T. Hirashima et al. (Eds.) (2011). Proceedings of the 19th International Conference on Computers in Education. Chiang Mai, Thailand: Asia-Pacific Society for Computers in Education

Kit-Build External Expression of Problem Solving Process in Physics Learning

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Abstract: Diagnosis of errors in problem solving process is very important to support learner's problem solving exercise. Although externalization of the problem solving process by a learner is a promising way to realize the diagnosis, this task is hard for a learner and it is very difficult to interpret the expression automatically for a computer system. In this research, we pay special attention to Kit-Build method to help this task. The expression made by the learner is diagnosed by comparing the ideal one, and the differences are targets of learning support. We have design and implemented a learning environment where a learner expresses his/her problem solving process with the provided parts and the expression is diagnosed. In this paper, results of a preliminary use of this environment are also reported.

Keywords: Problem solving process, External expression, Learning of physics, Kit-build method

Introduction

Problem solving exercise is an indispensable phase in learning where practice to use acquired knowledge is strongly required for learners. The exercise, however, is not always easy for learners even if they have already acquired necessary knowledge and difficult points in their problem solving are often different in each learner. Therefore, this exercise is one of the most important research topics in technology enhanced learning [1-3].

Diagnosis of errors in problem solving process is very important to support learners. Although externalization of the problem solving process by a learner is a promising way to realize the diagnosis [4, 5], the externalization itself is hard task for a learner and it is very difficult to interpret the expression automatically for a system. In this research, we pay special attention to Kit-Build method [6] where (1) an ideal expression of a problem solving process is prepared beforehand, (2) a set of parts is generated by decomposing the ideal expression, and then (3) the learner expresses his/her problem solving process by composing the parts. The expression made by the learner is diagnosed by comparing the ideal one, and the differences between them are targets of learning support. We have designed and implemented a learning environment where a learner expresses his/her problem solving problem by using these features.

In this paper, in Section 1, a model of solving process of a physics problem is explained. In Section 2, a learning environment that supports learner's externalization of his/her problem solving as kit-building is presented. Results of an experimental use of the learning environment are also reported in Section 3.

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1. A problem solving model of physics

Several investigations have already indicated that the problem-solving process is composed of four phases [7-9]. Then, they also insisted that “comprehension of a problem” and “planning a solution” are further more difficult phases than others. Therefore, these two phases are important targets to support by technology enhanced learning. In physics, Hirashima [9, 10] proposed a model where (I) “comprehension of a problem” is described as building a surface structure and (II) “planning a solution” is described as building a solution structure. In this research, we have designed and implemented a learning environment where a learner built the surface structure and solution structure as an external expression of his/her problem solving process by composing parts of the structures. In this section, the surface structure and solution structure are explained.

1.1 Surface structure

A problem usually includes several elements that are necessary to solve the problem. “Interpretation of each sentence” is a phase to extract the elements. Comprehension of a problem is a phase to make a structure composed of the elements. Surface structure is an expression of the structure built in the process. As an example, one surface structure of physics problem is described in Figure1.

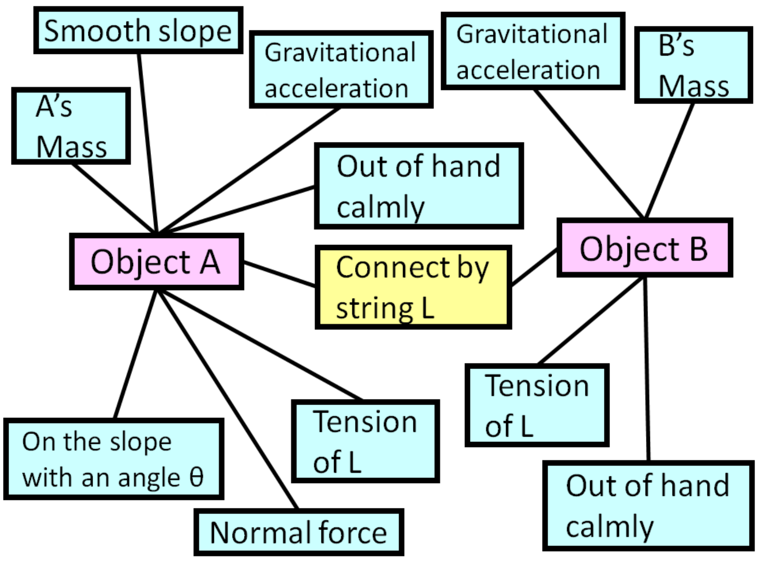

Figure.1: The example of surface structure

1.2 Solution structure

Physical attributes included in a phenomena are connected each other by numerical relations. By using the numerical relations, an answer of a physical problem is derived. Physical attributes included in a problem are described in a surface structure. The solution structure is composed of the elements in the surface structure (given attributes) and derived elements (derived attributes) by using the given one. Figure 2 is an example of solution structure. Several derived attributes are included in the solution structure. The derived ones are able to add to the original surface structure. The extended surface structure expresses more detailed comprehension of the problem through the problem solving.

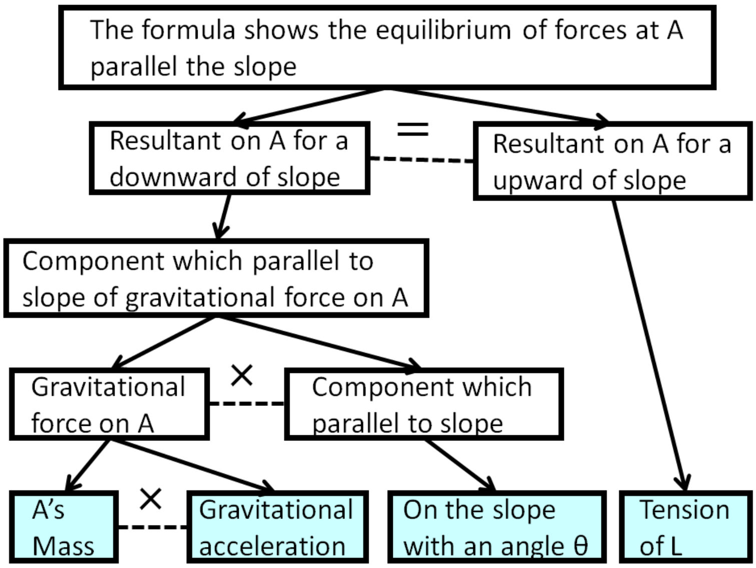

Figure.2: Solution structure

2. Learning environment

We have designed and implemented a learning environment where a learner built the surface structure and solution structure as an external expression of his/her problem solving process by composing parts of the structures.

2.1 Surface structure building

In the surface structure building phase, a learner is given a problem and a set of parts. By composing the parts, a learner is required to build a surface structure with drag & drop operation. When a learner clicks on a part in the interface, corresponding portion to the part in the problem is highlighted. By this operation, the learner confirms the meanings of the part. Because all parts are the same with the ideal one that is prepared beforehand, it is possible to overlay the ideal surface structure and learner's one, and if there are several differences, a learner is required to resolve them.

2.2 Solution structure building

In the solution structure building phase, a learner is required to build a solution structure by using provided parts. In the solution structure, not only given attributes that appear in the surface structure, but also derive attributes that are derived by using given and derive attributes. The interface provides a learner with those attributes and calculation operations. The given attributes and derived attributes are distinguished by color of the parts. When the solution structure built by the learner is not matched with the ideal one, the differences are indicated and the learner is required to dissolve the differences.

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3. Evaluation test

We conducted an experimental use of the learning environment. Because the activities are really new ones, it is indispensable to confirm that a learner is able to carry out the activities.

3.1 Experiment method

In this experiment, participants are six college students who belong to engineering course and have experience to learn physics in high school and college. The participants were required to solve two physics problems and to explain the solution as a pre-test. Then the participants conducted exercises with the learning environment. They solved three problems with the system. After the system use, they solved two problems and explained the solutions as a post-test, and then, answered a questionnaire.

3.2 Pre and post-test

In the pre and post-test, participants are required to solve two problems. In each problem solving, they derived an answer of the problem first. And then, they listed all formulas that were used in the problem solving and explained the reason why the formulas were able to apply in the solution. One of two problems is common in the pre-test and post-test and it is also used in the system exercise(Problem A). Another problem in the two is different between pre-test and post-test and the same problem is not used in the system exercise(Problem B is in the pre-test, and Problem C is in the post-test).

3.3 Results use

The participants took 32.8 minutes in average to complete three problems. In the process, the environment detected 57 errors in structure participants made, that is, a participants made 9.5 errors in this use. The errors were indicated to the participants and all of the errors were dissolved by the participants by themselves.

3.4 Results of tests

Regarding Problem A, four participants out of six gave a correct answer in the pre-test and all the participants gave a correct answer in the post-test. Moreover, as for Problem B and C, all participants gave a correct answer. Therefore, the participants had had enough ability to solve physics problems in a usual way.

3.5 Questionnaire

Table 1 shows results of questionnaire. Most of participants agreed that the structures that they built in the system use were fit for their comprehension and building surface structure was useful to understand a problem. As for solution structure, more than half participants positively answered. All participants agreed that the exercise was useful learning activity. However, more than half participants indicated that feedback from the system was not enough.

Table 1. Results of questionnaire.

	Strongly agree	Agree	Disagree	Strongly disagree
The structures were fit for your comprehension	2	3	1	0
Building of surface structure was useful to understand the problems	3	2	0	1
Building of the solution structure was useful to understand the solutions	2	2	2	0
The exercise was useful for learning	1	5	0	0
The software was easy to use	0	4	2	0
Feedback from the software was enough to help the exercise.	1	1	3	1

4. Conclusions

In this paper, we have proposed a framework of external expression or problem solving process composed of surface structure and solution structure. We then have introduced a learning environment where a learner builds his/her external expression of problem solving process in physics as combination of provided kit. Through an experimental use of the learning environment, we have confirmed that learners were able to complete the external expressions and they thought the activity was useful for learning.

The experiment was small in participant numbers and short in use time. Besides, participants were not practical learners. Therefore, it is a preliminary one to confirm the possibility of our approach. Because the results suggested that the framework would contribute to more advanced learning, we are planning larger size and more sophisticated designed experiment. Before the experiment, then, we have to improve the learning environment as software, especially from the viewpoint of usability.

Acknowledgements

We'll express our deep sense of gratitude for all people who gave us much useful advice and other helps here.

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