DEVELOPMENT OF SCIENTIFIC SKILLS AND VALUES IN PHYSICS EDUCATION

V. M. Talisayon
University of the Philippines

INTRODUCTION

Research in physics education at secondary and tertiary levels in recent years has focused more on concept learning or understanding than on skills and values development. Values development has received the least emphasis. The teaching of physics in lectures often stresses concepts and their relationships, while physics laboratory emphasizes, too, laboratory skills development.

However, in the work place, the employability of physics graduates appears to hinge more on generic skills and values that are transferable to many areas of research, work and life, itself [1,2]. For the general population, the great majority of students who will not pursue a physics career, the teaching of physics for scientific literacy and science culture in a given society is a priority thrust in physics education. UNESCO has led international efforts towards scientific literacy, particularly, in developing countries, cognizant of the crucial role of science and technology in national development.

Lately, international emphasis is on education for sustainable development, with 2005-2014 declared as the United Nations Decade for Sustainable Development. Like scientific literacy, sustainable development is laden not only with concepts but also skills and values such as the development of human potential, moral, cultural and gender sensitivity, participatory democracy, collaboration, unity and peace.

This chapter examines selected researches and perspectives on development of skills and values in physics teaching for patterns and trends and posits directions for the physics education community to consider. Skills needed to learn physics may be categorized as thinking skills, including science process skills, ICT skills, communication skills, and interpersonal skills. The values development section focuses on attitudes towards science and its image to students.

DEVELOPMENT OF SCIENTIFIC SKILLS

In promoting physics to the public and encouraging students to have a career in physics, the development of problem solving ability in physics is usually emphasized. In a survey of the value of a physics degree, physics alumni of an American university [2] underscored the importance of the following skills in their profession, as follows:

1. Problem solving skills, mathematics and other technical skills
2. Problem solving skills – allow work from one leading edge technology to another
3. Mathematical skills applied to physical systems

4. Analyzing and modeling a physical process
5. Gathering data, making and testing models and predictions
6. Experimental, computation, theoretical skills – applicable to a broad spectrum of problems
7. Scientific method of thinking that is applicable in all areas of life
8. Ability to learn new information rapidly and efficiently
9. Ability to logically and systematically pursue a line of thought
10. Analytical skills, precise thinking, clarity of thought
11. Logical, data-based decision-making
12. Writing, speaking, thinking in a logical, predictable and consistent way - appreciated in work
13. Learning how to learn new things on your own
14. Skills on how to learn, define problems, strategically plan, implement and communicate solutions; creative thinking skills
15. Independent learning skills and time management

Redish [3] notes that general skills learned in undergraduate physics like complex problem solving , physical modeling, and estimation have a wide range of applications from science to finance.

The school physics curriculum in Hong Kong [4] lists the following goals for skills development:

1. Develop skills for scientific inquiry
2. Develop ability to think scientifically, critically and creatively, and solve physics-related problems individually or collaboratively
3. Understand language of science and communicate ideas and views on physics-related issues
4. Make informed decisions and judgments on physics-related issues

The international study, Trends in International Mathematics and Science Study (TIMSS) 2003 [5] established international benchmarks for science process skills from data of 25 countries for fourth grade and 46 countries for eighth grade (Table 1). The benchmarks are set at cut-off scale points. For both grade levels, on average, highest percentage of students were at or above low benchmark (82%- Grade 4, 78% - Grade 8), intermediate benchmark (63% - Grade 4, 54% - Grade 8), high benchmark (30% - Grade 4, 25% - Grade 8), and advanced (7% - Grade 4, 6% - Grade 8). For example, 82% of the sample

Table 1

International Benchmarks of Science Process Skills at

Grades 4 and 8 (TIMSS 2003)

International Benchmark	Science Process Skills	
	Grade 4	**Grade 8**
Advanced	Demonstrate beginning scientific inquiry knowledge & skills, and skills below	Understand some fundamentals of scientific investigations, apply basic physical principles to solve some quantitative problems, provide written explanations to communicate scientific knowledge, demonstrate skills below
High	Briefly describe & explain some daily phenomena, compare & contrast, draw conclusions, demonstrate skills below	Demonstrate some scientific inquiry skills, combine information to draw conclusions, interpret information in diagrams, graphs and tables to solve problems, provide short explanations conveying scientific knowledge & cause-effect relationships, demonstrate skills below
Intermediate	Apply factual knowledge to practical situations, interpret pictorial diagrams, combine information to draw conclusions, demonstrate skills below	Apply & briefly communicate knowledge, extract tabular information, extrapolate from data in a simple linear graph, interpret pictorial diagrams, demonstrate skills below
Low	Interpret labeled pictures & simple pictorial diagrams, provide short written responses to questions requiring factual information	Interpret some pictorial diagrams & apply knowledge of simple physical concepts to practical situations

could interpret labeled pictures and simple pictorial diagrams and provide short written responses to questions requiring factual information. The results, which indicate an empirical hierarchy of the science process skills, can guide a physics teacher on the skills that can be emphasized for further development.

Strategies for skills development are varied. For example, Parisi et al. (1999a) used the environment outside the school laboratory to develop science process skills [6] in a student experiment on electromagnetic radiation and its interaction with the physical environment. The amount of solar ultraviolet radiation in tree shade is measured at different times of the day and compared with changes in illumination levels and temperature.

Solano-Flores (2000) had a fun-filled activity on bubbles and soap solutions to enable students to construct their own solution strategies for making longest-lived bubbles [7]. They are given relevant and irrelevant pieces of equipment. The activity aimed to develop and assess science process skills and high-level thinking skills such as problem solving skills and creative thinking skills. Student investigations, project-based learning approach, and undergraduate theses also aim to develop these kinds of skills.

With the introduction of the science, technology and society approach in the late sixties and more recently, the physics in context approach, decision-making skills have come to the fore. In physics, for instance, energy resource allotment and development scenarios have been used in the classroom for role-playing and students' exposure to elements of the decision-making process [8] like identification of key players and the values they cherish, uncertainty and consequences of a given decision, evaluation of quality of information at hand, alternatives and trade-off to be considered, and negotiations to be made in the real world.

As the world moves on in the 21st century, the increasing demand for ICT skills in the work place and schools has necessitated technology integration in teaching. TIMSS 2003 results for fourth and eighth grade showed that science achievement was positively related to computer use, particularly at eighth grade. Average achievement was highest among students reporting using computers at home and school. Students who used computers elsewhere or did not use computer at all had the lowest achievement.

Intel Teach and Microsoft Partners in Learning are examples of international programs that have helped teachers and students enhance their ICT skills for teaching and learning physics concepts and doing laboratory work. Computer interfacing experiments and robotics have enhanced student laboratory experience in physics. Developing students' ICT skills in physics teaching is also a way of narrowing the digital divide within a country and across countries.

Communication skills – listening, speaking, writing and reading – are basic skills that are needed and further developed in courses like physics. Students' reading comprehension of physics texts is often assumed, but the technical writing style and presence of equations, graphs and tables lower the readability of the text. If students come to a physics class ill-equipped to understand physics texts, development of reading comprehension skills for a physics text needs to be a concern of the physics teacher. Such skills can be developed, in consultation with the communication arts teacher and with the physics teachers drawing from their experience and strategies of understanding physics texts.

Interpersonal skills most developed in a physics class are those needed for a group to accomplish its task, be it an activity, experiment or project. Such skills, together with

thinking skills and reading comprehension skills are among self-learning and lifelong learning skills applicable to many areas of life. For physics teaching to be better appreciated by students, skills development can be equally emphasized and uses to life pointed out to students.

A sustainable development principle is the development of human potential as shown in Figure 1 [9].

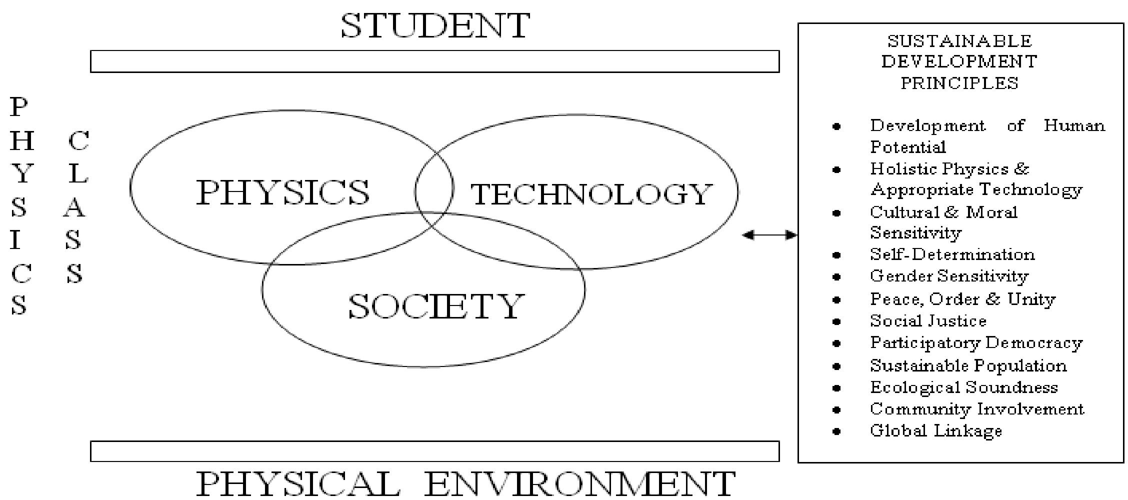


Figure 2. Sustainable Development in Physics Teaching

Development of critical thinking skills, including science process skills, ICT skills, communication skills contributes to the development of students' potential in a physics class, considering the applicability of these skills in many areas in life.

DEVELOPMENT OF VALUES AND IMAGE OF SCIENCE

Other sustainable development principles (Fig. 1) are values like cultural sensitivity. Physics-related artifacts, e.g., native toys [10] and musical instruments can be brought to class by students. Physics-related cultural practices (scientific and unscientific), e.g., fishing in a full moon, can be taken up when appropriate [11]. Moral sensitivity can be demonstrated by discussing cultural values vis-à-vis scientific values, for example, influence of friendship on one's objectivity.

Community-based physics teaching [12], an approach for community involvement of the class, addresses physics-related community needs and uses physics-based resources. Self-determination and participatory democracy are developed in a physics class with group activities, experiments and discussion, inclusion of design of investigations or projects, and use of self-learning modules and Internet.

The principle of social justice can be actualized with quality physics teaching for the poorest of the poor in public schools, especially remote schools. These schools need to be provided with master teachers and given the same instructional materials used in city schools. In any class, students at risk of dropping out can be identified and given instructional remediation program and counseling. Outreach physics programs like community-based physics projects can be designed for student dropouts for them to eventually come back to the formal stream.

To promote peace, order and unity, a physics class can have cooperative learning in group activities and experiments and a classroom climate conductive to learning. Values of responsibility, openness and respect for others can be developed among the students as they work in groups.

Global linkage or cooperation in physics teaching can take the form of collaboration with scientists through email, e-group discussion, common laboratory experiments and videoconferences with classes in other countries, and international competitions like the International Physics Olympiad.

Gender sensitivity, which contributes to social justice, can be promoted with (1) active equal participation of boys and girls in a physics class, as well as in textbooks, (2) encouraging girls to handle electrical and electronic devices, and (3) motivating girls to consider a career in physics.

The principle of gender sensitivity is based on researches like the international survey [13] on the Relevance of Science Education (ROSE) involving 38 countries (Sjoberg, 2004). The study involved Grade 10 students (15 years old) in 38 countries and used a questionnaire with four-point rating scales to determine students' self-ratings on out-of-school experiences, what they wanted to learn about, their future job, environment and science classes, themselves as scientists, and science and technology.

Among the findings are:

1. Students in all countries strongly agree that science and technology are important for society and providing greater opportunities for future generations;
2. In most countries, students think that science and technology make work more Interesting; and
3. Most students (mainly boys) think that the benefits of science are greater than its potential harmful effects.

In all countries, boys liked science better than the girls did (Table 2). In some countries, mainly developing countries, the students liked science very much (Table 3). In developing countries, all students wanted to have as much science in schools as possible. In some countries, girls disliked science very much and did not want to have science in school. These findings argue for encouraging girls to participate and even lead in physics class activities.

While the students generally liked science, very few students wanted to become scientists, with boys wanting to be scientists more than the girls. In developing countries, all students wanted to become scientists, and many wanted to get a job in technology (Table 3). More boys than girls wanted a job in technology. In all countries, the boys

Table 2

Some Gender Differences in Attitude Towards Science

(ROSE Survey, 2004)

Girls	Boys
*Few want to get a job in technology *It is more important to work with people than with things	* Like science better *Much more interested in working with machines & tools *More think that benefits of science greater than its potential harmful effects

Table 3

Students' Attitude Towards Science in Developing and Developed Countries (ROSE Survey, 2004)

Developed Countries	Developing Countries
Few want to become scientists	*All students want to become scientists *Like science very much *Want to have as much science in schools as possible

were much more interested in working with machines and tools (Table 2) than the girls were. On the other hand, the girls in all countries thought it was much more important to work with people rather than things.

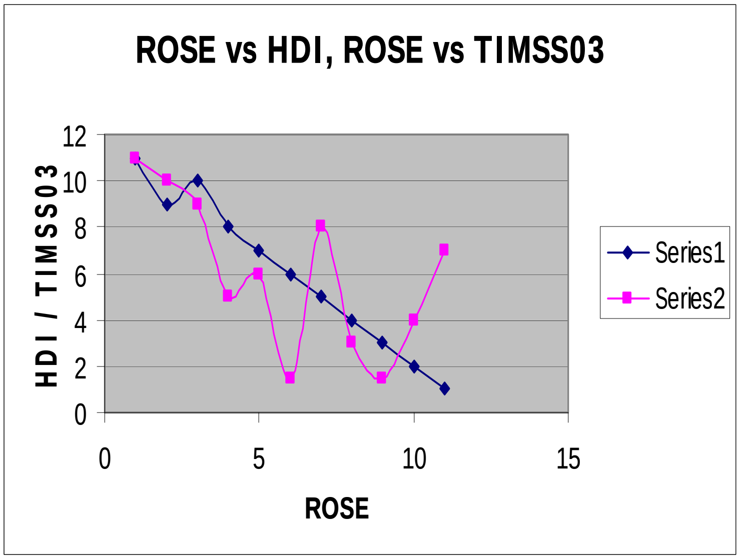
For the eleven countries, the overall ROSE rating had a significant ($p < .000$) negative, very high relationship with human development index (HDI), as indicated in Table 4 and Figure 2 [14]. HDI is a composite index of development of a country, used by the United Nations Development Programme [15]. The correlation of the ROSE rating with the TIMSS science score was also significant ($p < .022$) and negative, but moderate in value. A positive attitude towards science is expected to be associated with high science achievement. The reasons for the negative relationship need further investigation.

Table 4

Correlation Between ROSE Rating and HDI, and TIMSS Science Score

Variables (Ranks)	Spearman Rho Coefficient	Degrees of Freedom	Level of Significance
ROSE Rating & HDI	- 0.991	11	0.000
ROSE Rating & TIMSS Science			

Score	- 0.624	11	0.022



Series 1: ROSE vs HDI

Series 2: ROSE vs TIMSS

Figure 2. Correlation Between ROSE Rating and HDI, and TIMSS Science Score

The negative, high relationship between science-related interests and experiences and the human development index, a composite index, calls for an in-depth study. For instance, have students in countries with high HDI taken the benefits of science and technology for granted, since these benefits are part of their daily life?

The Hong Kong physics curriculum [4] goals include sustainable development, specifically, the awareness of social, ethical, economic, environmental and technological implications of physics and develop an attitude of responsible citizenship. The curriculum is one of several school curricula around the world that lists among its values goals the development of students' interest, sense of wonder and curiosity about the physical world. Other physics curricula as in the Philippines underscore the values of openness, tentativeness of science findings and other limitations of science, humanity of scientists, and respect for life.

The physics graduates in the American university alumni survey [2] cited values developed in a physics degree that are useful in work, such as patience and perseverance in solving problems, self-discipline, self-motivation, team work, and willingness to change based on new information and feedback.

Physics teaching in rich or poor countries at all academic levels needs to focus on developing generic values useful in life, as well as positive attitudes towards science, particularly, physics, which has acquired a reputation of being a boring and difficult subject.

FOCUS SHIFTS IN TEACHING PHYSICS

Physics concept has been a main goal of physics teaching with skills often considered as tools to learn the concepts (Fig. 3). Values like a positive attitude towards physics, perseverance and patience have served as motivation to learn the concepts. Yet, if skills and values are equally important, particularly because of their transferability to many areas in life, focus shifts (Fig. 4) are needed in teaching physics.

	Concept Focus	Skill Focus	Value Focus
Concepts	End-Goal	Context	Context
Skills	Tools	End-Goal	Tool
Values	Motivation	Motivation	End-Goal

Figure 3. A Model for Focus Shifts in Development of Physics Concepts, Scientific Skills and Values

If a physics teacher is intent in developing decision-making skills among the students, the decision-making process is explained and demonstrated using energy resources as the topic and context. The value of energy conservation is the motivation for doing the activity. On the other hand, if the development of a value, e.g., perseverance, is the focus or end-goal, having three trials in measurement of a variable is the tool, and the context is a physics concept or variable that can be measured.

The three shifts can take place in one physics class session, if these are among the learning objectives of the teacher for the day. What is important is the teacher's awareness that such shifts are to be made for skills and values to have greater emphasis in a physics class.

CONCLUSION

Focus shifts to skills and values in physics teaching, complemented with greater research on skills and values development, are recommended. Transferability of skills and values to many areas of life and their crucial importance in scientific literacy and sustainable development in rich and poor countries cannot be overemphasized.

Some skills like reading comprehension of physics texts, decision-making skills, complex problem solving, physical modeling and estimation need greater emphasis in physics teaching at the appropriate school or university level. Values development can be made more explicit and deliberate in a physics class, with physics teachers and faculty receiving training on values development strategies.

REFERENCES

1. Ripin, B. (2001). Preparing physicists for life's work. *Physics Today,* April 2001.
2. http://www.physics.purdue.edu
3. http://www.physics.umd.edu/~redish/Papers/EFRBarcelona.pdf
4. http://www.edb.gov.hk/FILEMANAGER/EN/CONTENT_4036/phy.pdf
5. Martin, M., Mullis, I., Gonzales, E., and Chrostowski, S. (2004). *TIMSS 2003 International Science Report.* Boston: IEA and Insternational Study Center, Boston College.
6. Parisi, A.and Kimlin, M (1999). Determination of the solar ultraviolet transmission tree shade. *Australian Science Teachers' Journal*. Vol. 45, No. 2, 55-57.
7. Solano-Flores, Guillermo (2000). Teaching and assessing science process skills in physics: the "bubbles" task. *Science Activities.* Vol. 37, No. 1.
8. http://www.faculty.fuqua.duke.edu/~clemen/bio/DMSkills.pdf
9. Talisayon, V. (2005). Sustainable development in physics teacher education. *ICPE International Newsletter on Physics Education*, No. 50, 4-7.
10. UP NISMED, University of the Philippines National Institute for Science and Mathematics Education Development (2000). *Science and Mathematics of Toys*. Quezon City, Philippines: UP NISMED.
11. ___________(2000). *Philippine Folk Science: Sourcebook for Teachers*. Quezon City, Philippines: UP NISMED.
12. __________ (2001). *Materials and Methods in Science and Mathematics Education in the Philippines.* Quezon City, Philippines: UP NISMED.
13. Sjoberg, Svein and Schreiner, Camilla (2006) How do learners in different cultures relate to science and technology? Results and perspectives from the project ROSE (Relevance of Science Education). *APFSLT: Asia-Pacific Forum on Science Learning and Teaching*, 7(1), Foreword.
14. Talisayon, V. (2006). Science-Related Attitudes and Interests of Students. Paper presented in the IOSTE XII Symposium, Penang, Malaysia, August 1-4, 2006.
15. UNDP (2003). *Human Development Report 2003. Millenium Development Goals: A Compact Among Nations to End Human Poverty*. Oxford: Oxford University Press.