teachers and students to identify which step is causing difficulty for the student. Since students traditionally have felt difficulty in solving mechanics problems, they need a concrete guide. While it would be beneficial to know the entire process of the students' problem solving at a glance, previous methods are in linear and mechanical forms. Thus, we developed the HM, which has a visualized structure and a natural process. The HM's order for solving a problem is generally from top to bottom (①Visualizing, ②Knowing, ③Finding, ④Planning, ⑤Executing, ⑥Checking); in some case, ①~③ are able to be exchanged in order and ④ and ⑤ can be united. In the HM, we provide a blank for each step for students to check degree of their difficulty, from 0 (never difficult) to 3 (very difficult).

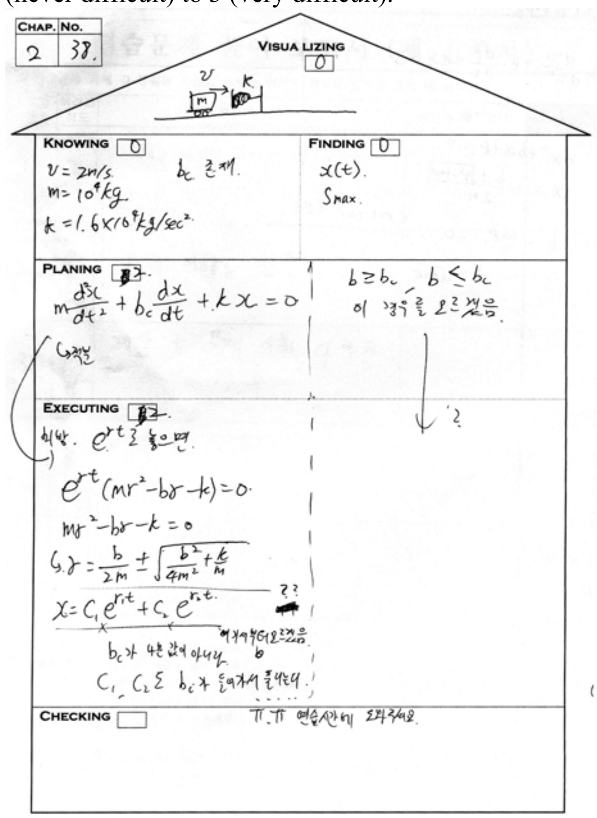

FIGURE 1. This is an example of a House Model report. The HM is a visual problem solving method. We asked students to rank their degree of student difficulty for each step in the process of solving mechanics problems. For instance, in Figure 1, a student ranked 0 in the difficulty of visualizing step since he could draw the problem situation. However, he had difficulty (ranked 2) in planning step.

RESULTS

Degree of student difficulty in the process of problem solving

Figure 2 shows how students have difficulties during each step of the problem solving process. As we can see, the executing step is the most difficult step, and the planning step is the second most difficult step. Thus, the difficulty in visualizing, knowing and finding steps are similar, and lower than those in executing and planning.

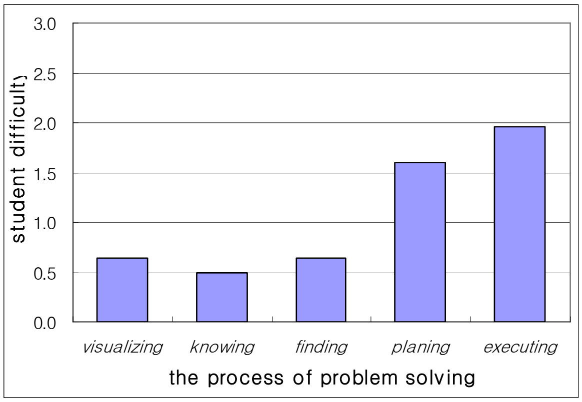

FIGURE 2 Average difficulty of each step in the ten HM problems. Difficulty in the executing step is the highest; planning is the second highest. The others represent a similar degree of difficulty (0=never difficult, 1=a little difficult, 2=difficult, 3=very difficult).

The results, which we analyzed by ANOVA in α=.05, show that differences among student difficulties in the steps are significant. For a more detailed analysis, we conducted Tukey's test as post hoc comparison. We found that the students' difficulties in the visualizing, knowing and finding steps are rarely the same. Thus, the degree of student difficulty in the planning step is higher than that in the three other steps and the degree of student difficulty in the executing step is higher than that in the planning step.

Through interviewing three students and analyzing weekly reports and Exercise Self Reports, we identified the reasons why these differences in the degree of student difficulty occurred as follows.

The first source is a lack of mathematical skill. In this type, students said that they felt difficulty in the executing step. Through conducting individual interviews, the Exercise Self Reports and the weekly reports, we found that most of the students had difficulty understanding the differential equation and approximation used on the Taylor or Fourier series. Since the students did not learn these mathematical skills until university, they were not adept at utilizing these skills.

The second source is a lack of physics knowledge for solving a specific problem. These kinds of physics knowledge include theory, concept and equation. In this type, students said that they felt difficulty in the planning step. Some students did not possess the necessary physics concept for solving a mechanics problem. Some others possessed the required physics knowledge, but could not connect their previous knowledge to a particular problem situation

In some cases, a lack of understanding of the situation in the problem is a source of student difficulty. In this type, students said that they felt difficulty in visualizing, knowing and finding steps. Some of the students did not know the physics terms being used or could not interpret the problem text because of poor English ability. Since most of the participants were relatively strong in their command of physics and English, few students experienced difficulty in these steps.

Comparison student difficulty between in easy and challenging problems

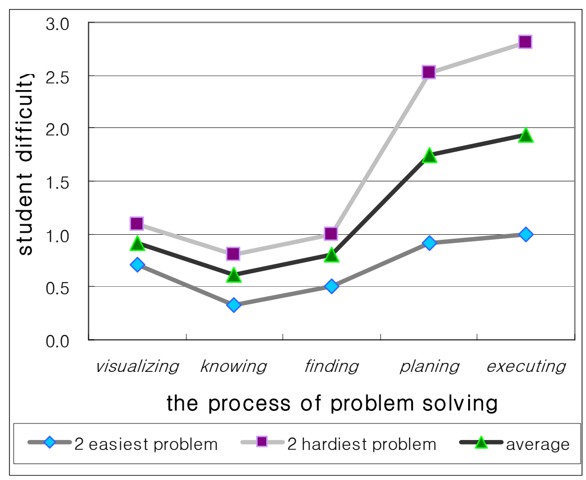

FIGURE 3 The degree of student difficulty in the process of problem solving. As the problems increase in difficulty, the degree of student difficulty in the planning and executing steps increases (0=never difficult, 1=a little difficult, 2=difficult, 3=very difficult).

As we stated in the methodology section, we also examined the degree of difficulty in solving problems by Exercise Self Reports. Figure 3 shows how the pattern of student difficulty changes between easy and challenging problems. Whether a problem is easy or not, the degree of difficulty in the visualizing, knowing and finding steps rarely change and as ever the planning and executing steps display a high degree of student difficulty. However, as the problems increase in difficulty, the students' difficulties in the planning and executing steps increase. In the t-test results, the difference of student difficulty in executing step was 1.80, and it showed largest value among difference of all step. The difference of student difficulty in planning was 1.57. The difference of student difficulty in visualizing step (difference=0.57) was smaller than executing (difference=1.80) and planning (difference=1.57) steps, however difference of student difficulty in the visualizing step shows significant difference, too. On the other hand, difference of student difficulty in the knowing and finding steps do not represent significant value.

Via analysis of the interviews and the Exercise Self Reports, we knew that these differences originated in the characteristics of challenging problems. In challenging problems, students cannot process the visualizing step until they understand the conditions and ascertain a proper representation. Thus, challenging problems require an understanding of high-level physics concepts such as forced harmonic oscillation, orbital motion, effective potential and Rutherford scattering. The challenging problems sometime have hidden conditions and complex sub problems. These problems disturb the students in devising planning. In addition, challenging problems require high-level mathematical technique and strong ability at calculating complex equations.

The Case of Student difficulty in the process of problem solving

8-week HM problem

a) Discuss the types of motion that can occur for a central force

$$F(r) = -\frac{K}{r^2} + \frac{K'}{r^3}$$

assume that K>0, and consider both signs for *K'*

b) Solve the orbital equation, and show that the bounded orbits have the form (if $L^2 > -mK'$)

$$r = \frac{a(1-\epsilon^2)}{1+\epsilon cos\alpha\theta}$$

c) Show that this is a precessing ellipse, determine the angular velocity of precession, and state whether the precession is in the same or in the opposite direction to the orbital angular velocity.

FIGURE 4. 8-week HM problem. Most of the students felt difficulty in solving this problem; overall score of difficulty=3.53 (1 is min.; 4 is max.).

The 8-week HM problem (see Fig.4) was one of the most challenging problems. Three interviewers (Peter, Kevin, James) said they could not solve this problem. They sought for useful textbooks or asked classmates for help. James checked his difficulties as follows: visualizing (3), knowing (2), finding (3), planning (3) and executing (3). He said, "I don't understand well the central force and effective potential. I could not understand the problem situation." Peter checked his difficulties as follows: visualizing (0), knowing (0), finding (0), planning (2), and executing (2). He said, "The process to find a proper equation is difficult. Even after solving this problem, I don't know its physical meaning." Kevin checked his difficulties as visualizing (0), knowing (0), finding (1), planning (2) and executing (2). He remarked, "It is too difficult for me to substitute a variable in differential equation." We found that student difficulty in the HM steps was related to the source of difficulty that students identified.

CONCLUSIONS & IMPLICATIONS

When university students solve mechanics problems, they feel the greatest amount of difficulty in the executing step and the second greatest amount of difficulty in the planning step. Students feel that visualizing, knowing and finding steps are easier than executing and planning steps. Whether a problem is easy or not, this pattern is maintained. However, as problems become more challenging, difficulties in planning and executing steps increase. The sources of these difficulties originate from a lack of essential physics concepts, and lack of mathematical skill.

This study is a preliminary stage, however, the result of this study could give basic ideas how to find and address a student difficulty in problem solving process. Further research needs to include more extensive analyses of collected data and exploring student responses to HM and new approaches designed to address the student difficulty.

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REFERENCES

1. C. Williams, M. Stanisstreet et al. *Physics Education* **38,** 324-329 (2003)
2. J. Tuminaro and E. F.Redish, "Understanding students' poor performance on mathematical problem solving in physics." *in AIP Conference Proceeding 2004*
3. G. Polya. *How to solve it?.* Princeton Univ. Press (1957)
4. J. H. Larkin. Skilled problem solving in physics: A hierarchical planning model. University of California, Berkeley (1978)
5. K. Heller and P. Heller. *The Competent Problem Solver*. University of Minnesota, 1992.
6. F. Rief, *Understanding Basic Mechanics*. NY;John Wiley & Sons Inc. (1995)
7. S. Lee, Master Thesis, Seoul National University (2006)
8. K. R. Symon. *Mechanics 3rd/ed*. Addison-Welsey Publishing Co. (1971)
9. E. Etkina. *Science Education*, **84**, 594-605 (2000)
10. T. Byun, S. Lee and G. Lee, "House Model: new model in solving physics problem" *in Proceeding of the 46th KASE Conference 2004*