Science Awareness and Science Literacy through the Basic Physics Course: Physics with a bit of Metaphysics?

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Abstract. Until the 1980s, it is well known and practiced in Indonesian Basic Physics courses, to present physics by its effective technicalities: The ideally elastic spring, the pulley and moving blocks, the thermodynamics of ideal engine models, theoretical electrostatics and electrodynamics with model capacitors and inductors, wave behavior and its various superpositions, and hopefully closed with a modern physics description. A different approach was then also experimented with, using the Hobson and Moore texts, stressing the alternative aim of fostering awareness, not just mastery, of science and the scientific method. This is hypothesized to be more in line with the changed attitude of the so-called Millenials cohort who are less attentive if not interested, and are more used to multi-tasking which suits their shorter span of attention. The upside is increased awareness of science and the scientific method. The downside is that they are getting less experience of the scientific method which intensely bases itself on critical observation, analytic thinking to set up conclusions or hypotheses, and checking consistency of the hypotheses with measured data. Another aspect is recognition that the human person encompasses both the reasoning capacity and the mental-spiritual-cultural capacity. This is considered essential, as the world grows even smaller due to increased communication capacity, causing strong interactions, nonlinear effects, and showing that value systems become more challenging and challenged due to physics / science and its cosmology, which is successfully based on the scientific method. So students should be made aware of the common basis of these two capacities: the assumptions, the reasoning capacity and the consistency assumption. This shows that the limits of science are their set of basic quantifiable assumptions, and the limits of the mental-spiritual-cultural aspects of life are their set of basic metaphysical (non-quantifiable) assumptions. The bridging between these two human aspects of life, can lead to a "why" of science, and a "meaning" of life. A progress report on these efforts is presented, essentially being of the results indicated by an extended format of the usual weekly reporting used previously in Basic Physics lectures.

1. Introduction

Since the 1960s I experienced and practiced the existing way to proceed with lectures in basic physics at the Institut Teknologi Bandung, using the Francis Weston Sears texts [1]. Their content was completely technical, with the level of technicality being indicated by the course type: A for a 4 semester course, B for a 2 semester course, and C for a 1 semester course. That approach was fine with me, as I was already self-motivated to master the technicalities, and to appreciate their effectiveness in solving technical problems quantitatively. However from the first semester in 1969 when I was given the C course to do with Architecture and Town-planning students, and in Leeds, Britain with non-Physics students doing physics laboratory experiments, I started to get aware that not everybody was


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happy with doing physics that way. So when in the early 1990s a change of textbook to the Douglas C Giancoli text [2] was suggested, accepted, and then introduced, I was happy to implement the nicely illustrated text. Still it was a struggle to motivate undergraduate students; apparently the "Millenials" attitude of short-span-of-attention and multi-tasking [3] was coming to the fore. Attention to details was quite often lacking, students getting lost in detailed calculations, and quite unable to follow reasoned thinking.

Then in 2008 I got hold of the Hobson textbook [4], which uses social context as frequent reference, arguing that physics should be learned as connected to common life and culture. The texts of Moore [5], while more quantitative, also stress unifying themes like conservation of energy and momentum, universality and independence of natural rules from the observer, duality of electricity-magnetism and particle-wave, irreversibility of macrophysics, to show that physics does relate to, or parallel, common life with its social and cultural context.

On the other hand, my interest was increasingly attracted to the relation between science and religion. Studying this, parallels were slowly discovered between those two [5], leading to awareness that those two ways of thought could and should be fruitfully related [6], using the concept of dialogue. The results are discussed below.

2. Hypothesis

Continued reflection and study of the above topics led to the following hypothesis: For man to become fully integrated in attitude and actions (having "integrity"), as has been realized by the Indonesian community since its inception [7], her/his education should have an integrated form, encompassing both the scientific rationality and the social-cultural-religiosity capacity. Considering the study load and the study time available, and not the least the changed attitude of the student due to increased awareness of freedom of expression and freedom of choice, the rational choice or hypothesis is to emphasize awareness as a starting point to act, and not the past focus on mastery of the educational materials.

Unwillingness to opt for this rational choice for a hypothesis, has produced attitudes like cutting corners in studying, memorizing, condoning plagiarisms, and other negative attitudes.

This rational choice is clearly not without problems, and a very important aspect is, that the teacher / lecturer has to adjust relevant attitudes as well, actually very much in line with the the responsible conduct of research ("RCR") discussed in an AAAS (American Association for the Advancement of Science) Professional Ethics Report [8]:

a. A scientific virtue-based approach begins with aims and methods, which should be conducive to the achievement of excellence.

b. The central aim of scientific practice is the discovery of empirical truths about the natural world.

c. The methods of science reflect its basic epistemic values, such as testability and repeatability.

d. Curiosity and honesty are the most central scientific virtues, together with attentiveness, objectivity, skepticism, and meticulousness.

These attitudes or virtues can be more easily introduced, if time is made available to raise awareness of the student, and postpone technicalities if time does not permit.

Simultaneously, the teacher or lecturer should progressively improve his/her ability to raise such science and scientific awareness, to conduct question and answer time on various topics raised, and to offer answers at suitable level, to encourage further study and further questions after the student has reflected on her/his answers. This process is slow; it cannot be rushed. I myself started this process in the 1990s, at first struggling to find suitable ways to answer questions enrichingly.

3. Humanity

The human is clearly a complex system, having both a physical body, and a self-awareness and self-consciousness which defies simplification. The first aspect is more quantifiable, and properly has become the easier object of study, resulting in the sciences, both the natural and also the biological sciences. The social sciences are more complicated, having as subject that human personality, not just

the physical body, and then both as an individual, and also as a community; and lately, also as a global community encompassing the whole of Earth.

The easier aspect were the physical sciences, which showed the weird effectiveness of mathematics in producing consistent results, consistent with reality of the measured world, science, and technology.

The more complicated aspect were the social and cultural sciences, and soon to be coming, the religious "sciences", the quotes emphasizing that "sciences" usually are tied to observations and measurements, not only hypothesizing and relying on common sense.

Nevertheless, previous studies [9] have concluded that to serve the human person well, science is not enough; inquiries into the religious aspect of man should also be made the object of research. Therefore, a series of small studies has been initiated [10], studying the setting up of the so-called units of measurement in the International System of Units, to show that history (social and cultural science), human experience and chosen decisions, besides rationality, have formed the present era of science, and as being science-based, also technology.

Furthermore, such studies can lead also to the question of "why so", not only why mathematics and its physical predictions are so effectively (and weirdly) consistent, but also why the human could be so able to discern the patterns of processes in the universe. This easily leads discussion into the (non-quantifiable) metaphysical area, even touching the role of religion etc. So humanity can be shown to be also of dual nature: having both physical and spiritual capacities, but with a seemingly common way of processing observational data.

A cautionary note is important: Due to existing sensitivities of religious issues, sometimes, the teacher or lecturer should tread in full awareness of the trickiness in safeguarding the scientific virtues mentioned above, and not become an apologetic person, meaning a person who wants to solely defend or propose a certain (non-quantifiable) opinion, idea, ideology, or faith.

What can be underlined is the parallelism between those two threads: Both science and faith show similar ways of processing and progressing. Both can be realized as being based on human experience, measured and non-measurable. So both are based on empirical truths. Both have been using rational thought, and the cause-effect pattern has been found to be essential in both. Both have been predicting results or consequences. Both have been trying to uphold the assumption of consistency of data, consistency of thinking, and consistency of acknowledging results.

4. Progress Report

Here are the main points in concretizing the above considerations in the Basic Physics lectures, and actually it also has been implemented in various other physics lectures. This has the essence of a work in progress, a so-called action research; and a progress report is as follows:

a. The teacher or lecturer should be aware of their responsibility in doing research: Being conducive to the achievement of excellence; not fostering mediocre ways of thought, but trying to foster curiosity and to seek honest ways of thought, showing courage in listening to various incisive questions from students. This is a quite religious, or spiritually enriching way of facing the class, as it is based on a set of assumed virtues.
b. The teacher or lecturer should focus on fostering awareness of the meaning of essential concepts and rules (I avoid the term "physical law" to show that we are not telling the universe how to perform; we are just describing some rules that the universe seems to be subscribing to). This needs fostering of rational thought, slowly increasing the sharpness of critical thought. As the teacher or lecturer cannot be aware of everything in science, she/he should be humble enough to listen to students, show honest surprise when an unexpected question is asked, and slowly try to show the way how to find a proper description for the answer; if necessary, promise to try to find the answer the following week, and use the Internet or available help to find some satisfactory answer before the next (or a further next) session.
c. Technicalities in quantitative calculations can of course be used, but these are subordinate to the focus on getting awareness of the students of the concept or principle or rule. How to solve problems can be focused on simple (but not trivial) problems.

d. If occasionally a link between science and metascience (defined as those aspects which cannot be measured scientifically, but have to be taken as assumptions which can be true but also be untrue in the end) appears, depending on the level of attentiveness of the students, a short but useful comment can be offered, to be reflected on by some students who are interested to delve into such difficult and un-common thoughts.
e. To help the process of reflection of the lecture materials, a weekly report of maximum one A4 page (to keep the student load small enough) has been used as tool, being extended in the past year to become as follows:
    1. A summary of the essentials in the lecture, as an exercise to recall the lecture content and discover the essentials of it.
    2. One question, with a guessed answer, as an exercise to become aware of critical gaps in understanding the thoughts offered, AND exercising to find some answer to it. This will improve self-reliance and self-study.
    3. A reflection on the usefulness of the lecture, its positive effect for the student. This is an exercise to foster a constructive attitude.
    4. A reflection on the risks involved with the content of this lecture. This is an exercise to be aware of risks, and that nearly everything has negative besides positive effects; that things are usually not just black or white but are of varying degrees of gray.
    5. One small but concrete task or plan that can be done using the content of this lecture, especially in service of the weaker part of the local community. This is intended to shift attention from oneself toward the environment, both the human or the natural environment, and focusing on those who are on the weak or suffering side of the community. The very human-like community-sense is expected to be supported by such attitude.

Results of this procedure show no opposing attitudes, but positive thinking in the students. It is expected that continually improving this procedure will improve attitudes in being holistic, neither secular nor fanatical in ideology or religion.

5. Response to some comments

Some comments and questions were received when this paper was presented at the Symposium. The response given, in a bit extended form, is as follows:

a. Is the metaphysics discussed in this paper, similar to the meaning of "learning how to learn"?
No; the term "metaphysics" is used to mean an area where the scientific method still can be used, except for the "measuring quantitatively" step, as this "metaphysics" area can be defined as an area of knowledge which cannot be measured quantitatively. I am recommending to enter this (non-measureable) area a bit, by learning how to do the entering in a constructive way. Learning can be said to be adjusting or changing a state or situation, and learning to learn can be said to be adjusting a usual learning method, to deepen and/or broaden our/someone's knowledge. Deepening or broadening our scientific knowledge will bring us to the limits of our ability to measure quantitatively. The uncommon recommendation is: Try to be courageous enough to cross that boundary into the metaphysical area a bit, where no measuring quantitatively is possible anymore. However, entering the metaphysical area should be done "scientifically", still using rationality to the utmost, using the cause-effect (causality) argument to the utmost, and using the assumption of consistency as a measure in predicting conclusions. This means that we are trying out a qualitative measure, the quality of conclusions judged by its consistency with common sense, experience, intuition, and conscience. "Using the heart" is a spiritual expression for that, and this expression can be honed by every time doing a reflection on the meaning and calling (of God). Here the assumption is used that God exists. Fortunately, the Indonesian people in general have no problem in accepting this assumption.

b. The weekly report method reported in the paper, even if enriched with letting the student try setting up a road map or concept map in solving a problem, or modelling a process, does not

always result in improvement of awareness or of understanding or of motivation of the student. What can be done?
This shows the complexity of the human person. It is recommended to keep searching for a more effective method, by observing closely ("student-centred"!) how the student responses, then try to discern what can be changed to improve the student's motivation and interest for hard work. The Millenial student seems to appreciate a simple, clear answer; or a bit of information or easily processed thought; before moving on to another topic. So we as teachers or lecturers would be wise to heed and develop short, clear bits of information. This needs doing frequent reflection on physics topics, to discover interesting aspects, and find clear, simple (but non-trivial) expressions to give to the students, and show the connections between the various short statements.

c. What is the difference between religion, spirituality, and metaphysics?
Metaphysics is an area of knowledge, that is non-measureable quantitatively, but claimed by this author to be measureable qualitatively, meaning that truth and non-truth can still be "measured".
Spirituality is a sub-area of metaphysics, as it also cannot be measured quantitatively, but what is "felt" intuitively as the "truth", can still be acknowledged; and the sub-area is directed towards a higher concept or entity called "God".
Religion is a sub-area of spirituality, centered on the concept of God, and more or less attentive to procedures and concrete actions.

6. Conclusion

A case has been made, for a format of the Basic Physics lectures, firstly to focus on improving awareness of what the student already knows and can further know. The further step is to prepare the student to consider some metaphysical thoughts, based on the awareness of some concepts and rules learned. This further step should be handled courageously but in keeping with the scientific method. Ultimately, this process, if done slowly and reflectively, is expected to help the student into growing to be a person of integrity, being mature both scientifically, and spiritually.

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