DEVELOPMENT OF SIMULATION TOOLS TO ENHANCE THE REAL-WORLD CONNECTIONS FOR ACTIVE LEARNER

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ABSTRACT

A new utility of computer graphics (CG)-based simulation in the class is discussed in connection with the Active Learning through the activity in the physics class of National Institute of Technology, Tsuruoka college. It is proposed to utilize the simulation to connect the learner's schema in daily life with the system learned in physics class. Especially, it is aimed to effectively introduce the concept of idealization in the fundamental physics for learners. This topic is closely related with how to motivate the learner toward the active and independent learning beyond the memorization-based learning like pattern matching.

KEYWORDS

CG simulation, Conceptional understanding, Real-world connection, Standards: 8, 10,11

INTRODUCTION

How to effectively utilize ICT tools, in connection with the Active Learning (AL) (Standard 8) and related teaching competence (Standard 10) with learning assessment (Standard 11), is one of important and hot topics in modern engineering education. From the teacher's side, these tools are expected to give a variation for the learning, enhancing the independence of learners (Khoon, Leong, Joo & Anwar, 2021), (Onufrey, Berglund, Bienkowska, Magnusson & Norrman, 2019). Related to this topic, computer graphics (CG)-based simulation tools, including virtual/augmented/mixed reality technology are now widely introduced in the classes to support the learner's understandings (Hatchard, Amin, Rihawi, Alsebae & Azmat, 2019), (Yang & Cheah, 2020), (Yu & Li, 2020).

One of existing problems in engineering education, especially in the study of theory, is that learners are often missing a link among theoretical contents and the real situation, which may be experienced in the laboratory activities or in the real life. In this case, the learning may become just a pattern matching or memorization to gain the score for the credit, resulting in a passive attitude in the class. Furthermore, in such a situation, the motivation for the learning may be lost. Physics is one of subjects that such a situation is frequently seen. In the Physics Education Research (PER), a lot of effective teaching methods have been developed with the assistance of the cognitive science to overcome the above problem (Redish, 2003), (Wieman, 2007). While the interactive and learner-oriented teaching methods have been developed, the use of the CG-based simulation tools is one of new stream in the PER (Wieman & Perkins, 2006), (Granholm & Ohnishi, 2018), (Suzuki, Kazi, Wei, DiVerdi, Li & Leithinger, 2020).

In this paper, we will argue about what kinds of essences or tricks are necessary to realize an active learning environment with CG-based simulation tools, focusing on the introductory physics for the engineering from the activity in National Institute of Technology, Tsuruoka college (NITTC). In the AL, what the student does is actually more important in determining what is learned than what the teacher does, as suggested in (Shuell, 1986) (Murphy & Kontio, 2018). On this point, our insight discussed below is brough through the interactive communication with the students by interview, and hence, our study would be useful in many classes, although we discuss about our experience in physics class.

OUR ACTIVITY

National Institute of Technology (NIT) called KOSEN in Japan has a hybrid educational system of high school and college with the five year's curriculum, which are extended with the two year's advanced course for a bachelor's degree. In Japan, there are more than fifty NIT colleges, and all the NIT colleges commonly have fundamental physics classes as a basis for the engineering.

In NITTC, the physics class starts from the second grade with algebra-based contents (which are standard high school level in Japan), and are continued up to 4th grade, migrating to the calculus-based contents of the introductory university level. Each class consists of lectures, laboratory works, team discussions and e-learning by using LMS. To evaluate the conceptional understandings of the learners, the survey by using the Force Concept Inventory (FCI) has been introduced. It should be noticed that this survey is not for the assessment of the course, but for the feedback to prove our class overall to determine whether the instruction we are delivering is meeting our goals. The FCI is one of major surveys to measure the conceptional understandings about mechanics (Hestenes, 1992), (Redish, 2003). The FCI consists of thirty questions with multiple-choice format and the question 1 is shown in Fig.1 as an example. While we conduct the FCI, we also have another survey which are introduced as a review exercise in the class. This review exercise asks practically the same thing with the FCI questions but with the format answering numerical values or algebraic format as shown in Fig.1. We have analyzed these two surveys to evaluate the gap between the conceptional understandings and problem-solving techniques.

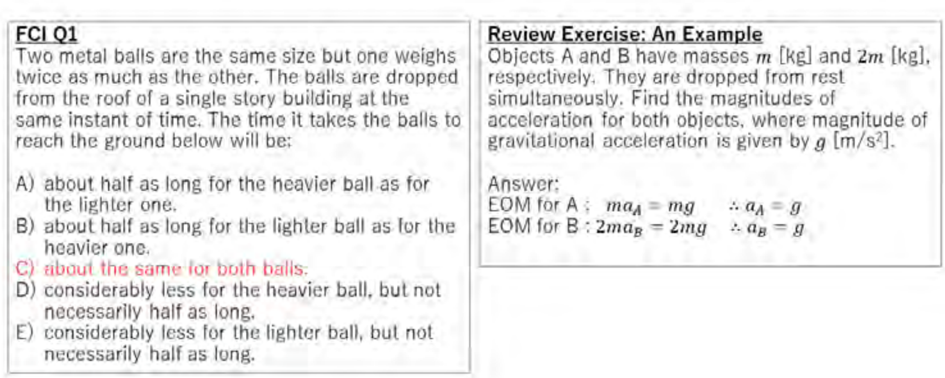

Figure 1. Question 1 in the FCI and the corresponding review exercise.

In this paper, we show the survey conducted in 2017-2019 for the class, consisting of 37 students belonging to electric and electronic engineering course of NITTC. The result is shown in Table 1. We can see a gain of total correct answering rate in the FCI year by year. Then, our instruction goes well in one sight. Total tendency of the present FCI result is nothing special compared with previous studies (Ohnishi, 2022). On the other hand, the highest correct answering rate for FCI Q1 is seen at second grade. This may be because the students learn about freely falling bodies at the second grade, and hence, many students remember the fact that is studied in class. When we look at the result of the review exercise related to FCI Q1, interestingly (from the viewpoint of teacher in charge, this is not interesting actually), the correct answering rate rises year by year. This result suggests that a certain number of students acquire the problem-solving skills year by year, but there is no gain in the conceptional understanding to the phenomenon, resulting in memorization-based learning.

Table 1. The correct answering rate for the question 1 of the FCI and the corresponding review exercise.

	2nd grade	3rd grade	4th grade
FCI Q1	84%	62%	68%
Review Exercise	73%	78%	84%
FCI (total)	35%	44%	46%

To investigate what happens more deeply, we had interview for students, who gave the incorrect answer for FCI Q1 and the correct answer for the corresponding review exercise. Some comments from the students are as follows:

- I know that the magnitude of acceleration for freely falling bodies does not depend on the mass of object, but I cannot image them. (Since you (the teacher) suggested that this survey is not related to the assessment of the class, I answered honestly along my sense.)
- It is a different activity to answer the questions along my sense with solving numerical or algebraic problems.
- There is no description that air resistance can be negligible in this problem.

These comments apparently indicate an isolation of their physical model or schema learned in class with the real world. Even if they know the correct answer, it is not connected with their schema constructed in daily life. An important thing is that this isolation is no matter for their daily life in many cases. What kind of trick or method is effective to improve this situation? In the AL environment, a learner is expected to have independent work with the own responsibility instead of teacher’s guidance (Kontio, 2015). Then, it is important to show the appropriate direction for the learning in the beginning with giving the attractive motivation.

LINKING THEORY WITH THE REAL-WORLD

Important awareness in our survey is that there is a huge jump, which may bring a confusion for learners, in the beginning of learning in physics. In the conventional way, the learning starts from an idealized system with mass point system. In the motion of freely falling bodies, air resistance is neglected. These situations are quite different from our daily experience. In our life, every object has a size and shape and may deform. Motion of object such as translation and rotation apparently seems to be affected by friction and air resistance. Thus, learning of physics for beginners starts from unknown world. Afterword, extra factors such as air resistance, size of object are introduced, and the treating world is getting closer to the real world with the increase of mathematical difficulty, as shown in Fig. 2. In this flow, the teacher implicitly expects that the learner finally combines its schema for physics with the real-life experience, however, not a few learners cannot achieve them.

To overcome these difficulties, we propose a new way of learning by using the CG-simulation for an appropriate starting point of learning. Since the CG simulation can reproduce the variety of situation by changing the parameters, we can visualize both the realistic situation and the idealized one, and continuously connects both situations. As shown in Fig. 2, then, we can transfer from the realistic situation, in which the learner has a feeling for the phenomenon, to the idealized situation, by seeing how the system is affected by each physical parameter. In other words, the CG-simulation can utilize as an assistant of “thought experiment”. The learner can think about what the idealization is and can understand the connection with the real world. This is a new possibility of the CG simulation, while we utilize the simulation to visualize the situation teacher wants to explain in many cases.

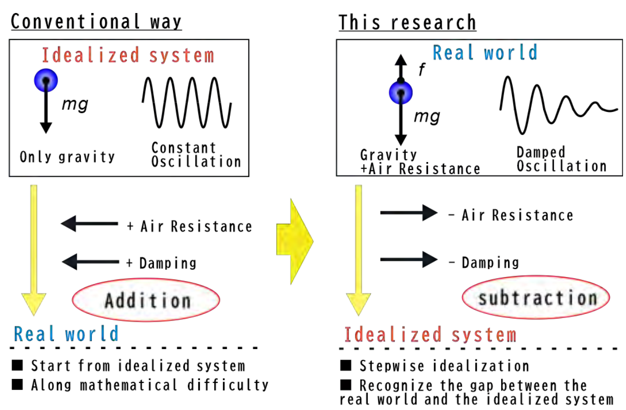

Figure 2. Direction of learning in conventional learning way (left) and the way proposed in this research (right).

The CG simulations to connect the real world and idealized system have been developed by using HTML5, and some of them have already been published in our site [Ohnishi, 2021]. An example of the developed simulation is shown in Figure 3. In this example, motion of two object on a slope can be compared, changing the strength of friction, mass, size, shape of objects, and so on. Hence, the learner can think about variety of situations, changing the parameters. In actual introduction of CG tools in class, we have interactive discussion among learners and with teacher, referring the Interactive Lecture Demonstrations method (Sokoloff & Thornton, 2001).

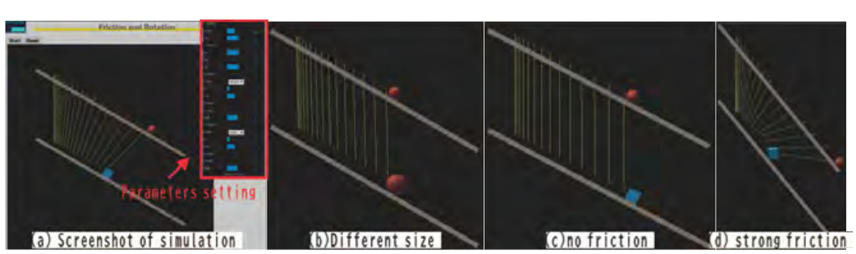

Figure 3. Screenshot of simulation for the motion of object on the slope.

As an example, the simulation given in Figure 3 is used to consider about how do size and shape of object affect to the motion on the slope. This topic is aimed to consider the idea of mass point, which does not have size and does not rotate. A typical flow of discussion is as follows: At first, the teacher indicates some situations, and the learners guess the result and its reasoning. Interestingly, even if the learners can guess the result correctly, its reasoning is incorrect in many cases. In the present case, many students think that the strength of friction depends on the contact area between the object and ground. In the second stage, we have a discussion among learners to compare the opinions. In the third stage, teacher show the case, which conflicts with learners' idea. If it is possible, the real demo is performed in this stage. After that, students consider whether they need to improve their schema or not. In our experience, it is better to change the implementation date until the second stage with third stage because the teacher can consider what should be proposed in the third stage carefully, basing on the learners' opinions. For the beginner, it is practically impossible to understand the idea of physics perfectly in this stage, but the learners can make an overlap between the real world and the idealized system in their schema. Furthermore, since the simulations are available on the web, it is always available in their independent work.

It should be noted that experiments at laboratory (or demo) is very important to improve or stimulate learners' schema since physics is an empirical science. However, experiments are not always easy to understand their meaning when they are technical and have errors, while such technical aspects with errors are inevitable in science. Furthermore, the time for experiments is limited in class. Hence, to motivate the beginner, experiments is not always the best option to learn the phenomenon. Video teaching materials, which record the phenomenon, is another option for learning. While they can use repeatedly, the situation is not able to change by users.

Since we do not have enough sets of simulations and coupled learning materials to argue the change of FCI score on the present stage, it is difficult to evaluate the effectiveness of the present method. However, we can see the rise of score in the survey about the real-world connection in preliminary. The questions are selected from the CLASS survey (Adams, et al., 2006). The questions consist of the following 4 questions.

A) Learning physics changes my ideas about how the world works.
B) Reasoning skills used to understand physics can be helpful to me in my everyday life.
C) The subject of physics has little relation to what I experience in the real world.
D) To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

The Pre-survey and Post-survey were conducted in 2022 at NITTC for 81 students of second grade in the learning of motion of object on slope. The answer is given in a value from 1 to 5 (1 for strongly disagree and 5 for strongly agree) for each question. It should be noted that the lower score is preferred only in the question C. The result is given in Table 2. Except the question B, we can see the positive shift in the average score. The decrease of score in question B may be because the beginners have less confidence about their opinions, especially they start to understand the difficulty of physics in the learning progress. Although we need longer term observation with developing learning materials, we have gotten positive feedback for our proposal on the present stage.

Table 2. The average score about the real-world connection given in the text.

	A	B	C	D
Pre-survey	3.56	3.55	2.18	3.06
Post-survey	3.88	3.32	1.82	3.55

SUMMARY

We proposed a new usage of CG-simulations in the class. While the CG simulations are often used to explain what the teacher want to explain, they can be used to connect learner's concept or schema in the daily life with the system learned in physics class. Such CG simulations are expected to enhance the motivation for the learning along the appropriate direction. The key awareness for the present study, which cannot be seen in the survey by paper, is brought through the interview to the students. On this point, an interactive communication among teacher and students is one of crucial aspects for the improvement of class. The development of the CG simulations with coupled learning materials are still in progress. We will introduce about them elsewhere.

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BIOGRAPHICAL INFORMATION

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