The Scientific Approach To Higher Education: 
Examples From Physics Education Research

Allen Price
Emmanuel College, Boston U.S.A.

Economic development hinges on the scientific and technical preparation of future workers. In particular, training in physics teaches critical thinking, quantitative reasoning, and hands-on technical skills. It is obvious that the adequate preparation of teachers of science is essential. In spite of its importance, the traditional preparation of students in the field of physics has been found to be inadequate in teaching conceptual knowledge (Hake, 1998). While Indonesia has made great strides in improving literacy and school enrollment (Ahlburg, 1997), teaching methods have not evolved at the same pace. Whereas university level education in the fully developed economies is moving to a more student oriented mode, the Indonesia classroom remains more teacher centered (Frederick, 2011).

Many emerging economies, including Indonesia, have called for improved science education. Indeed, studies show that pedagogical reform can be cost effective in improving learning in the emerging economies (Kremer, 2013). Indonesia has experimented with such educational improvements as hands-on experimental kits for primary and secondary school classrooms (Zurcher, 2013), as well as professional development innovations, such as lesson study (Suratno, 2013; Saito, 2006). Some programs have been partnerships between schools and universities (Saito, 2007). However, the majority of these experiments in reform have been aimed at improving primary or secondary education, indicating a need to examine methods at the university level.

Yogyakarta State University (UNY) has a history of involvement in educational reform and experimentation. Faculty at UNY were directly involved in experiments in reform in science education at the secondary level (Saito, 2006; Saito, 2007). The University has one of the most respected teacher training programs in Indonesia, as well as technical programs of study in the field of physics. In addition, the city of Yogyakarta is a center of higher education in Indonesia, with several institutions of higher learning, thus giving access to many educators and professionals in the field of higher education in Indonesia.

Properly used, hands-on activities have been shown to increase conceptual learning (Hoellwarth, 2005). The topics of motion, mechanics, basic electric circuits, and optics can be effectively demonstrated with simple and often readily available components. See Gupta, 2010 (web link available in references listed at end of proposal) for an inspiring example of how this can be achieved in an emerging economy. Designed to be simple in execution, but conceptually engaging, each activity challenges students to solve a problem or to explain a simple demonstration. For example, one lesson in optics requires students to place a small mirror on the wall so that they can see the image of a piece of tape on their knee in the mirror. The solution
(placing the mirror exactly halfway in height between the knee and eyes) requires a working understanding of the principles of reflection and geometry. Some example activities and required materials are listed in the table below.

<table>
<thead>
<tr>
<th>Topic Of Activity</th>
<th>Required Materials</th>
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<tr>
<td>Free fall</td>
<td>String, washers or nuts</td>
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<tr>
<td>Projectile motion</td>
<td>Ball, pieces of tape</td>
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<tr>
<td>Circuits</td>
<td>Battery, short piece of bare wire, small light bulb</td>
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<tr>
<td>Reflection</td>
<td>Piece of mirror, tape</td>
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</tbody>
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The choice of activities and how they are used in the classroom must be done with the guidance of experienced faculty. The implementation of these activities requires extensive interaction between instructor and small groups, as well as Socratic questioning. Initially, these techniques may not fit the cultural expectations students have of the classroom dynamic. To foster acceptance, the goals and expectations of the activities must be clearly explained to both students and instructors, and the cultural norms of behavior in the classroom must be respected. In addition, any written materials must be reviewed by before administering to reduce possibilities for misunderstanding.

In addition to hands-on inquiry group activities, there are other methods such as pre/post testing (in which student conceptual gains are measured), “just-in-time” teaching (in which pre-class online quizzes are used to guide in-class use of time), and peer-instruction (in which students debate amongst themselves solutions to conceptual questions). Hands-on activities make use of simple and inexpensive materials. Students work in small groups and often report in evaluations that these activities are the most memorable parts of the course for them.

Courses can be structured in a non-traditional format: students work in small groups with hands-on experiments and group problems. Students construct their own explanations of their observations and then debate them in a classroom environment, with the instructor playing the role of moderator.

Understanding which methods are successful and how to implement them will require a science of learning. Fundamental studies must reveal how the brain learns and in particular, how the mind applies concepts in physics, both correctly and incorrectly. Researchers are now developing this science which can only improve our ability to effectively teach at the university level.
References


