Implication of physics active-learning in Asia

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Abstract

In teaching and learning physics, it is always difficult to make students interested in the subject or to realize connections between physics and phenomenon in everyday lives. Recent research in science education suggests that traditional instruction hardly improve students' understanding and appreciation in physics even if the instruction includes physics demonstrations, simulations or computer-aided instruction. All these techniques are not that effective because students are not engaged or participating actively in the learning process. Therefore with supports from UNESCO, physics experts and science education researchers from developing and developed countries and Asian Physics Education Network (ASPEN) have developed a new effective approach in teaching physics, called an "active learning" method, which is actively engaging students in learning physics. The instructor using this method has to prepare learning environments through activities, questions, or discussions. Students actively construct their learning while observing and doing experiments, making mathematical descriptions along with constructing theories, and developing scientific reasoning through discussions.

Keywords: Active learning, Physics Education, Physics teaching in Asia

Resumen

En la enseñanza y el aprendizaje de la Física, siempre es difícil hacer que los estudiantes interesados en el tema realicen conexiones entre la Física y el fenómeno de la vida cotidiana. Investigaciones recientes en la enseñanza de la Física sugieren que la instrucción tradicional difícilmente mejora la comprensión del estudiante y su apreciación por la Física, aún si la instrucción incluye demostraciones físicas, simulaciones o instrucción asistida por computadora. Todas estas técnicas no son tan efectivas porque los estudiantes no son encausados a participar y trabajar activamente en el proceso de enseñanza. Por lo tanto, con apoyos de la UNESCO, investigadores expertos en Física y Ciencias de la Educación de países desarrollados y en vías de desarrollo y la Red de Educación en Física de Asia (ASPEN) han desarrollado un nuevo y efectivo enfoque en la enseñanza de la Física, llamado método de la "Enseñanza Activa", el cual está siendo aplicado para encausar a los estudiantes hacia el aprendizaje de la Física. El instructor que usa este método, tiene que preparar ambientes de aprendizaje a través de actividades, preguntas o discusiones. Los estudiantes construyen activamente su conocimiento mientras observan y realizan experimentos, elaborando descripciones matemáticas acompañadas de teorías constructivas, y desarrollando el razonamiento científico a través de discusiones.

Palabras clave: Enseñanza Activa, Educación en el área de la Física, Enseñanza de la Física en Asia

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I. INTRODUCTION

For over 30 years, physics community has recognized the important of Physics Education Researches (PER) and realized the trend of physics teaching that is different from traditional one. Research since 1970 until now [1, 2, 3, 4, 5, 6, 7, 8] has discovered problems and difficulties in learning and making sense of physics, ranging from high school to university level. This problem is commonly found world-wide, not depending on culture, government or topography; and learners in US, Europe, or Asia experience the same problems. Hake [9], Redish [10] and McDermott [11] mentioned that findings from PER had initiated a tremendous effort in improving physics teaching since 1990.

Numerous research findings indicated that physics misconceptions are deeply rooted and resulted from students' misinterpretations of everyday experience and incorrect observations [2, 3, 4, 9, 12]. As a result, students' conceptual understanding and appreciation of physics could not be improved with traditional instruction [12, 13]. However, model of student understanding and misconceptions from quantitative interpretation research has built a pathway for curriculum development and effective teaching of introductory physics; for example, works done by Hake [9, 14], Bao and Redish [15], and Thacker [16] etc.

II. ACTIVE LEARNING

In recent years, numerous studies have shown "active-learning" instructional methods to be effective in increasing student conceptual understanding. The main reason is that this method solves differences in students' learning style and endeavors to match the teacher's strategy with the students' learning styles. Successful physics curriculum in both US and Europe are based on this teaching approach that encourages students to construct their own knowledge. The active learning methods can be categorized according to a classroom arrangement and management [17, 18, 19] as follows:

A. Studio Model

Lectures in this classroom format are kept to minimum or almost none. Students form a group and work together to explore and discover physics principles from conducting experiments. Laboratory equipments are simple and well prepared as a module in sequences. Teachers' role is a facilitator in helping with the experiments, arranging discussion, and guiding students toward a correct conclusion. Many successful physics programs are arranged in this format such as Physics by Inquiry [11, 16, 20, 21], Workshop Physics [22, 23], and Studio Physics [24] etc.

B. Discovery Lab

This classroom format creates an opportunity for students to have direct phenomenological experiences through performing an experiment before dealing with mathematical expressions. They carry out experiment to collect evidence and draw a conclusion based on that evidence. The instructor roles are to guide students in making predictions and formulating questions. A laboratory manual, direction or instruction is provided as necessary with minimum details. Examples of this classroom format are Real Time Physics [25, 26] and Socratic Dialogue Inducing Lab [27] etc. Figure 1 shows a learner-instructor interaction in classroom teaching with Real Time Physics.

C. Lecture Based Model

This teaching format is slightly modified from the traditional lecture. The instructor gives lecture mostly but adds and emphasizes on asking challenging questions. Student beliefs and misconceptions are conceptually challenged by these questions. Also, students are motivated through discussing and exchanging ideas with their neighbors in a lecture hall or a classroom. Examples of this teaching format include Interactive Lecture Demonstration (ILD) [13], Peer Instruction [28], and Just In Time Teaching (JITT) [29] etc. Figure 2 shows instructors prepared equipments before teaching with ILD that usually requires at least two instructors for team-teaching, demonstrating, posting challenging questions and keeping students actively engaged in learning.

FIGURE 1. In Real Time Physics classroom, learners and the instructor discussed results of a thermal sensor in a thermodynamics experiment. (ASPEN Workshop 2003, University of Peradeniya, Sri Lanka)

D. Recitation Based Model

This teaching format requires extra class time for activities that makes students think and construct better understanding of physics concepts. The class time might be extra lecturing or solving challenging problems. Students have to work as a group to interpret the problems, discuss solution approaches, and search for additional information to solve these problems. Examples of this format are Tutorial in Introductory Physics [30, 31] and Cooperative Problem Solving [32] etc.

FIGURE 2. A group of instructors prepared laboratory equipments and contents before teaching with ILD in a one dimensional kinematics (ASPEN Workshop 2002, Vientiane, Laos).

More information on each active-learning curriculum can be found from the cited references. Although these active-learning techniques have different format, they all share the same special characteristic, which is extensive student-student and student-instructor interaction during class time. These interactions encourage students to make a prediction of physics phenomenon by observing a demonstration, doing the experiment, or solving a physics problem. Students are guided and motivated to construct their knowledge of physics concepts during in-class activities. In recent years, numerous investigations have shown active learning to be more effective in increasing students learning of physics concepts than traditional physics lecture at all levels [17, 9, 12, 16].

However, student learning and understanding of physics concepts do not depend on demonstrations, using technology, or making students solve problems. Students have to take parts in their own learning and be active in constructing their physics concepts. Active learning approaches are based on three important assumptions:

(1) Learning is an active process and relies on interactions between student-instructor. Students' learning hardly occurs if their classroom role is only to be simple receivers of information.

(2) Different students have different learning styles and thinking processes.

(3) Knowledge will be meaningful for students only if they discover and realize meaning of that new knowledge and be able to construct an association with their previous knowledge. In other word, students have to construct their own knowledge.

The instructors have to create an active learning environment based on these assumptions. For example, various techniques are employed to accommodate diverse range of student learning styles. Learning opportunities are prepared throughout the whole class time to constantly challenge students. The instructors have to aware of students' physics misconceptions, so teaching materials are prepared with a series of connected sequential questions that are carefully constructed to help students develop a conceptual change process and construct a correct conception. Table I compares characteristics of active and passive classroom environment [33].

TABLE I. Comparison active versus traditional learning environment [33].

Active learning environment	Traditional Learning environment
Evidence collected from hands-on observation or experiments are learning resources.	Instructors and textbooks are learning resources.
Students are challenged to compare their predictions to observations of real experiments.	Students are infrequently challenged to think during lecture time.
Students develop a conceptual change process when their beliefs or misconceptions are in conflicted with their observations of real experiments.	Students' beliefs are rarely challenged, so they may never know differences between their own beliefs and materials in lectures.
Instructor's role is as a facilitator in students' learning process.	Instructors' role is as authority or a source of information.
Collaboration with peers is encouraged. Students often communicate their understanding or exchanges ideas with peers or the instructor.	Collaboration with peers often discouraged. Students hardly exchange their understanding with anyone during class period.
Results from real experiments are carefully observed and recorded before being used to draw a conclusion in terms of physics principles.	Lectures often present physics laws or principles with little reference to experiments.
Laboratory instruction is normally presented in a series of questions to guide student thinking. Thus they can make a connection between real observations and basic physics concepts.	Laboratory instruction is normally presented as a cookbook and used to confirm theories learned in lecture.

III. ASIAN PHYSICS EDUCATION NETWORK

For over 25 years, Asian Physics Education Network, ASPEN has been developed, collected, and distributed various physics teaching techniques to physics teachers all over Asia. ASPEN is operating under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Regional Office for Science and Technology (S & T) in Southeast Asia. Recently, ASPEN mission emphasizes on introducing the principle of active learning, various active-learning curricula, developed curriculum materials and teaching techniques to member countries. This mission is carried through physics education workshops at both national and international levels for universities in member countries. Until now, ASPEN Active Learning workshop, ASPEN-ALW have been run in almost every countries in Asia including Laos, Vietnam, Malaysia, Thailand, the Philippines, Indonesia, South Korea, India, Pakistan, Sri Lanka, and China. The workshop also runs in countries in other continents such as Australia, Tunisia, Ghana and Papua New Guinea.

FIGURE 3. The discovery lab in a topic of ray optics without computers (ASPEN Workshop 2005, Tunisia).

In the past 5 years, ASPEN-ALW activities have emphasized on training trainers or international resource person to become active learners themselves. Consequently, they can become an active learning resource person in their countries, especially the developing one [34, 35]. This is perhaps the biggest challenge in adopting this method of teaching since most teachers must have learned in traditional passive learning environments. However in an active learning environment, the instructors must give up their role as the authority or the source of all information in the classroom and to become facilitators, instead [33]. Therefore they have to be trained so that they can become active learners, and finally, they can formulate and use instruments to facilitate students' active learning. ASPEN-ALW has been organized in many countries such as the Philippines (2001), Sri Lanka (2002), and Tunisia (2005). By considering the diverse needs and conditions existing in developing countries, learning and teaching curricular are to be developed based on inexpensive, locally-available materials and the cultural context. Therefore, the activities in recent workshops were adapted to existing conditions of target countries [34]. For example, ILD lessons and discovery labs were excluded any sensors or computers in displaying results. Figure 3 shows a discovery lab in ray optics without using any sensors or computers. ASPEN-ALW illustrated that effective demonstrations can be assembled from inexpensive, simple and locally-found components. For active-learning classroom, the instructors are far more important than expensive or high-technology lab equipments [36] because they have to prepare the learning environment through activities, questions, discussions, guides students through the reasoning necessary to construct correct physics concepts.

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