BETTER PHYSICS TEACHING CAN INCREASE PHYSICS ENROLLMENT

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Our main goal is to develop plans to increase physics enrollment. Once again we thoroughly analyze the problem from the beginning and reach the conclusion that the most appropriate starting point in this direction should be to look into K-12 teaching. We give a few recommendations to improve science/physics teaching at K-12 level. It is proposed that the quickest way to make some advancement is to start teacher training or refresher courses for school teachers to fill up their gaps in knowledge. We suggest a comparison of the affectivity of different methods of teaching to decide which one of them works better under what type of circumstances. We also propose a few steps to improve physics teaching standards at the higher levels.

I. WHY DO WE NEED PHYSICS?

We start our analysis by reminding ourselves with the future needs of societies. In this technological era only those nations that can keep a balance between the development in science education and the development in technology will rule the world. Keeping that balance is perhaps the only way to get a respectable position in the technology based future and to enjoy the modern time lifestyle. Therefore, mankind will have to develop scientific approach towards life through the basic science education. However the standard of basic science level is also being changed with time. When we talk about science education, we mean all kind of sciences but talking about technology, we have to give physics a little more importance than some of the other branches of sciences as it is helpful to understand almost each and every branch of science, especially in relation to technology. Physics obviously has many more applications to technology and is actually a language of technology in modern era. It should, therefore be realized that learning basic physics for every citizen is almost as important as learning a common language to completely share the joy of a social life. In other words physics is the mother of engineering and technology. It has suffered most because it is always associated with mathematics and is an accepted difficult subject. It could easily be decoupled from mathematics at the elementary level. The interested students who are motivated enough to learn the subject in detail, would be able to learn required mathematics at a later stage. However, to really improve the interest in science education, because of their interest, we need to improve mathematics teaching right from the very beginning. This will not only help to develop a well-planned and financially organized society but also help to increase the physics enrollment as well as the quality of physics education.

If we want to do anything to improve the physics enrollment and learning, we have to improve physics teaching. Unfortunately, physics teaching is one of the most ignored areas in several ways. We have very effective and dedicated teachers, very learned physicists and even enough motivated students. The problem lies in the system itself and we have to look at the origin of this problem. We are convinced that the roots of this issue arise from public schools. At K-12 level we do not have enough physics majors to introduce physics in an appropriate way to the young children. When we go back to look in to the reasons behind it, we find that a few years ago, a physics degree was considered to be a paying degree. Even then, a physics degree holder would not prefer to teach as it is not a well-paying job. It is still not a well-paying job but the general cuts in physics jobs could have attracted a bigger ratio of physics majors to teaching. But we could not still improve the ratio of teachers with a physics degree. As a consequence, we are losing interest in physics among children and are expected to be even unable to get the minimum required American national scientists. On the other hand, because of the changing situation with the immigration rules, it might even not be possible to bring as many physicists from other countries, especially for some special projects running in sensitive areas. We still have students, but as soon as they get the degree, they go back to their countries. On the contrary, American students are losing interest in physics. We need to plan now to avoid that situation where we may not be able to win the complete supremacy in technology, especially to compete the continuously growing trend almost everywhere else on the globe. The US-Government has to handle these long-term issues more seriously.

Most of the physicists after obtaining Ph.D. prefer to join computer-related jobs in industry or sometimes even provide cheaper labor by teaching as adjuncts in colleges. Some of them are undoubtedly great teachers or researchers and hiring them by colleges may not be any financial burden as they may attract a large number of students and
Physics along with its own image of being difficult and boring subject. Higher level usually say math is boring and physics is math. All the negative comments about math are associated to even earn enough money with that' and most tragic statement which we hear is, 'physics is interesting but I cannot
difficult that I cannot understand.' 'What is the use of studying physics, it has no practical applications. We cannot
see the speed of their development regardless of their limited resources. But we are perhaps too busy in enjoying
the present and may even ignore our future. Falling behind in that, we forgot to do much for securing our future.

We have seen several state colleges where physics programs are being run by a single full-time faculty member or even
by non-physics faculty. This badly affects all the related programs and spoils the quality of physics teaching in such places. The cutting budgets of colleges have raised this trend to hire less expansive teachers, which in turn affects the standard of education and the decrease in science enrollment, in general. Physics has suffered greatly by this policy. The impact of this happening is clearly seen from the data of physics enrollment during last few years. There could sometimes be an increase at the undergraduate level at some places [2] because more programs have started requiring physics courses. However, we are addressing here the enrollment in physics programs itself instead of the elementary level physics courses required by several other majors.

When the question of physics education comes under discussion, we have to differentiate between science majors and non-science majors. We all agree that physics is compulsory for all engineers and science majors. They can excel in their careers with a better physics background only. Actually at the research level, physicists can even work as engineers. So there are always physics courses for these programs and they are almost standard. There is always room for improvements, and we in the University of Houston Clear Lake are trying to improve our undergraduate physics teaching to a greater extent to be able to attract more students in graduate program. We could see the immediate effect through the increase in enrollment by 20% or more. This increase is with respect to the physics enrollment in subsequent years. However, the ratio of physics majors with majors in other disciplines is not increasing so much.

However we want to step back a bit and see how we can get more students in science in general and physics in particular. Our main concern is to increase physics enrollment and attract more interest in the subject itself. Science and engineering majors have to take physics to satisfy the requirement of their programs. Whereas non-science majors usually put physics at the bottom of the list of courses of their choice among the science courses. Or we can safely say that there would be hardly anybody who would like to take physics if he or she does not have to take it for the program requirement. Our main goal is to bring physics at the equal level with other introductory science courses, although it is always considered to be a difficult subject. A better mathematics background definitely makes a difference and is proven to be helpful always. This is the actual situation in some of the other countries which have not yet adapted to technological development so much.

Countries like India, China and Japan are working hard to teach mathematics and science to their children and we can see the speed of their development regardless of their limited resources. But we are perhaps too busy in enjoying the present and may even ignore our future. Falling behind in that, we forgot to do much for securing our future.

Now we have reached a point where we always hear, ‘I hate math’. ‘Physics: it is hard and boring’ or ‘physics is so
difficult that I cannot understand.’ ‘What is the use of studying physics, it has no practical applications. We cannot
even earn enough money with that’ and most tragic statement which we hear is, ‘physics is interesting but I cannot starve’ ‘I would enroll in physics if someone promises to pay me in this career like others.’ Moreover, students at the higher level usually say math is boring and physics is math. All the negative comments about math are associated to physics along with its own image of being difficult and boring subject.

Programs such as ‘No Child Left behind’ [3] should include science along with mathematics. Every child deserves to be exposed to science in relation to daily life. We need to help our children to learn how to contribute to assure a safe and healthy future. We need to make them aware of our future needs. Physics is an amazingly important subject in this regard. It is considered the mother of technology. Especially in this technological era, it helps to enjoy the technological development in its entirety. All branches of engineering have their roots in fundamental physics. Knowing this, we need to teach physics adequately at all levels and maximum students should be attracted to physics to continue leading the entire world in technology. Unfortunately, we are not doing very well there. Physics has been tied up with mathematics to the extent that it is usually taken for granted that you can only understand physics if you are exceptionally smart in mathematics. It is not incorrect that physics could properly be understood with the help of mathematics only and it could be fully described mathematically. Still it is not all mathematics. It is only one of the applications of mathematics. It has experimental and observational components built-in there. No physics course can be completed without the integral component of laboratory work. We somehow completely ignore
the applied physics which has much more overlap with engineering itself. On the other hand math as a subject is considered to be a subject for very smart students. In this situation if we need to attract more students in science we have to start attracting students in science right from the beginning. So, the teachers from elementary, middle or high schools can play the most important role in developing an interest in science. For this purpose, our school teachers need to be trained in physics so that those who were not physics majors but are teaching physics can have adequate knowledge to satisfy immediate needs of the corresponding subject. Moreover, teachers are needed to be aware of the latest development in science and should be able to share the fascination of new discoveries with children who are our future scientists. In this situation if at the early stages of school, students can get some inspiration about science subjects from their parents or teachers; getting into these fields is no more difficult for them. This is what is really happening in most of the countries in Asia, Russia and Japan.

In this era of science and technology where computers have made it possible to visualize things a lot through simulation, we do not want to learn through equations or our imaginations only. However, the beginners need motivation by the fascination of physics through visual mode of learning. It even compels those beginners to learn whatever is involved in the learning of technical language of the subject such as mathematical equations and computation. Mathematics itself is not interesting to most people. It is a great tool and is learned when you want to understand some other concepts and ideas in business, science or computation, etc. If you can get adequate mathematics training for business majors why cannot we do the similar amount of mathematics training for physics majors? The courses like methods of mathematical physics can be taught very well in a physics department to satisfy the immediate needs of physics majors in the beginning. I guess such courses are much more helpful when they are taught in the physics department and students do not have to go with several courses in mathematics which are sometimes not offered in a convenient time for physics students. Either the mathematics and the physics faculty has to work together to offer appropriate mathematics courses for physics students at the time of their convenience or some mathematics courses are especially designed for physics students and are taught as a part of physics program.

In this situation I guess physics teaching needs a lot of improvement. Not because the other science subjects are not equally important, just because physics is equally important and still undermined for several reasons. One of the big reasons is that the most of the science teachers in high schools are science majors, but most of them are not the physics majors because we do not have such a high enrollment in physics degree as we have in other science subjects. This obviously affects the ratio of physics majors in the recruited science teachers. The simple reason is again because it is considered to be very tough to have too much mathematics and not to have so much practical applications to life. There are several reasons behind it and we have discussed them in Ref.1. How can we expect those teachers to make physics attractive for students who did not choose to study it themselves? At this point we just need to know how to come out of this mutually entangled problem where the decrease in enrollment keeps on growing without even giving a starting point or an end point. We just want to see how to overcome this problem here. Let us start from trying to find the root cause of this issue. I think it lies somewhere in school education where the students develop a mathematical background and are exposed to science subjects for the first time in life. We need to look at this carefully and take some concrete steps to improve the level of science teaching in schools. According to our analysis, the best starting point would be middle and then high schools, where students are exposed to science for the first time as a real subject. In good school districts we have a better ratio of science teachers with physics degree. However, it is a big concern for the educated community that the middle school teachers who almost give the first proper introduction of science to students may not even have their major in science subjects and if they do, may not be equally trained to teach the subject, they are teaching. It has even be noticed in the elementary schools that sometimes teachers may not be able to answer science questions appropriately. With a small number of physics majors, in general, there is a big possibility that physics is being taught by those people who may have just taken one physics course and have hardly passed it. Should we expect from such teachers to attract our new generations to physics and be able to prepare more physics majors? May be not! They can only promote subjects of their own interest that they know better than others. This is quite well-known and pretty understandable also that the teachers can always teach those subjects better than others which they like most and enjoy to teach. Moreover, those teachers prove to be better teachers for whom teaching is a passion and they love the subject itself.

II. IDENTIFICATION OF THE PROBLEM

When we started investigating the root cause of this problem, everything appeared to be tied up in a loop and we had to decide on a starting point by carefully analyzing the situation in detail. The science community has a special concern about the decreasing enrollment in science, in general, and physics, in particular. This decrease in physics enrollment obviously can lead to a situation in which we do not have enough physics majors to fill the basic needs of employers or to introduce this subject adequately to our children. As a consequence we will not be able to attract
our children into the subject. This is unfortunately what is happening in several school districts nationwide. We have analyzed some data in order to look at this situation quantitatively.

- The nation’s schools employ 21,000 physics teachers [4]. Two-thirds of them do not have a degree in physics or physics education. The most common degree in science is biology, and in this degree only two semesters of general physics are required. Students, who are taught by biology majors, usually do not do as well in physics. Thus there is a great need for more physics teachers and for preparation of cross-over in-service teachers. In this situation these out-of-field teachers should be required to do some preparatory courses in physics before they start teaching physics. It will be a much faster approach than bringing in all new physics majors to teach physics.

- Senior teachers with physics or physics education degrees may have studied physics many years ago. They may be very good teachers and are perhaps the only ones who are playing a major role in maintaining our physics enrollment. However, these teachers will be better prepared to face their professional challenges in attracting students to physics if they are aware of new developments in the subject and if they are exposed to new teaching techniques.

- Moreover, it has been noticed that in most of the teacher’s certification programs the minimum requirement to get into the program is the same as the minimum requirement of getting in the school [5]. Moreover, this certification just requires passing grades (C or above) in any subject. This standard is not attracting our best physics students to a teaching career as a majority of the students with good grades can get into other higher-paying careers. Those who could not go to another career would go into teaching as an alternative. This obviously affects those subjects which need to be taught by people who are really interested and knowledgeable in the subject itself and can teach it adequately to attract children to the discipline.

- We have looked at the salary structure of schools in Texas [6]. The salary difference between a bachelor and master degree is just $1,000 dollars per annum and with Ph.D. teachers only get $200 extra in a year as compared to the master degree. In this situation, why would a teacher spend the extra time for a Ph.D. or even a master? So, there are no real incentives for teachers to go for higher education.

- On the other hand, there are several Ph.D.’s available who could have taught in schools, but can not as they do not have the school certification. They do not want to spend money and time to get certification and then end up getting low school teacher salary without getting any benefit of higher specialized degree. They instead accept computer or other related engineering jobs in industry and pretty much leave physics and get much higher salaries as compared to school teachers.

- Recruiting students in physics program is also a very tricky job. Physics enrollment is already significantly below the desired level. There are not many people taking interest to join physics. In this situation we have to relax enrollment criteria a little bit to keep the enrollment above the minimum requirement for any program. Sometimes, because of the decreasing interest in mathematics, we have to compromise on the mathematics background. On the other hand, it is noticed that those students who do not have ever taken physics but have better background in mathematics could easily manage to pick-up the calculus-based physics course. These students may do much better than those who have even taken algebra based physics but have not completed the mathematics courses. In this situation we may have to think about revising our prerequisites. If we cannot fix the problems related to mathematics teaching in schools, we may want to fix it at the college level to get help in developing a better physics background. However, in this attempt of increasing standards, there is a danger of students dropping out the existing enrollment level due to a greater failure rate also. Therefore, just to keep program running, sometimes we have to compromise on those things which should not have.

- People who are working in physics education are developing teaching models which work in their setup; however, it may or sometimes may not be so effective in other situations. Some of the good examples are modeling [7-10] techniques and thinking skills [11]. John Clement[12] has given a comparison of gains between FMCE [13] and some of the other methods[14,15].
III. ROOTS OF THE PROBLEM

We have just mentioned a few reasons for the decreasing interest in physics. We could analyze the situation through our personal experience, some data analysis and the exposure to the existing literature. But this analysis cannot be a thorough analysis as it has too many variables. All our results somehow seem to depend a lot on local circumstances and individual factors. We can pretty much find the reasons of whatever is happening and how our teaching becomes a sensitive function of several variables. Some of them have already been discussed in Ref. [1]. We will postpone the detailed analysis of these issues and will concentrate on finding a solution. We can even list some of the well-known variables as follows:

- instructional resources
- educational training
- financial satisfaction
- professional commitment
- career goals
- personal priorities
- academic interests
- Family background.
- Work atmosphere

Teaching can be made a lot more effective using the modern technology. Computer simulations make it possible to visualize things that could not have been imagined only a few years ago. Because of this, we do not want to learn through equations or our thinking skills and visualization only. Beginners need motivation via the fascination of physics through a visual mode of learning. Demonstrations, experiments and simulations play an important role in this fascination. It even compels them to learn whatever is involved in the learning of the technical language of the subject, whenever it is needed.

Modeling [7-10] and other visual methods are definitely very effective and in some cases, they are the only methods to teach some of the students. However, we should be able to train at least some of the students in a way that they can look at the situation intuitively and able to make an educated guess before even doing any calculations. Thinking skill is a key to research contribution. For example, mathematics itself is never interesting for most people. It is learned when someone wants to understand the basic concepts and ideas in business, science, computation, or some other fields. If we can deliver adequate mathematics training for business majors why can’t we teach our students just as much mathematics in a physics class?

I guess all of us have noticed that a better mathematics background leads to the development of a better ability of visualization of the physical concepts. In this situation, we should try to segregate between those students who want to go for a physics program and the ones who just want to take physics for other programs. Even elementary physics courses like calculus-based physics should have at least two different groups. Having these two groups is all possible, but we do not want to hire enough teachers and compromise our standards and even our future. It is a real disappointment when a teacher of calculus-based physics course has to teach two hundred students in the same class at a lower level to make it understandable for majority of the class. But, doing that, we may discourage or lose some of those twenty students who may want to become future research physicists and cannot comprehend enough in this type of class setup. On the other hand, it is almost impossible for students to get reasonable individual help from the instructor. Failure rate in these big classes is usually higher and students are unhappy as they cannot communicate with the instructor directly. Usually teaching assistants, who are graduate students themselves, help students.

Moreover, there is a well-known hierarchy in teaching standards between community colleges, state colleges and the research universities. We need to start some work from the school level. Research universities try to keep standards at the cost of high failure rate. Students can save money in the same order and compromise on the standards in the reverse order. Partnership between community colleges, state colleges and research universities is also a good way to overcome the problems due to this hierarchy.

Before we discuss about how the physics enrollment can be increased in the presence of all the above mentioned factors, we want to indicate that the causes of problem can be found at each and every institutional level including middle schools, high schools, community colleges, state colleges and research universities. However, a few things can still be recommended at all different levels and should be applied simultaneously to overcome these issues.
IV. HOW TO IMPROVE THE SITUATION-A FEW RECOMMENDATIONS

We propose a few recommendations to start efforts at several institutional levels at the same time. We want to discuss them one by one and see what can be done about it. We start from lower to higher level.

• At K-12 level the problem are briefly indicated. In the long run we should plan to hire physics majors to teach physics at school levels. However, as an immediate solution, we would recommend starting summer workshops for school teachers or summer refresher courses for them. These courses should be organized by the physics department or program of a school and are taught by the physicists. All the physics teachers should be required to these courses at least once in three years. These courses are especially needed for those teachers who are teaching physics based middle school courses and in some cases, high school physics courses and have not even opted to be a physics major themself. We want to initially collect data on the ratio of non-physics majors to physics majors among middle school and high school physics teachers in several school districts and then would like to investigate the functional dependence of science majors on the qualification of teachers in general. For this purpose we will have to collect data on the number of students going for science majors from our test school districts. We would also like to see how our program makes a difference in this ratio of students going for science majors.

• We are also interested to keep a continuous check on our program. For that purpose we want to work very closely with the school of education and keep a continuous check on the affectivity of our program. From the school of education, we can share expertise in data collection and sometimes even research students who are interested in specializing in science education along with introducing research in the topics of physics and science education in the college of science and computer engineering. This way we should be able to generate some inter-college collaborative work within the campus. In the first year we need to collect data on all the middle school teachers from almost all school districts of Houston region and then will compare it with the existing school district ratings. We will also gather data about the ratio of students going to colleges and ratio of science majors getting out of each school. Then after introducing our program, we would like to see the impact of this program on these ratios. From here we can not only apply this program to schools in Texas, we can even expand it nation-wide and who knows how much success can be achieved!!

• Some of the school districts have special programs like Science-Magnet program [16], Science-Olympiad [17] etc. These programs are very effective; however a partnership between schools and colleges could make the program a lot more effective. If these schools can arrange some science workshops for students at individual grade level or arrange science fairs, that will be very helpful. Such programs will at least increase the ratio of science majors by 10-20%. This number is based on the data collected from overseas, where the circumstances may be different from here. Though, we still believe that it will not be very different over here.

• In the community colleges or some four year colleges which have physics program to support other degrees, the standard is decreased when we see a master-degree holder engineer as the program coordinator for physics. Just to keep his or her position secured, he or she will never prefer to hire a physics Ph.D. as a second or third faculty member. These qualification deficiencies may some times lead to generate inappropriate relationship between different parties and spoils the academic atmosphere. How can we expect a good physics program if the program coordinator has a limited knowledge in the subject. This is how the standard of program is severely damaged, sometimes. So we have to take care of this problem. Even a community college or a two- year physics program should have at least one physics Ph.D. as the program chair. That will make a difference.

• We need to reduce the difference of standards between same types of courses. One example is an algebra-based physics as the most common course which is taught as AP (Advanced Placement) physics course in high schools, college physics course or algebra-based physics course in community colleges and state colleges. This is the type of problem with calculus-based university physics course. This course has a large difference of standard between state colleges and research universities. Some times physics programs make a decision in accepting credits from other colleges to keep the same standards. However, students are discouraged or cannot afford time and money to go to join physics program and take those courses again, which they have already done in other colleges.
Money and time are other big concerns for students who join a physics program. We in the University of Houston Clear Lake have introduced a non-traditional physics degree program [18] where we have a majority of students as in-service part time students. These students are not full time students and obviously have some limitations of time due to their work responsibility. However, it has been noticed that these students are still more motivated students as they choose to learn physics and have job satisfaction and are satisfied financial issues. These types of programs are very good to promote physics and increase physics enrollment as these students come from the background where they do not worry so much about finding a job after getting physics degree and also have no rush to get a degree. They take one or two courses every semester and study it seriously. Good grades are also a kind of requirement for such students as they can only get financial support from there companies for studies if they get at least B-grade. Our class size for graduate course is usually 8 to 10 which is comparable with many research universities. And students are doing even better than research universities, as they have lesser course load and can manage it easily with their work. These types of programs could be developed in other state colleges and universities, especially in the campuses which are situated on favorable locations such as UHCL.

These types of programs could be started at different levels simultaneously and the immediate increase in the standard of physics education as well as the physics enrollment. We are expecting the most immediate dissemination to the students of the teachers who attend this workshop. Students will have the most effective modes of instruction and will be better prepared in physics. They will learn better how to understand physics concepts, how to solve problems, how to use computers as scientific tools, how to communicate, how to transfer their knowledge to daily life and how to become lifelong learners. We intend to present workshops on these topics at regional meetings and conferences of the American Association of Physics Teachers (and/or the State Science Teachers’ Association).

These types of programs may initiate collaborative efforts between Schools of Education and Schools of Science in several campuses, which will set-up a trend for further inter-school programs and help to develop inter-disciplinary research trends in US campuses in general. We are working on developing inter-disciplinary collaborations at UHCL. This partnership of campuses to public schools will automatically introduce the ongoing science program in different campuses and students will easily be able to decide on their choices. It is also noticed that if kids get opportunity to directly talk to highly educated professional community, they may be impressed by their personalities. Due to that reason sometimes they idealize them and decide to follow their educational path. This way, we can attract more students in science. This will lead to the growth in campus enrollment in general and will help to grow the science enrollment in particular. The growing trend of science growth, in the presence of our geographical location, will help us to develop stronger ties between different educational institutions. It is expected to be a very effective way to attract more students to science subjects and prepare for our future properly.

V. REFERENCES AND FOOTNOTES:

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13. Details can be found in several places, see for example: [http://perlnet.unephy.maine.edu/materials/index.html](http://perlnet.unephy.maine.edu/materials/index.html)

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