Tutorials in a stand-alone large class

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Abstract. Among various types of curricula incorporating interactive-engagement, Tutorials are well known to be effective for students to transform their naïve concepts into fundamental physics concepts. They are materials designed for a recitation class in the United States. Implementing Tutorials in other environments needs some modification. An attempt to reconcile environmental and cultural differences and to change students’ attitudes towards learning is reported.

1. Introduction
Physics education research has proved that classes based on interactive engagements are much more effective than traditional lectures for students to acquire fundamental physics concepts. Many instructional methods and materials designed for a class at a university in the United States are introduced [1] and implementation in many schools has been reported [2].

Every country or district has its own curriculum and own cultural background different from those in the United States. Implementing new instructional methods and materials requires additional adjustments to solve the problems caused by those differences without spoiling the original intentions.

Among various types of curricula incorporating interactive engagement, Tutorials in Introductory Physics (TIP) [3] are well known to be especially effective. They are originally designed to replace a recitation class. Discussions and logical arguments are emphasized. The materials start with common sense or intuitions and make students confront cognitive conflicts between their naïve concepts and physics concepts. Students resolve those conflicts and reach qualitative understandings of physics concepts through group discussions.

In this article, implementing Tutorials into a university recitation class in a country other than United States is reported. Actually we adopted Open Source Tutorials (OSTs) [4] with the help of University of Maryland physics education research group. OSTs have much in common with TIP but rather emphasize epistemological aspects. There were two major problems in implementation. One is a local problem due to difference in environments and the other is a rather universal one, which is due to students’ learning attitudes. Both dealing with environmental difference and attempts to modify students’ learning attitudes are important to make Tutorials really effective.
2. Background

2.1. Difference in Environment
Tutorials are originally supposed to be taught in a physics course together with lectures and labs. Students take lecture classes, labs and a Tutorial class in a week. All the classes in a course should be consistent with each other. Even if the lectures are taught in a large class of hundreds of students, Tutorials are taught in a smaller group of 20 or so students. One or two instructors, who are often teaching assistants (TAs), play an important role as a facilitator eliciting students’ naïve concepts or asking guiding questions without explaining them “the correct answer”.

In our university, lectures, labs and recitations in introductory physics course are taught independently and do not necessarily have coherence, which is often the case in our country. Assessment is also done independently. In fact, freshmen take classes of lectures and labs in introductory physics and they cannot take a recitation class until they become sophomores. Thus students cannot associate fundamental concepts they were taught in lectures immediately with problems in a recitation class. They do not have chance to reflect or confirm what they learned in the class. There are about 140-160 students in a recitation class as well as lectures. Only labs are taught in groups. Every lecture class or recitation class is taught once in a week and takes 90 minutes, which is almost twice the length of a class in the original Tutorials.

2.2. Students’ Learning Attitude
In addition to very common misconceptions, students tend to have their learning attitudes according to how they have learned so far. They depend on cultural backgrounds and are sometimes undesirable. Such learning attitudes are deep-rooted and continued efforts are required to convert them into that of an expert.

Most of our students are pre-service science teachers. However, they have a variety of learning situations at high school. Some students major in physics and hope to study advanced physics courses deeply, while others have learned nothing about physics since their junior high school days. When they become sophomores and take recitation class, the latter remember rarely what they were taught in physics lectures a year ago. Our students are basically studious and had studied hard to pass the entrance exams of universities. The most efficient way for students to get a high score in exams seem to look for the correct answers and just memorize the pattern of problems and answers. It is the way they “study”. Students sometimes give up applying their own ideas or common sense to physics. When they enter the classroom it is time for them to switch to physics-class thinking, which almost means shutting down their own ideas. They are used to waiting to be given the correct answers and chug them. Reconciling students’ own ideas and what they have learned as physics concepts is hardly seen.

3. Implementation

3.1. Outline
We replaced a recitation class by Tutorials in 2011. Tutorials are based originally on students’ independent activities but we need to bring in the class both the process of ensuring fundamental knowledge and the process of reflecting what they learned because the class is stand-alone. At the end of each lesson we get students to write on worksheets what they think is the point of the lesson and what they feel they are not sure about. At the beginning of the next lesson students’ reflections are reviewed and shared. When we first taught Tutorials in 2011 we gave 15-minute lecture to review the fundamental concepts of the day necessary to proceed with the worksheets. After a couple of semesters, review of students’ reflections proved to be much more effective than those lectures done rather in a traditional way. We have got to provide a 7-minute preparatory video to ensure fundamental knowledge in advance of the lesson.
3.2. Materials
The topics are mainly kinematics and mechanics in 1-dimension. We translated worksheets and homework of 10 subjects from OSTs into our own language and utilized them. Although some modifications to the materials were needed for practical reasons, we paid special attention not to spoil the original intention to derive what students really think, not what students think we want. Homework, quizzes and exams are graded. They all emphasize that reasoning should be consistent with the lessons. Worksheets are collected but not graded. It is just for making students serious and for checking the students’ thoughts.

Epistemological aspects of OSTs help much to change students’ learning attitude. Moreover, we always emphasize reasoning rather than knowledge through facilitation of discussion and grading. To explain why the answer is reasonable is also emphasized rather than to find “the correct answer”. On discussion students are required to talk in complete sentences. It helps them to recognize ambiguity and unreasonableness in their own talk. TAs and teachers try to remember the students’ names and to be concerned with individual students, which makes students responsible for their words and makes it possible for TAs and teachers to elicit what they really think.

3.3. TA training
Efficient facilitation of students’ discussion is key to succeed in Tutorials both for conceptual understanding and for changing learning attitude. We teach TAs in a 2-hour training session before every lesson, where TAs simulate what students will think while proceeding with the worksheets. They also consider and discuss what questions they should ask students and in what context. Each TA is required to confirm students’ progress, to help students’ discussion by asking appropriate questions, and to exchange information and collaborate with other TAs. They rarely tell students “the correct answer” even if the students want him/her to do so.

There are about 40 student groups in the classroom and about 10 TAs facilitate students’ discussion. TAs and teacher(s) look after a whole classroom. They are not in charge of specific groups and a TA could interact with every group. Efficient guidance by each TA and TAs’ team-work is essential. Students have a variety of difficulties and a variety of ways to solve them. Teachers are not necessarily able to recognize all the difficulties but some TAs might be. TAs variety solve a variety of students’ difficulties.

Debriefing immediately after the class is also very valuable. Every TA always finds something in the class and wants to report it. TAs and teacher(s) share information on each group of students. Most of our TAs had experienced Tutorials as a student and recognized the benefits of discussion and of representing their own ideas in Tutorial sessions. Such experiences make TAs’ morale high. In that sense they play a role of a Learning Assistant [5]. Although debriefing is voluntary, almost all TAs willingly attend it.

4. Results and discussion

4.1. Conceptual Understanding
Table 1 is a score of Force Concept Inventory (FCI) [6]. A score of 15 questions of FCI excluding 2-dimensional motion and rotation is also shown in Table 2 because we only deal with 1-dimensional situations in the class. The Hake gain \(<g>\) [7] varies from year to year but that of 15 questions is averagely high compared to other interactive classes in this country. As a reference \(<g>\) of 30 questions in 2010 was 0.17, when we had traditional problem solving with a lecture part of Peer Instructions.
4.2. Learning Attitudes
The Colorado Learning Attitudes about Science Survey (CLASS) [8] is a well-known attitude survey of 42 statements. 26 statements are organized into 8 categories: Personal Interest, Real World Connection, Problem Solving (PS) General, PS Confidence, PS Sophistication, Sense Making/Effort, Conceptual Understanding and Applied Conceptual Understanding. Students are asked to respond on a Likert-like scale depending on whether he/she agrees or disagrees the statement. For 36 statements the expert’s belief is defined. When a student agrees with the expert’s belief, the response is counted as “favorable” and when a student disagrees it, the response is counted as “unfavorable”. We do not always have enough time to survey students’ learning attitude. A result of CLASS in 2016 is shown as an example in Figure 1. The vertical axis indicates the shift of average favorable percentage of students’ scores from pre-survey to post-survey normalized by the percentage they could have gained (100 – the average favorable percentage of pre-survey). The horizontal axis indicates the shift of average unfavorable percentage of student’s score normalized by the unfavorable percentage of pre-survey with the sign inverted. That is, the more the mark is upper right, the more students get to have the expert’s belief. Figure 1 indicates learning attitudes shift in the class by category. It tells that students’ attitude as a whole improves in many categories. However, there always remain some students who do not find Tutorials valuable and prefer traditional problem solving. Moreover, some students complain not being able to finish worksheets of the day. They still believe that sweeping all the subjects is more important than their active engagement.

Table 1. FCI scores (30 questions).

| year | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|------|------|------|------|------|------|------|------|
| pretest | 63% | 67% | 64% | 68% | 64% | 69% | 70% |
| posttest | 72% | 77% | 75% | 73% | 75% | 79% | 78% |

<gt> 0.24 0.32 0.29 0.15 0.30 0.31 0.26

Table 2. Score of FCI excluding 2-D motion and rotation (15 questions).

| year | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|------|------|------|------|------|------|------|------|
| pretest | 62% | 65% | 62% | 66% | 62% | 68% | 70% |
| posttest | 76% | 82% | 78% | 76% | 79% | 83% | 82% |

<gt> 0.37 0.50 0.43 0.30 0.45 0.47 0.41

Figure 1. Normalized pre/post movements of CLASS [8].
5. Conclusions
Tutorials as a new curriculum incorporating interactive-engagement have been implemented to replace a stand-alone large-scale recitation class in a university in Japan. Although some modifications were made in lesson structure and materials because curriculum and cultural background are different from United States, Tutorials proved to be effective for students to transform their naïve concepts into fundamental physics concepts. Students’ conceptual understanding is much improved. Students’ learning attitude is also improved but it is deep-rooted and we still have to keep working on it.

In order to make Tutorials effective in a stand-alone large-scale class, a group of well-trained instructors who facilitate students’ discussion should be organized. They need to understand the intention of materials, be concerned with what students really think and collaborate each other. The points for teachers in a class are to keep emphasizing reasoning and to be consistent through facilitations and grading. Organizing a group of facilitators and keeping their morale high are also important factors.

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