Physics Education: Its Importance in the Education of Young Generations

Carmen Gil

Introduction

The 20th Century has created an accelerated way of life. Hearing Professor Perot in his Physics class talk of how through the study of Physics we “will be able to touch the stars with the tip of our fingers"[1] made Maria Sklodowska dream about the natural world, helping her during her studies in Dr. Pierre Curie’s laboratory in Paris University, where she remained after their marriage.

The strength of her dream guided her to the discovery of radium, following the steps of the French scientist Becquerel who discovered radioactivity in uranium, which opened the door to the manifold scientific advances of the last century.

The knowledge that we live in a world under the influence of so many unseen forces introduces us to the mystery of life. The ability to tame some of these forces is so wonderful that many people have dedicated their lives to their investigation and use for scientific purposes. In this way we entered the technological era which we find ourselves in.

Many of these advances have been used for astounding purposes in medicine, electronics, and other areas for the benefit of mankind, although on other occasions man has used them for wars and to create fear between countries.

It seems to me that it is very important for young people to deepen their knowledge of themselves through a knowledge of the natural world and the knowledge of what man is capable of. For the young, these are the years to enjoy learning, the years to start the learning process that will last their entire lives.

Lifelong Learning

Many university students consider that the completion of their studies represents the end of their learning. However, the rapid growth of information and technology, as well as changes in all aspects of society, makes it necessary for most graduates to continue to learn through out their lives. This learning may take place in either formal or informal settings, such as in formal courses of study, in the workplace, in professional education courses, or through self-education and enrichment.[2)]

As students move through life, what they need to know changes, therefore it becomes necessary to help them not only make it through college memorizing and reporting facts, but also teach them how to learn new bodies of information after graduation. This need for new information is being demonstrated by the increasing number of non-traditional and part-time students matriculating into institutions of higher education.

Candy et al (1994) suggest that university graduates should possess the following characteristics if they are to continue learning after they have completed college:[3)]

- An inquiring mind, which includes a love of learning and sense of curiosity.
- An extent and ample vision, which includes the ability to ask questions and use and evaluate information in a range of contexts and media.

- A sense of personal efficacy, which includes having a concept of themselves as capable and autonomous learners.
- A repertoire of learning strategies that can be used in a variety of contexts, which includes an awareness of their own learning strengths and weaknesses.

It is not easy for the women I teach at a junior college to acquire these characteristics in only two years, but it would be very good if they became interested in the many problems which surround us in our daily lives. Furthermore, until now they have been accustomed to a surface approach to learning, memorizing subject matter in a way that leads to learning with little understanding. This results in a low academic self concept and little interest in further formal education.

It would be much better if they would adopt a deeper approach to their learning in which case they are more likely to display the characteristics of lifelong learners.

Students adopting this approach use strategies that involve working with information at high cognitive levels, identifying main ideas, relating ideas to each other and looking for themes or unifying principles. In this way the students develop a high academic self-concept, perceive themselves as competent learners, and are willing to continue formal study in areas that interest them.

In the natural and life sciences, the need to provide continuing education to post-college adults is enormous. Therefore, if we wish our students to be lifelong learners, we must try to introduce lifelong learning strategies in our courses. The students need to learn how the technical aspects of their careers relate to the social and ethical aspects of society.

Tokai Nuclear Accident

In October 1999, a clear case study presented itself to a Nuclear Physics class which I was teaching. A chain of events at a uranium processing plant in Tokai, Ibaraki Prefecture, pushed radiation levels up perhaps as high as 20,000 times that of normal levels. The accident left three workers hospitalized, forced some nearby residents to be evacuated, and prompted the government to ask residents as far away as Ibaraki City to stay indoors. Two hospitalized workers died later.

At a news conference at the Science Agency early in the day of the accident, the head of the JCO's processing plant Tokyo office said that they were still trying to find out exactly what had happened, but they believed the uranium had reached the critical point. Criticality is the point at which neutrons produced in the fission process are sufficient to sustain a chain reaction without outside stimulus. A critical accident occurs when a malfunction causes a concentration of nuclear fission.

We only knew of the accident through TV news and continued to follow it through the newspaper and special programs on television. Because only a few of the students understood the accident's importance, we made copies from the newspaper's reports and also prepared videotapes of the television programs explaining the accident's causes as well as its dangers.

Soon it became clear that human error was to blame for Japan's worst nuclear accident. The company bypassed part of the required procedure, a move which was responsible for the disaster. The workers had ignored legally mandated procedures. They used only stainless steel buckets instead of the required apparatus when pouring a uranium solution into a mixing tank. Because they were doing the job by hand, they mixed nearly seven times the allowable amount of uranium into the tank.

Lack of awareness and poor communication among workers have been cited as the main causes of the accident. They had manuals for the different stages of the production process, as well as a manual for when criticality is reached. But nobody thought about the possibility of reaching that point, because in that case a high level of caution would be required.

The facility had been reopened a month before after a suspension of almost two years. Although the workers were "educated about the possibility of a chain reaction and dangers of radiation"[4) they had little experience using the facility. "Someone decided to add 16 kg of uranium, instead of 2.4 kg, a clear mistake of judgment. Such an elementary mistake shows a decline in professional awareness among technicians and failure in safety management" said Agency chief Prof. Akito Arima.[4)

A nationwide inspection was held in the wake of Japan's worst nuclear accident. The Labor Ministry has uncovered 25 violations of the Industrial Safety and Health Law at nine nuclear-related facilities. According to the Ministry, 19 of the 25 violations involved insufficient health and safety control systems, such as health commissions not meeting legal requirements and shortfalls in regular inspections by industrial doctors. The Ministry also found six violations involving working environment measurements not being taken and a lack of dental checks.

Further investigation at the Tokai plant found that the company changed its procedure manual for processing uranium without government approval. In a clear deviation from state-approved procedures the JCO's manual allowed workers to move uranium processed at the plant in stainless steel containers similar to buckets. This method had been used for about four to five years "apparently because it was easier"[5] and that the company included it when it revised its manual about two years ago. But the accident took place after its workers deviated even from the company's unauthorized work manual, bypassing a part of the procedure.

It is difficult to accept that in Japan, a country which experienced atomic bombs in Hiroshima and Nagasaki, where everybody is afraid of nuclear radiation, and where nuclear plants to produce electricity find general opposition, the companies related to them display such a pattern of disregard for safety rules and procedures.

Experts from the Tokyo Institute of Technology said that the JCO "must have been run by amateurs".[5] "The company lacks both fundamental knowledge of nuclear matters and safety measures and it is mind-boggling to think how both the JCO and the government allowed this to happen". Even the Prime Minister told the press reporters: "I doubt that workers there were trained and that they really knew the safety manual".[6]

Nagoya University's Professor Naito said: "The Japanese accident occurred due to a lack of fundamental safety measures. I feel embarrassed to say this to the world".[6]

From Embarrassment to Good Resolutions

It was clear human error was at fault. The students and I felt very embarrassed. It was also a very good occasion to think about the necessity of knowing more about these matters that relate to our everyday lives. Ordinary citizens frequently belong to different groups and associations, and each of us must know what things must be opposed to or what matters must be taken into account and be pursued passionately. To be ignorant or to follow blindly what a leader says is to be an irresponsible member of society. Even to follow the everyday news, intelligent people, as college graduates are expected to be, must take advantage of their time in college to learn and be prepared to be lifelong learners.

In this special case of nuclear energy, this accident will be a setback for the nation's nuclear development program and it will be hard for the government and the nuclear industry to persuade the public that nuclear energy is safe despite the fact that Japan cannot survive without nuclear energy, which in actuality provides a third of the nation's electricity needs.

Radiation Risk and Ethics

Ethics is a very important consideration to be taken into account in every working field, however, it is especially important in the case of nuclear energy. One of the expert's comments about the Tokai accident was that "it demonstrated the gross amateurism and low morale among plant workers at every level",[6] I would add, especially at high levels where ignorance is more difficult to forgive, because of the dangerous consequences.

On the other hand, there is a popular belief that any amount of man-made radiation, no matter how small can cause harm.This was an assumption that gained wide currency when it was accepted in the 1950's, arbitrarily, as the basis for regulations on radiation and nuclear safety. Over the last decades the principles and concepts of radiation protection seem to have gone astray and to have led to exceedingly prohibitive standards and impractical recommendations. Revision of these principles and concepts is now being proposed by an increasing number of scientists and several organizations.[7)]

We are all immersed in naturally occurring ionizing radiation. Radiation reaches us from outer space and it comes from radio nuclides present in rocks, buildings, air, and even our own bodies. Every day, at least a billion particles of natural radiation enter our bodies.

The individual dose rate of natural radiation an average inhabitant of Earth receives is about 2.2 mSv per year. In some regions, like parts of India, Iran and Brazil, the natural dose rate can be up to a hundred times higher. And no adverse genetic, carcinogenic, or other malign effects of these higher doses have ever been observed.

In the case of man-made radiation, the global average dose has increased by about 20% since the beginning of the 20^{th} Century, mainly as a result of the broader application of X-ray diagnostics in medicine. Other major sources of man-made radiation, such as nuclear power plants, nuclear weapons tests and accidents, have contributed only a tiny proportion, less than 0.1%, to that increase. Even in the regions that were highly contaminated by the fallout from Chernobyl accident, the increased radiation dose rate for local inhabitants is far less than the dose rate in areas of high natural radiation. In those places, the entire man-made contribution to radiation dose amounts to a mere 0.2% of the natural component.[8)]

The concern about large doses is obviously justified. However, the fear of small doses is about as justified as the fear that an atmospheric temperature of 20℃ may be hazardous because, at 200℃, one can easily get third-degree burns.

Perhaps we humans lack a specific organ for sensing ionizing radiation simply because we do not need one. Our bodies' defense mechanism provides ample protection over the whole range of natural radiation levels -- that is, from below 1 mSv to above 280 mSv per year. A lethal dose of ionizing radiation delivered in one hour, which for an individual human is 3000 to 5000 mSv, is a factor of 10 million higher than the average natural radiation dose that one would receive over the same time period (0.00027 mSv).

This being the case, it is not necessary to feel that any level of ionizing radiation is dangerous. The radiation protection authorities introduced a dose limit for the public of 1 mSv per year, which is less than 1% of the natural dose rates in many areas of the world. This has led to the spending of hundreds of billions of dollars a year to maintain this standard. And what started as a working assumption for the leadership of ICRP came to be regarded in public opinion and by the mass media, regulatory bodies, and many scientists, as a scientifically documented fact.

Each human life hypothetically saved in a Western industrial society by implementation of the present radiation protection regulations is estimated to cost about $2.5 billion. Such costs are absurd and immoral, especially when compared to the relatively low costs of saving lives by immunization against measles, diphtheria, and pertussis which in developing countries entail costs of $50 to $99 per human life saved.[9)]

Billions of dollars for the imaginary protection of humans from radiation are actually spent year after year, while much smaller resources for the real saving of lives in poor countries are scandalously lacking.[10)]

Natural Radiation Measurements

In the three Physics Courses which I teach, I include at appropriate times in the different courses, measurements on the natural radiation that occurs around Sophia Junior College.[11)]

The students are very surprised to know that if they collect dust in the classroom, they can measure the half-life of the Radon present in the indoor air. They cannot imagine that we are inhaling radioactive substances when we breathe. Of course a minimum quantity enters into our lungs, a quantity which depends on the geological location we are in. Different studies[12)], beginning in the 1970's, have found numerous homes having levels of many hundreds of Bq/m3, causing estimated risks of cancer for lifetime residents, from several percent to 25 percent. This exceeds by many times the magnitude of the environmental risks that we ordinarily worry about.

Nevertheless, it seems that we, humans, have developed resistance to natural hazards, especially to these kinds of short-lived radionuclides present in the air.[12)]

We try to study and understand all these problems and the students become serious when they learn the importance of the many problems in the environment around us. Surely they will forget many of these things, but I hope that when the occasion arises they will remember and will take into account the surrounding circumstances, then, as good life-learners, they will be careful and able to join forces with those groups which will help to be "Builders of Hope for All Humanity" as John Paul II asked the scientists in his address during their Jubilee in Rome on May 25, 2000.

Ar-40 → K-40 Generator: Milking Experiment

Another experiment I do with every group of students which I teach is the measurement of the isotope Kalium-40 life-time. In 1984 Professor Haruhiko Morinaga, who supervised me in Tokyo University when I studied there in the 1960's, brought me one of his important Ar-40→K-40 generators which he had developed in Germany, for my use with the students in Physics Education classes at Sophia Junior College.[13)]

The generator is a lead cylinder filled with the isotope Ar-40 from inert argon-gas. Ar40 decays with a half-life of 30 years to K-40, a kalium-isotope which decays with a 12.5 hours half-life, just an appropriated time span, to be measured during a day's time. Because the cylinder is full of K-40, the generator is like a cow and the procedure to extract it is called milking.

As I said before, it is very important that young people are able to know more and more about radioactive substances. One of its characteristics is its decay: short or long half-lives will have different uses depending on their value.

Special Note

Professor Morinaga knew that I would not be able to do a real experiment with the students unless I had a suitable radioactive source that would decay in a time that would allow the students to measure and calculate the results during one class period. So he tried to help me in every way possible in order that I would be able to teach properly and that my classes would be scientifically sound. I am really grateful to him and all my life will acknowledge his understanding, acceptance and unconditional help.

Last Comments

I have been teaching at Sophia Junior College since its beginning in Hatano in 1973, always trying to help young people to become learners. In fact, I have learned very much with them and through them, trying not to remain behind the many discoveries of the last decades.

Mme. Curie's words after she was awarded the Nobel Prize have been a wonderful message for me as much as for my students:

> "Each one of us perhaps can't do much, but we can catch some gleam of knowledge which can make man dream of truth, and through these small candles in our darkness release before us little by little the dim outline of the great shape of the universe. And I remember those who think that by this reason Science has great beauty and with this great spiritual strength, within time, can clean this world of its evil, its ignorance, its poverty, diseases, war and hatred.
>
> Look for the clear light of truth, look for unknown new worlds, even when man can't reach them.
>
> Every age has its own dreams, live them the dreams of yesterday... Youth! Take the torch of knowledge and build the paths of the future!"[1)]

We can also learn from the address of John Paul II to the Scientists in their Jubilee in Rome and how the Pope quotes the Scripture to talk with them:

> “The heavens are telling the glory of God, and the firmament proclaims his handiwork" (Ps. 19.1); with these words the psalmist evokes the “silent account" of the Creator’s marvelous work inscribed in the reality of creation itself. Those involved in research are called in a certain way to have the same experience as the psalmist and to experience the same wonder. “One must aim, at encouraging the human spirit to develop its faculties of wonder, of understanding, of contemplation, of forming personal judgements and cultivating a religion’s moral and social sense". (Gaudium et spes, n.59)

I would like to be young again and able to continue my lifelong working and learning with new generations of students.

Note: The sievert (Sv) is unit of equivalent radiation dose.[15)]

An equivalent dose of 1 Sv is received when the actual absorbed dose of ionizing radiation, after being multiplied by the quality factor Q and the product of any other multiplying factors N, is 1 joule per kilogram. In this scheme the relationship between the absorbed dose of radiation D and the dose equivalent H is, therefore, given by $H=QND$. Both Q and N stipulated by the International Commission on Radiological Protection. Q depends on the nature of the radiation and has a value of 1 for X-rays, gamma-rays and beta particles; 10 for neutron1s; and 20 for alpha particles. N is a factor that takes into account the distribution of energy throughout the dose.

Notes

1) Film *Madame Curie*, M.G.M. 1943.

2) Ideas taken from 21st International Conference on "*Improving University Teaching*" Nottingham, England, July 1996.

3) Candy, P.C., Crebert, G., & O'Leary, (1994). *Developing lifelong learners through undergraduate education*. Commissioned Report No.28 National Board of Employment, Education and Training. Australian Government Publishing Service.

4) News Conference in the Science and Technology Agency. October 1, 1999. *Japan Times*, October 2, 1999.

5) *Japan Times*, October 4, 1999.

6) Reported by Shino Yuasa (AFP-Jiji). *Japan Times*, October 4, 1999.

7) *Physics Today*, Sep. 1999 p.24. Z. Jaworski.

8) Data from UNSCAR, *Physics Today*, Sep. 1999, p. 26.

9) B.L. Cohen, in "*Rational Readings on Environmental Concerns*", J. H. Lehr, ed. Van Nostrand Reinhold, New York (1992) p. 461.

10) "Radiation Risk and Ethics" Z. Jaworski *Physics Today*. Sep. 1999, p. 29.

11) "A Small Attempt in Ecological Studies: Learning about the Surroundings at Sophia Junior College" Carmen Gil p.55-65. *Sophia Junior College Faculty Bulletin*, 1995.

12) *Physics Today*, April 1989, p. 31. "Earth, Air, Radon and Home". Anthony Nero.

13) "*Genshiro o nemurase, Taiyo o yobisamase*" Haruhiko Morinaga, p. 100〜112.

14) *Archivo informático de la Santa Sede*. May 25, 2000. "Jubilee of Scientists".

15) Adapted from "*Scientific Unit Conversion*" by Francois Cardarelli, Springer Verlag, London (1997).