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Analyzing Cognitive or Non-Cognitive Factors Involved in the Process of Physics Problem Solving in an Everyday Context

- An Effort for Sucessful Problem Solving in an Everyday Context -

Jongwon Park

(Chonnam National University)

ABSTRACT

In the previous study, six factors which could disturb students' problem solving in an everyday context were identified and discussed. In this study, teaching materials to help students overcome those disturbing factors for successful problem solving in an everyday context were developed and applied to twenty-nine grade 10 students, and the effects of teaching materials were analyzed. According to the analysis of the correlation between the performance in everyday context problem solving and the benefit from the teaching materials, it was found that students who received the help from the teaching materials showed better performance with statistical significance. And students noted that teaching materials were helpful for them to solve the physics problems. Analyzing the overall performance of students in solving the everyday context problem, students in the experimental group showed better performance than the control group and this performance difference was larger among low-score students in school science testing. However, these differences were not statistically significant because the sample size was small. And, based on the analysis of interviews with students, it was also found that some students who showed low performance might not receive help from the teaching materials because the materials were too complex to be read easily, or because the basic concepts needed to solve the problem were not understood. Therefore, the results obtained from the interviews will be used to design more effective teaching for problem solving in an everyday context.

Key words: physics, problem solving, everyday context, interview, teaching material

I. Introduction

Everyday contexts in physics teaching and learning have been emphasized in the 7th Korean National Curriculum (MEHRD, 1997).

> "Physics should be learned in everyday contexts that can arouse students' interest and curiosity, for instance, in the context of sports, transportation, amusement parks, music, household electric appliances, communication, medical treatment…" (MEHRD, 1997, p. 347)

Wilkinson (1999b) introduced and reviewed various context-based physics courses. The LCP (Large Context Problem) approach in Canada, Applications-led approach in Scotland (UK), ECL

*Received on 30 July 2004 **Jongwon Park(jwpark94@chonnam.ac.kr)
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(Event Centered Learning) in Brazil and UK, SLIPP (Supported Learning in Physics Project) in UK, and the VCE (Victorian Certificate of Education) physics course in Australia (Wilkinson, 199b) are examples of context-based learning materials.

Literature have shown various positive effects of everyday context on physics learning such as improvement of conceptual understanding, motivation, and interests (Schwartz, 1999; Ramsden, 1997; Lubben *et al.*, 1996; Treagust, 1993; Baker & Miller, 1999), or increase of the number of students enrolling in physics courses (Whitelegg and Parry, 1999; Wilkinson, 1999a).

And many studies have shown students' preferences for everyday context when they learn science or physics (e.g., Dlamini *et al.*, 1996). In Korea, Choi and Song (1996) also observed that many Korean students preferred an everyday context in learning science over a context of laboratory or natural phenomena.

However, in relationto problem solving, the effect of everyday context on students' problem solving have shown different results, according to the different tasks (Toh & Woolnough, 1994). For instance, Rennie and Parker (1996) and Johnson-Laird *et al.* (1972) observed that many students performed better with real-life problems which were familiar to their everyday life, when compared to abstract ones. But, according to Song and Black (1992), students showed no different performance between everyday or scientific problems when scientific concept application was required to solve the problems. And Gomez *et al.*, (1995) observed that students' performance varied according to the contents involved in the problems. Park and Lee (in press) also did not observe any consistent effect of context on physics problem solving.

Therefore, it can be said that everyday context may affect students' problem solving positively in some cases, but not in other cases. Therefore, Park and Lee (in press) assumed that additional factors may interfere with students' successful problem solving, investigated students' processes of solving the problems in an everyday context, and found out that the following six factors could impede the successful solving the everyday context problems

- some students try to import personal/subjective judgments which are not presented in the problem.
- some students fail to grasp the situation or context of the problem.
- some students do not make sense of the given information, because the numerical value of information has an undefined range or is not in a simple format, such as that of an integer.
- some students miss some important descriptive information in long sentences.
- some students are concerned about information that is irrelevant to solving the problem.
- some students experience difficulties in solving a problem because the form of the problem is different from that usually used in school tests.

Then, how can we help students overcome these disturbing factors for successful problem solving in an everyday context? This is the main question of our study and as such is closely connected to previous research. That is, while previous research (Park and Lee, in press) focused on identifying and analyzing cognitive or non-cognitive factors which could interfere with students' physics problem solving in an everyday context, this study focused on an effort for successful physics problem solving in an everyday context by helping students overcome the disturbing factors.

To do this, I developed teaching materials explaining the negative effect of the disturbing

factorson physics problem solving in an everyday context by introducing and analyzingthe cases in which students failed to solve the everyday problem because of those disturbing factors. And I investigated the effect of teaching materials on physics problem solving in an everyday context by letting students solve the everyday context problems after applying the teaching materials to them.

Ⅱ. Procedure

Subjects

To compare the performance of students to whom teaching materials were applied with that of students in a control group, 2 classes of grade 10 (29 students in an experimental group and 31 students in a control group) were randomly selected from a high school located in Yoesu, Korea.

To check out whether two groups were identical in the scientific ability, their mid-term school examination score in science were compared. As a result, the difference of average scores of the two groups was not statistically significant ($t=1.424$, $p>.05$).

1st stage of the procedure

To help students overcome the disturbing factors found in the previous study (Park and Lee, in press), teaching materials were developed. In these materials, six cases in which students failed to solve the physics problem in an everyday context because of the disturbing factors were introduced, and an explanation was given of how those factors affected problem solving negatively. These materials were applied to the experimental group for about forty minutes. An example of these materials is attached in the appendix.

2nd stage of the procedure

To investigate students' performance of physics problems in an everyday context, 4 problems were developed (Figure 1). The contexts of each problem are, 'car accident', 'sky diving', 'door bell', and 'a pole jump in sport'. These problems were administered to the experimental group and the control group, equally. However, for the experimental group, a checklist to help students remind them of the six disturbing factors explained in the teaching materials was presented (Figure 2). That is, in the checklist, a brief guideline of six cases for overcoming the disturbing factors were suggested. Therefore, students referred to the checklist during solving the problems. After solving a physics problem, students indicated whether the teaching materials helped them solve the problem or not. And, if they answered 'yes', I let them choose which among the 6 cases in the teaching materials were especially helpful for solving everyday context problems. To solve the four problems, it took about 30-40 minutes in each group.

3rd stage of the procedures

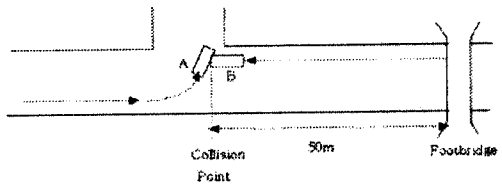
In this stage, the researcher interviewed five students of the experimental group. This interview was taken to investigate the effect of teaching materials on problem solving more deeply. To obtain the results systematically, the following 4 cases were selected for interviews:

- case in which student solved the problem correctly, and responded that the teaching material helped his/her problem solving

In an intersection without traffic signals, car A turning left collided with car B which was running straight. Following diagram and information are obtained from a policeman.

〈Traffic Rules〉
* The speed limit of this road is 19.4m/s (70km/h)

〈Information obtained by a policeman〉
* When car B passed under the footbridge, car A started to turn left.
* After passing under the footbridge, car B decreased speed continually.
* After 2.5 seconds when car A started to turn left, car A collided with car B.



Choose all correct answers in the followings:
(1) The average velocity of car B from the footbridge to collision point was 20m/s
(2) The instantaneous velocity under the footbridge exceeded 20m/s
(3) Car A caused the traffic accident.
(4) Car B caused the traffic accident.

Fig. 1. Example of physics problem in an everyday context

CHECKLIST

2. Do you grasp the situation of the problem well?
→ If you read the problem carefully, you can understand the situation of the problem, because in many cases, important clues are included in the description of the situation. If you grasp the situation well, there are frequent cases where the problem is easily solved.

Fig. 2. Example of checklist presented to the experimental group

- case in which student solved the problem correctly, but responded that the teaching material did not help his/her problem solving
- case in which student failed to solve the problem even though responded that the teaching material helped his/her problem solving
- case in which student failed to solve the problem, and responded that the teaching material did not helped his/her problem solving

Table 1 describes major questions used in the interviews.

Table 1. Major questions used in the interviews

· Is this problem easy or difficult to solve?
· You solved the problem correctly and said that the teaching material helped your problem solving. Can you explain more concretely how the teaching material helped your problem solving?
· You solved the problem correctly, but you said that the teaching material did not help your problem solving. Can you explain the reason?
· Your solution is not correct, but you said that the teaching material helped your problem solving. Can you explain why you failed to solve the problem even though the teaching material helped your problem solving?
· Your solution is not correct and you said that the teaching material did not help you. Can you explain the reason?

Ⅲ. Results

Students' responses about the teaching materials

To remind the students of the teaching materials developed for helping them overcome the disturbing factors, a checklist was presented to those in an experimental group. On the checklist, a brief six guideline for overcoming each disturbing factor was suggested. And I let students refer to the checklist when solving the physics problems in an everyday context. After solving each physics problem, additional questions about whether the teaching materials helped his/her problem solving or not were asked. Then, students answered each question by marking a check one of five responses 'strongly yes', 'yes', 'I don't know', 'no', and 'strongly no'. And their markings were converted to a five-point scale, that is, 2, 1, 0, -1, and 2. Because there were 4 problems, I could obtain students' responses to the checklist four times. As a result, the highest score was 8 and the lowest score was-8.

According to the analysis of students' responses, their average score on a five-point scale was 2.52. Compared to 0 scale, which is the neutral response, this difference is statistically significant ($t=5.55$, $p<.001$). This means that students generally thought the teaching materials were helpful for solving physics problems in an everyday context.

When students answered 'yes', they were asked again which explanations about the disturbing factor in the teaching materials were helpful to solve each physics problem. The total number indicated by students was 138 when twenty-nine students solved 4 everyday context physics problems. Therefore, 1.2 explanations in average were indicated as helpful for any one student solve one physics problem in an everyday context.

Table 2 shows the number of explanations indicated by students according to the disturbing factors. As a result, the most helpful explanation was about the second factor, and the least explanation was about the first factor. That is, students thought that explanation about the grasp of the situation of the problem was the most helpful (figure 2), and the recommendation of the objective judgment when solving everyday context problems was the least helpful for them. And for other explanations, students responded to them uniformly.

Table 2. The number of explanations indicated as helpful by students according to the disturbing factors

factor	1	2	3	4	5	6
number	14(10%)	35(25%)	24(17%)	20(14%)	20(14%)	25(18%)

Correlation between the performance score and the responses on the checklist

Did the students who thought the teaching materials were helpful obtain the high score of performance in solving the everyday context physics problem?

To answer the above research question, I analyzed the correlation between the performance score and their responses on the question asking whether the teaching materials helped their problem solving or not. According to Figure 3, the correlation was high (Pearson Correlation Factor = 0.42), and this result was statistically significant ($p<.05$). This means that, even though a specific teaching material did not help all students, the more students were helped by any particular teaching material, the better they could solve physics problems in an everyday context.

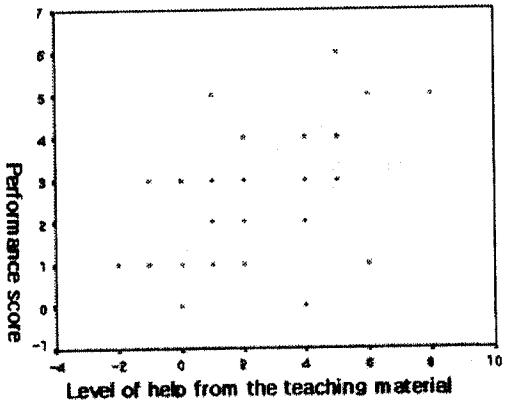


Fig. 3. Correlation between the performance of problem solving in an everyday context and the level of help from the teaching materials

Comparison of the students' performance between the experimental group and control group

According to table 3, the average score of the experimental group is higher than the control group, however, this difference in the average score was not statistically significant. This may be because the sample size was not so large. But, other possible reasons that the difference in performance is not statistically significant will be discussed in the final section analyzing interviews conducted in the 3rd stage of this study.

Table 3. Average score of experimental group and the control group

Experimental Group (N=29)		Control Group (N=31)	t
2.4	>	2.1	0.83*

* $p>.05$

To check out the effects of teaching materials on problem solving more deeply, I divided students into two groups; the high-score group and the low-score group in mid-term school examinations for the science subject. According to table 4, the average score of the high-score groups were nearly the same between the experimental group and the control group. But the

average score of the low score-group in the experimental group was higher than that of the low-score group in the control group. But, even though this difference is more than two times as large as the result in table 3, this is not a statistically significant difference. This may be also because the sample size is not so large. Other reasons will also be discussed in the later section.

Table 4. Average score of the high-score and low-score groups in the experimental and the control groups

	Experiment Group (N=29)		Control Group (N=31)	t
High-Score of School Exam	2.7	≈	2.7	0.05*
Low-Score of School Exam	2.2	>	1.5	1.23*

* $p > .05$

Interviews about the effects of a checklist on physics problem solving

In these interviews, I interviewed students about whether the teaching materials benefited their problem solving in an everyday context or not, and asked the reasons for their answers. Followings are the major responses of the students:

· Case in which student solved the problem correctly, and responded that the teaching materials helped his/her problem solving

In this case, some students responded that the teaching materials helped them because it made them think about the problem situation objectively, or because they could read the problem carefully, even though the presented problem situation looked complex.

Student C: In many cases, when the problem was presented like this (like everyday context problem), I usually judged the problem solution subjectively But, using this checklist, I could think objectively and this makes the problem easy.

Student B: At first, this problem looked complex... But I could treat this problem comfortably.
Interviewer: Why?
Student B: This (indicating checklist number2 described in figure 2) helped me.

· Case in which student solved the problem correctly, but responded that the teaching materials did not help his/her problem solving

In this case, students did not read the checklist to remind them of the teaching materials because the sentence in the checklist was too long.

Student E: I solved the problem without reading the checklist.
Interviewer: Why? Didn't the checklist help you?
Student E: The checklist was long and complex to read.

· Case in which student failed to solve the problem even though he/she responded that the teaching materials helped his/her problem solving

In this case, students tried to solve the problem referring to the checklist, however they failed to solve the problem mainly because they did not understand the major concepts needed to solve the problem.

Student A: I don't know the resistance well.
Interviewer: Can you understand the situation of the problem?
Student A: Yes, I can know the situation... But, I don't know about the resistant force in usual situation... Resistant force is... when it falls with terminal velocity I can not understand this meaning...

Interviewer: Did the checklist help you when solving the problem?
Student C: Yes. It helped me understand the problem.
Interviewer: Then, why did you fail to solve the problem even though you understood the problem well?
Student C: Because I did not know the formula well...
Interviewer: Then, how did the checklist help you?
Student C: This problem was long then, I usually read the problem here and there... but now I re-read the problem to check out whether major information was omitted or not.
Interviewer: Then, can you explain again the reason that you failed to solve the problem?
Student C: Impulse... I forget the method to derive the impulse... So, I did not know how to solve...

· Case in which students failed to solve the problem, and responded that the teaching materials did not helped his/her problem solving

Similar to the previous case, the students here also did not understand the major concepts needed to solve the problem. But, the difference with the previous case is that the students did not read the checklist because they felt that the problem was too difficult to solve.

Interviewer: Why didn't the checklist help your problem solving?
Student D: This part... about electricity... is difficult to me... I don't know about this well.
Interviewer: I said to read the checklist carefully when you solved the problem.
Student D: I did not care for the checklist.
Interviewer: Why?
Student D: Because the problem was too difficult... because I did not understand electricity well...

Ⅳ. Conclusion

Everyday contexts have been emphasized in physics teaching, learning, and problem solving in the literature. And it has also reported that many students, physics students, and physics educators in university preferred the everyday context in physics learning (Park and Lee, in

press). However, everyday context is not always helpful to students' problem solving; that is, other factors induced by the context itself could disturb students' problem solving. Therefore, it is necessary to find out how to help students to overcome such disturbing factors.

According to this study, it was found that students who received help from the teaching designed for students to overcome the disturbing factors showed better performance in problem solving in an everyday context. However, it was also found that some students did not receive help from the teaching because the teaching materials were too complex to be read, or because some students did not understand the major concepts needed to solve the problem.

Any teaching strategies for students' physics learning or problem solving can not help all students in all cases. Some students can not receive any help from the teaching strategies. In this case, an important point is to identify and find out the reasons. I believe that this kind of effort can give more concrete and effective means for improving the students' physics learning and problem solving in an everyday context.

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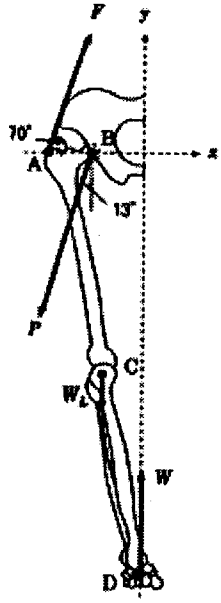
Appendix: An Example of Teaching Material

2. Sometimes, students often fail to understand the situation of the problem



(Example) The following figure indicates the forces acting on human leg when he/she is standing on the ground with one leg. And table indicates the 3 components of forces acting on each part of leg. (Here, body weight is W. And dot lines in the figure indicate the x-y axis, and all forces are on the x-y plane. And assume that the weigh of leg (W_L) is equal to 1/7W)

Force	Point	Direction	Magnitude
Muscle attract upward	A	70°	F
Pelvis push down leg bone	B	13°	P
Weight of leg	C	Downward	W_L=1/7W
Ground acts on leg	D	Upward	W

Considering the balance of forces, choose all formulasneeded to obtain the force F and P.

(1) $F\cos70^\circ - P\sin13^\circ = 0$ (2) $F\sin70^\circ + P\cos13^\circ = 0$
(4) $F\sin70^\circ - P\cos13^\circ - 1/7W + W = 0$ (4) $F\cos70^\circ + P\sin13^\circ + 1/7W + W = 0$

→In this problem, there are complex explanations about situation in which human leg is standing on the ground in the figure and the table. But, if you grasp that the situation of the problem is related to the balance of forces, the problem gets to be easy to be understood.

→In the case of real or everyday context problem, sentences and explanations can be long or complex to describe the real situation concretely. But, if you grasp the situation of the problem, you can easily find out the concepts needed to solve the problem, and as a result, you can solve the problem easily.