THE DECREASE IN PHYSICS ENROLLMENT

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Abstract

We discuss and analyze the fact that physics is generally losing its ability to captivate students who may possess the potential to enhance the quality of our future in this age of technology. We have tried to investigate the reasons behind this low enrollment in the light of the results of a few surveys with the undergraduate students in different physics courses and in current relevant college programs. It is not an exclusively descriptive issue, so our analysis is a way to delineate the details of the matter leading to the suggestions for future improvements.
I. INTRODUCTION

It is now well known that physics is losing its hook on the popular choices of elective undergraduate courses. The gradual decrease in physics enrollment is a thought-provoking issue for us all. Physicists are all concerned about the future of physics in this age of technology. But this problem is even more serious in the US where the great development in technology has been achieved through the continuous efforts of a few decades. Now, if this trend of low enrollment persists, most of the relevant physics programs may fade out and as a consequence, we may have to compromise standards, probably not the best thing to do. As a reality, students do not prefer to enroll in physics in the presence of other options. With increasing technological demands, though, it should be the other way around. So, we should accept the responsibility of failing to provide compelling reason to learn physics.

Nowadays, students will register in physics courses only if they have to take it to fulfill the mandatory needs of their major programs. In this situation, the physics undergraduate major and even independent physics departments are already disappearing from the community colleges. We would like to discuss here the root cause of this issue and point out those factors that lead to this situation. Avoiding these causes one by one should be considered as a part of the solution to the problem. We look at this issue based on our discussions with students at different levels from more than fifteen years of teaching and our personal experience of working with the physics community in different continents at different levels for more than two decades. We understand that we have to think about this issue very carefully without ignoring minor details. Some research is being done on a few related topics but, according to our information, this topic has not yet been discussed thoroughly elsewhere. In the reference section we have mentioned a few references [1-5] for the interested readers for further study of some of the individual topics. In the next section we give an overview of this problem in detail and point out the basic reasons for the decline in enrollment. In section III we discuss a few of the important factors in more detail. In sections IV, V and VI more individual issues are discussed. The last section VII emphasizes some of our immediate suggestions. This discussion will include the details of the underlying problems and procedures to get rid of these causes as a solution. Especially sensitive topics are briefly mentioned for completeness. The authors request readers not to take it personally.
II. OVERVIEW OF THE PROBLEM

When we start thinking about the reasons for the low enrollment, it appears to be a very tricky question. We cannot simply describe the reasons behind it. We need to analyze it in the complete scenario of educational system, employment opportunities, teaching and research needs and future perspectives. But we have to pause for a moment and ask ourselves a question before this. Do we all really care so much about it? Usually, we don’t. Probably we are convinced that we just need trained people in the field of technology and not basic sciences. It is probably because we just need very few experts in basic sciences and a large number of engineers and technicians to work for the development of technology. Several technologists can work with scientists even without any specialized high level science background. This is true. Data analysis and other computational help are examples. They could be handled without very strong science background to start with, as long as you are working in an active research atmosphere and have expert help available. However, we still need physicists to propose the basic design and purpose of the experiment. They can check the feasibility of certain features of the designs of new projects and contribute to the interpretation of the experimental results. Therefore, it is necessary to keep on producing quality physicists for our future needs. There should be much larger number of physics majors so that adequate physics training could be provided to enough future technologists. And we could even produce a sufficient number of competent physicists to fulfill future needs. Obviously we do not want to run the higher level physics education programs mostly for the foreign students. Available data [6] indicates the growing enrollment of foreign students at the undergraduate level. However, the ratio of foreigner graduate students in physics is increasing even more. To avoid this, we need to have physics majors in most of the colleges, in addition to the research universities. Otherwise, we might face more serious consequences in the future and almost limit the physics programs to the research universities and the institutes of technology.

We should start this analysis by convincing ourselves that physics is a very interesting subject. Physics is one of the very important undergraduate majors for most of the specialized engineering and technology programs. Let us look at the reasons why physics should be considered a good undergraduate major in support of most of the technical programs.
1. Physics is a very useful basic science subject and has to be taken as a basic requirement for several undergraduate/graduate degree programs in Science and Engineering.

2. Some very important issues in Imaging Science, Astronomy, Cosmology and Space Sciences can only be understood in the light of physics.

3. Physics knowledge is sometimes crucial in designing the projects in environmental science, medical diagnostics, defense, and many other areas related to the improvement of human security and livelihood. Especially, the working of all type of equipments can better be understood with physics background.

4. Development in modern technology needs multi-disciplinary contributions and physics is indispensable in this regard.

5. Fundamental research in physics, undoubtedly, has its own importance and applications. Findings of basic research help in determining new directions of development in technology. There is still so much to be done in the field of physics as in any other field of science.

6. Good physics teaching is essential to produce good physics teachers, simply to teach undergraduate courses in the future.

Moreover, I personally believe that physics plays a constructive role in the development of personalities and societies. Especially, in the current period of scientific and technological development, physics knowledge is very helpful in improving daily life. It even helps in self-reliance, human safety and money savings. Some of the common issues are safety tips in driving, energy and fuel conservation, the use and maintenance of appliances and several other related things. Physics labs give some hands-on experience in equipment handling and attract students to physics. Dr. Richard Hake has discussed the effectiveness of interactive engagements based on an extensive survey [7]. Physics courses could be useful for minor repairs at home even without any specific training. Moreover, the effect of physics on personality and the approach towards life is not ignorable. Science courses help to develop the scientific approach in our daily life and make us more reasonable and practical persons. So in general, physics helps to improve the quality of daily life. These are known facts but we have to communicate it to the students in an
appropriate way so that they can realize the general importance of this sub-
ject. One of the options is to introduce interesting inter-disciplinary courses
to increase the popularity of science, especially physics and its applications
to daily life. Some of the already existing similar courses could be introduced
in other colleges also.

It is also worth mentioning at this stage that our topic is physics in
general, which includes both fundamental physics and applied physics. However,
applied physics can only develop in the presence of good knowledge of
fundamental physics, either theoretical or experimental. In applied physics,
the basic concepts of physics are used to develop application of physics in
different directions. Applied physics directly helps in the development of
engineering and technology. This division includes all branches of physics,
depending on the demands and requirements. All the branches of physics
have a lot of overlap among themselves. This discussion is not in the scope
of our topic at the moment.

In fact, almost every good physics department has to have a couple of
very good groups in theoretical physics to work on the basic physics issues
and also to help the big experimental groups whenever they are needed. All
the big experimental labs also have a very strong theory division/department.
Theorists do independent theoretical or mathematical research work and also
can suggest new experiments based on their research. They are not confined
to the analysis of the final results or helping experimentalists in designing the
experiment or interpreting the results. They suggest and help in designing
new experiments also. In addition to that, they can teach a great variety
of the basic physics courses with their broad based theoretical background.
We are personally convinced that the theorist should teach the experimentalists
so that they can have some exposure to the theoretical / mathematical approach also. Similarly, for the theorists it is always better to have
some exposure to the experimental approach, though they get it through
teaching labs to some extent. Basic physics knowledge with a mathematical approach could be very helpful for engineers and technologists. In this
situation, physics should obviously be considered a great second undergraduate major for future engineers. This even helps to develop interdisciplinary
courses very well. With all this relevance with modern educational programs,
the lack of interest in the subject is strange and unnatural. We now have
to find out the reasons why students are losing their interest in this subject,
leading to low enrollment in physics courses.
We will also like to mention that our analysis is mainly based on the community colleges, state colleges and small institutes that only offer a limited number of undergrad or graduate programs. It also includes surveys from an institute of technology. However, this survey and analysis may not be so true for the research universities or institutes with advanced physics programs. They have a much better funding situation and much better equipment. In these institutes, active researchers are teaching elementary level physics courses with low teaching load and less job dependence on instructor evaluation. They have help in grading and have graduate students for the individual support of the undergraduate students in elementary physics courses. In this situation, they can afford to have large lecture sections. Teachers do not have an excessive load of individual guidance during their office hours. They have broad-based knowledge of physics and can be impressive and effective teachers and can become role models for students because of their academic standing. They have the liberty to try new effective teaching tools [8] and do not have to compromise standards for job security. Their job security depends primarily on their participation in research activities and research funding. So, they have a much better situation and are still able to manage research programs. This difference in situation supports our analysis below.

But these places are usually expensive places and most students cannot afford to go to these institutes, especially during the first couple of years of college. This is the very time when most decide their goals and future profession. Therefore, in the future physics majors will be coming mostly from better financial backgrounds and from expensive colleges only.

However, it is also noticed that in the community colleges or even sometimes in the state colleges, less qualified teachers are preferred to more qualified ones and these colleges tend to discourage research also. Moreover, engineers at some places are teaching the physics. We personally have seen cases where engineers are preferred over the physics doctorate degree holders for physics teaching because the recruiters were not physics degree holders themselves. Here standards are obviously difficult to maintain. A similar kind of effect on the quality of teaching could be observed if a theoretical physicist with a limited knowledge of engineering applications is teaching engineering courses. So it is just a question of having more qualification and broader background in the course to be taught.

In the next section we will mention the reasons for low enrollment in a little more detail. We have also incorporated accumulated data based on sev-
eral surveys from different colleges in New York State that were performed during the past several years. Some of this analysis is based on direct experience of teaching at different levels starting from very elementary level physics courses to the highly specialized Ph.D. courses. During this time, we directly worked with students from different cultural and ethnic background and we were exposed to the teaching systems of a few different countries. It is also worth mentioning that we have not included a quantitative analysis of this data in this discussion, though our conclusions are partly drawn from this data.

III. LOSS OF INTEREST IN PHYSICS

The first reason is obviously the image of the subject itself. It is undoubtedly a subject that needs adequate math background and dedication. The math component of the subject is a big repelling factor for students. Especially, non-science majors do not like to take physics because it needs much more involved math at every level, compared to other courses. I have taught astronomy courses to non-science majors and have seen this difference a lot. Yet, astronomy is a popular course because it can be taught to students without substantial math background. Students, even after finishing the pre-requisite math courses, have difficulty using calculators for very simple numerical calculations. They do not like to play with numbers at all. At least 70% of the non-science majors in astronomy courses do not have the concept of units and knowledge of scientific notation. They learn to plug in numbers in a formula but still are not able to evaluate the result. Though first math course in college is always a pre-requisite. Use of the calculator is a difficult task for them, though they are expected to know this, as they are not supposed to be able to pass pre-requisite math courses without this skill. Keeping track of all the units or other minor details of calculations is not even mentionable. These students cannot be expected to feel comfortable in the first algebra based course of physics. In this situation, physics courses with minimum math component are very mathematical courses for them even if they have at least covered the prerequisites. They may, for example, consider conceptual physics, physical science and/or introductory astronomy as very mathematical courses. But, I think the minimum required math background for physics courses is what is actually needed to improve the quality of daily life. Math itself is not a very popular subject either,
though this discussion is beyond our current topic. Math majors do not have to take physics because physics is not usually required for math majors. However, mathematical concepts are generally considered to be difficult to understand for non-math majors. Understanding the concepts of physics with the help of mathematical equations is even more challenging. Students prefer to give it up without even trying. Apparently, this subject looks more demanding and less interesting. Students think that they will have to spend a lot of their study time to pass the course and would not be able to get good grades out of it, either. They don’t even find it interesting. In this situation, it becomes a complicated problem. So we need to make it sufficiently attractive in both ways to get better enrollment in physics. We see different types of students in different level physics courses. It is also true that we need dedicated students in physics and only such students can survive in the higher-level courses. Regardless of the very low number of physics majors, our discussion is not about the physics majors. However, non-science majors mostly prefer other science courses to physics. Let us first look at the reasons that why physics is losing its popularity among the undergraduate students and cannot attract many promising students.

After these introductory remarks, we can include a somewhat quantitative analysis based on student surveys. We tried to collect some data from the undergraduate students to find out that what they think about it. Here is data collected from 300 randomly picked undergraduate students in different science and non-science programs in different colleges in New York State altogether. Almost half of these students were science majors. It includes community colleges, state colleges and a private institute of technology. We are not going to analyze this data individually at the moment. Also note that the following figures refer to students who had not yet taken physics. When some of these students did study physics their opinion was significantly changed. We are still in the process of data collection and would like to report the detailed quantitative analysis of this study later. The overall results from the students who have never studied physics courses in a college are as follows:

1. Around 80% of the students think that physics is a very difficult mathematical subject. And most of these students had inadequate math background.

2. 40% have no interest in physics and consider it a useless and boring subject.
3. 50% of the registered students want to pass physics courses to fulfill the requirement of the degree but do not like physics.

4. 70% students of the undergrad algebra based physics class (including around 20% non-science majors) think that this subject will consume most of their time outside a classroom and still not yield good grades. It could even have a bad effect on their other grades. Some of them even liked it as a subject or liked the teacher.

Some randomly picked students were asked a common question during discussions on what is the use of physics. For them, it is a pretty abstract subject that teaches the applications of mathematical equations. They cannot find any reason for studying physics and its connections to daily life. Most of these students never even try to take physics so this image may be from their exposure to physics from high schools and from their friends who took physics at some level. These results are not surprising for physics teachers, because we usually come across similar remarks. Almost every school has a more-or-less similar type of situation, though the colleges with two-year physics programs and less qualified teachers have even higher numbers of the above comments. This leads to further decrease in the physics enrollment as well as a job cut in physics. As a natural consequence, the interest in the subject is reduced and the production of good physics teachers in the future will become more difficult. Most of the small colleges have squeezed their physics programs and reduced faculty size. But, the others have made physics a requirement for more programs, to keep a better level of physics enrollment. However, this can help the undergraduate programs only. Attracting more students to physics majors is an even bigger challenge.

At this point, we cannot ignore the fact that a significant percentage of teachers are not able to play a role in the improvement of standards and/or attracting more students to physics and change this image of the subject itself. It is not because they are not competent enough to do that or they do not care about the promotion of the subject. It is mainly because they do not have job security. A large proportion of teachers have a great limitation in playing a big role in attracting students to the subject. There is no room to try new techniques or policies to increase standards and take the risk of getting students less happy with teachers. It will always lead to the insecurity of a teacher’s job. After all, they need money for their survival. New teachers would have to care more about the student’s evaluation than
the standards, anyway. When teachers have to compromise on standards for their job security, their dedication level is obviously affected by it. When their job commitment is not acknowledged at all and the financial pressures and insecurity leads them to the frustration level where they are badly discouraged to work for standards and/or to contribute good research. We need to discuss in detail the role of teachers to justify that the teacher’s frustration is not only for them, it has the long-lasting effects on future development. Anyway, we discuss some of the major factors behind this image of physics, the limitations produced by it and the suggestions to improve the image of physics among students. It is an even much more complicated issue and needs to be discussed thoroughly. We can briefly summarize these problems as follows:

1. Lack of appropriate math background among students.

2. Decreasing ratio of serious students for the sake of knowledge and growth in the easy-going approach among students to get a degree for better jobs and salaries, quickly.

3. Shortage of outside the classroom time for students.

4. Lack of understanding of the subject from the beginning.

5. Pressure on the contract teachers because of the security of teaching jobs that greatly depends on the student’s evaluation.

All of these points could separately be a research topic in itself. We have also postponed the discussion of the effect of this adjunct culture (due to the presence of part-time teaching faculty) on physics research. There are many adjuncts that are as specially interested in research and could contribute to good physics research if some job security and peace of mind is provided to them as the necessary components for the original research. We have seen adjuncts who would still like to do some research after teaching for something like twenty hours in a week. However, their research efforts are not even acknowledged by the institutes where they are teaching as adjuncts. Though they will use the college addresses and all that. In addition to job insecurity, the rules for research grants also need to be revised for the promotion of research in the country. We will come back to the details of this issue somewhere else. However, we will give here some of the analysis based
on our long-time involvement in physics teaching and our tremendous interest in the promotion of physics in developing countries. In these countries, limited resources and financial issues are bigger obstacles in higher studies, in general and physics education, in particular. Apparently these problems are not limited to one college course only. They have much deeper roots and need more detailed investigation to reach the root cause of the problem. We will look at some of the immediate issues individually in the following sections.

IV. MATHEMATICAL BACKGROUND

Mathematics is a very important tool to learn and understand physics. Difficult physics problems can be resolved, with equations and their physical interpretation. A good math background is always needed for physics because the mathematical equations always help in understanding the physical concepts. So, math courses are prerequisites for the physics courses. These prerequisites are an additional problem for physics enrollment, but we cannot do much about it because some math is needed for understanding physics. On the other hand, most of the students cannot develop appropriate math skill because they do not have enough background. Also their aptitude for math learning and the level of math teaching varies from college to college and even from teacher to teacher. There are other similar types of problems in the math courses, which we will briefly discuss here.

It is almost natural to think, in this computer age, that we do not need to spend a lot of time on learning and practicing math if we can easily use computers to get mistake-free reliable results. Computers can easily do almost all the mathematical calculations for us. The only thing needed is computer proficiency, which almost all modern students have, and are getting better in time. There is no problem in stating that their use makes research life easier and mistake-free and also saves time. Nobody can disagree with the fact that computation becomes a lot more reliable and quicker and even more detailed with computers. However, elementary physics needs a little more understanding of math to start with. Some hand calculation skill is needed to go through the derivation of physics equations and also the interpretation. Students need some practice in simple math to at least get used to playing with numbers. But calculators are usually introduced at the elementary level; this does not permit the students to understand very
basic ideas of arithmetic. This easygoing approach in math helps to generate math fear because they never get used to the calculations, properly. It has also been noticed that there is not so much a lack of math aptitude, as it is the lack of time and dedication to use math. This is because students are introduced to the easier way, using calculators and computers at very early stages of their student life. We would recommend encouraging school kids to do more hand calculations and to play more with numbers by hand in the elementary schools. Kids could be taught computers for other purposes but should be discouraged to use calculators for many calculations, even in the middle schools. Math skill is definitely affected by the basic training. This way, students will have enough skill to play with numbers and will be more used to hand calculations. Thereby, math teaching could become easier at higher levels.

Another big reason for lack of math interest and even math fear is linked with the problems of teachers. The performance of the teachers is usually judged in the light of students grades at all levels. So, to show better grades of the students for their own job security, they have to adopt examining and grading systems that can help students get good grades. In this process, sometimes, there can be compromises on the standards and loopholes are created in their knowledge and practice. This is obviously dependent on the individual school and the teacher. Again, high school standards are not our topic at the moment but its impact on college educations is inevitable. These problems have some long-lasting effects on the high school graduates who are college freshmen. As a result, students are not usually getting appropriate math training before entering the colleges. High school teachers are under the pressure of getting a high rate of graduation and have to keep it high for their job security. So they have to compromise on standards sometimes. Students usually have very limited practice. Study of sorted topics and exam preparation is the usual attitude of students. They use short-cut methods to get good grades even without adequate knowledge and the required practice for higher-level education. In short:

1. Lack of practice in math does not let the students develop enough interest in advanced math, even if they have enough interest to start with

2. Financial responsibilities including financial arrangements for their college education. Shortage of time outside the classroom and several
other factors are additional issues.

3. Students have to study a number of courses at the same time. So they do not have enough time for each subject. In this situation finding extra time for the math practice is not possible.

In this situation, math background plays a big role in the declining trend of physics enrollment. The detailed discussion of declining math background is a complete research topic in itself. Physicists in the field are very well aware of this problem and try to minimize its impact on the standards of physics courses. There are two usual approaches to handle this issue. Some of the teachers try to assume minimum math background and go over the mathematical steps in detail to make things clearly understandable to physics students. Others try to reduce math in their elementary level courses and try to explain the physical concepts using examples from daily life and certain analogies. Sometimes both of these methods are used to overcome math deficiency. It depends on the personal judgment of teachers about their class on how weak math background can be treated properly. Sometimes if this weakness is limited to a few students, then individual attention to those students and/or tutoring through learning centers in colleges can give enough help. But this could only be helpful if students are willing to get help from them and have a strong urge to study physics. This seems to be lacking these days. However, along with all the individual and collective efforts made by teachers in this direction some of the highly contributing problems are listed in the next section.

V. COMMON PROBLEMS OF PHYSICS TEACHERS

Now we come to a comparatively sensitive issue in the sense that some of us may not agree with it at all or may strongly disagree at certain points. However, we are trying to address this issue honestly and sincerely because when it comes to the analysis, it should be genuine and very honest. Our point of view may be different from others but our analysis is fair as it is based on our experience and on study of the issue in detail. And I think that we as physicists want to promote physics and want to see it as a popular subject. All of our discussions here are for the sake of this purpose.
Physics is a subject that can only be taught effectively with full dedication. This dedication is only possible with job security and financial satisfaction. All teachers do not have this now. With financial worries and job issues, it becomes very difficult to concentrate on standards rather than concerning oneself about evaluations by students in order to get a new teaching contract for the new semester or the new quarter. Tenured teachers are proved to be much better teachers due to job security and financial stability. They also have much more liberty to choose courses of their own interest and introduce new courses. They can pay more attention to teaching standards and try new effective tools on students for better results. They obviously cannot afford to do extensive surveys or work on the long research projects including the research in physics education.

On the other hand, contract teachers cannot afford this. However, even among the tenured teachers, everyone does not have equal interest in physics education, obviously. But almost 20-30% teachers and sometimes even more are on quarterly/monthly or yearly contracts. The continuation of their job is not usually based on the quality of their teaching or how much they care about the effective teaching. These teachers have extensions in their contracts depending on the evaluation by students. This instructor evaluation is apparently the only way to check the teaching ability of contract teachers. If, due to some reason they take more interest in standards and do not care about the evaluations, they may be sent home, even if they demonstrate their dedication to students and their role in effective teaching is unquestionable, otherwise. They do not even have options to pick up courses of their own choice and show their real teaching abilities and their professional strength. The opportunity is missed to show their full abilities or their own teaching style, due to the risk of losing their teaching assignments. They usually have to teach in the presence of mentors or tenured teachers and are expected to follow the styles and standards of their mentors. They have no way to introduce/try new ways to improve the quality. Their abilities are not tested even if they have more experience and knowledge. It is just their status that is counted. In a way, their contributions to the improvement of standards is not even tested or judged. All they need is good instructor evaluations, which depends on several other factors also.

Usually, the majority of students do not like teachers who are more demanding and are committed to raise standards. The student’s background and their seriousness in study and the expectations from the course itself are
some of the additional factors. There are several unknown parameters for new teachers, which can change evaluations altogether, regardless of the teaching quality or effectiveness. So the method of selection of contract teachers does not help much in effective teaching. Schools save money in hiring contract teachers instead of full-time visiting positions, at the cost of the standards of education. They can pay half of the minimum salary without any employment benefits to contract teachers and ignore the standards. Contract teachers can be acceptable for several subjects, but physics has a different situation. So these less expensive contract positions are affecting the standards of physics teaching badly, not because colleges do not hire equally qualified teachers, it is because they cannot get best out of their abilities.

Another issue associated with contract positions is the availability of teachers to students outside the classroom. This especially occurs when adjunct instructors come to the campus for a very limited time. They do not have proper offices and cannot usually be available other than at the class time. If they give a couple of office hours for their own satisfaction, most of the students cannot see them in this given limited time because of their schedule and most of the colleges do not require office hours for adjuncts because they do not want to pay them for this. Most of the adjunct faculty has to have some other source of income in addition to teaching so their involvement is not at the same level as that of the full-time faculty. Some colleges offer students help from other teachers, which may not be equally helpful either. Moreover, since adjunct positions are not long-term positions so adjuncts cannot have longer term planning with students for next term courses or undergrad research involvement and so on. Because of their minimum exposure to their teaching departments, they do not attend any meetings or understand very well the requirements of programs for which they are teaching. Again the simple solution to all these issues is to replace adjunct positions with full time short term contract positions at least, so that the part time faculty can work in one college at a time and spend some more time with students and teach more effectively and peacefully. They could be given more workload to compensate the salaries, so that they do not have to drive from one place to another place, which definitely affect the quality of teaching. Adjunct teachers can easily make an amount of money that is comparable to the regular starting salary of an undergraduate level teacher with some additional workload. The only problem is the benefit package that could be available for the adjunct positions in special situations also.
So instead of distributing this money among different colleges, some better arrangements could be done.

Some of the other common job problems for the qualified physics teachers are briefly unveiled here. The physics job market is normally low. There are several reasons behind this. Low enrollment of physics students is a big factor in reduced teaching positions. Teaching jobs are not well-paid jobs anyway. On the other hand, physicists are not much demanded in other jobs either. Especially, there are not so many openings in the field of theoretical physics. Usually, physicists have to depend on their side skills for livelihood and not their main expertise in physics. So the bright students would always be attracted to those programs which are most demanded for better paying jobs. On the other hand, we cannot deny the fact that physics majors have to be hard-working students with good mathematics background. Especially for theoretical physics, a strong math background and full interest in the subject with full commitment is needed. So it was a growing field when brilliant students chose physics because of the better job opportunities. The low enrollment in physics courses and in physics program lead to job cuts in physics everywhere and physics programs squeezed. The other factor leading to the low enrollment is the funding mechanism. The deficiency in basic theoretical physics research funds is a big discouragement for attracting brilliant students to adopt physics as a career. So physics is not an attractive career any more.

VI. OTHER ISSUES

Some of the other important issues contributing to our topics are related directly or indirectly to social and economic issues and affect education in general. One of the big problems, which students have to face during studies, is related to the economic matters. Usually, college students have to take care of all their financial needs. For that purpose they have to work during studies. Part-time jobs are still manageable, but some of the students have to work a lot to fulfill their financial needs, which includes college spending also. Of course, they take this out of their study time and hence prefer to take the subjects that do not need a lot of out-of-the-classroom time. Sometimes, they have to take several courses to make their study less expensive and save on college fees for a semester. In that case, they have a stipulated period of time for every subject. In this situation, they are not usually able to fit
physics in their schedule and if they do, they cannot do well.

Furthermore, most of the elementary level physics classes are comprised of a very diverse academic background and include different majors. These students come from all different places. It means that even the same prerequisites indicate different academic levels, depending on their previous institute and teachers. And, it is even more complicated in colleges. They come from different majors including all science and liberal arts majors, and even have spent different numbers of years in college. They have different reasons to enroll in physics courses. Some of them like physics and may even end up selecting physics as a career, whereas others would be sitting there just to complete the required credits and not to learn physics. In this case, it is really very difficult to teach large classes. This means if you are teaching a couple of hundreds of students you can always make four or five classes out of them with quite different backgrounds and different course goals.

In this situation a teacher cannot equally satisfy all the students at the same time. The level of the course has to be kept at the point where most of the students can pass it. This is how we run into the risk of losing some of the interested physics students who could have continued if they were taught in a different way. They could have put in more individual time to develop a better understanding of the subject. These types of students need a little bit more one-on-one discussion time with teachers and need to have more questions asked in class. It is impossible to satisfy them in big classes. Smaller class size could be very helpful in physics teaching because a teacher can pay individual attention to the students. Knowing that there are different reasons for the lack of interest in different types of physics at different levels, we should try to resolve these issues, in general.

Physics is being taught in high schools and colleges at different levels. We can classify these courses as the elementary, medium and higher-level courses. The students have their first exposure to compulsory physics courses in high schools. Compulsory physics courses at the college level come afterwards. These courses are either based on algebra or simple calculus. They are offered to big groups of students with a great variety of background and interest. In this situation, it becomes very difficult for teachers to make the subject attractive enough for the students to prefer physics to other better paying, easy-to-understand and seemingly more relevant subjects.

Once the students choose physics as a major subject, then their interest is clear. Now, just to keep the students interested in the subject, the physics
courses have to be kept parallel (in time consumption) to the courses in other disciplines. So, class demonstrations and problem solving strategies are used to help them learn the topics quickly and properly understand the concepts. This is very effective in developing working knowledge of the basic physics concepts among students of the engineering departments. However, in our point of view, deeper understanding of physics requires a combination of the observational/experimental as well as the mathematical approach, even at the elementary level. Sufficient theoretical background is needed to develop a real interest in the subject. For the rest of their career they can easily learn and understand through the physical demonstrations and the problem solving techniques.

Physics teaching is also done in engineering departments to give engineers the relevant physics background. Usually, the emphasis is on working knowledge and providing sufficient practice to use the relevant equations to solve given problems. This is understandable in that the main objective is to create acceptable and safe designs and resolve engineering problems. However, I would think that good engineers should also have a better background in the relevant areas of physics. This will help them throughout their career to face any unforeseen situation and make innovative designs. For this purpose, the engineering departments can arrange a couple of courses to develop this background. Good physics background with hands-on experience is equally helpful in medicine, experimental chemistry and biology, especially, when it comes to the use of optical, electronic or mechanical equipment. So all the science majors should have reasonable exposure to physics to develop better understanding in their own subjects also. Here, I would like to mention a personal experience. I asked about 60 students of Mechanical Engineering to define the word ‘mechanics’. Nobody could answer this question. Then I asked, what is Mechanical Engineering? And the answer was!! Problem Solving. We would expect them to at least know the role of mechanics in building modern inventive mechanical designs.

The next issue is funding. Since undergraduate research funds are mainly allocated for the experimental or applied science projects, new students are encouraged to choose their major research projects in experimental/applied physics areas. It is an established fact that there are several theoretical physicists from developing countries, which could convert from theoretical to experimental physics research after working for some time with the experimental research groups. However, a lot of work is required to develop
enough mathematical background to participate in theoretical research. In recent times, any good experimental group requires computational skills and theoretical physicists with good mathematical and physical background could serve this need and become an irreplaceable part of an experimental group. They could even replace computer engineers sometimes, because of their insight in physics.

High-level physics teaching is not our topic at the moment, because when the students reach that level, they already have sufficient interest and learning capabilities to cope with the complexities of the subject. Therefore, the student’s response and interest in the subject makes teaching enjoyable and academically challenging for the teachers. But that interest is only developed under favorable circumstances. At that stage, subject knowledge of the teachers is appreciated more than their handling of students or teaching styles.

**VII. CONCLUDING REMARKS**

In this section we will like to conclude our discussion by briefly mentioning what we think about this issue. It is clear that the decrease in physics enrollment should be taken seriously and we should try to take care of this problem in the light of all the above available details. It might lead to very serious consequences if it was not controlled at this stage. Some of our concerns are clear from the available statistical data [6]. However, we would like to emphasize a few points that include ways to re-establish the physics departments and to initiate undergraduate majors in two-year colleges. In this time of availability of more qualified physicists than suitable jobs, two-year colleges can also hire more qualified physicists who can participate in raising educational standards in such institutes. If the teaching load could be lowered to some extent and research is at least not discouraged, it will also lead to improvement in the educational standards. This strategy will attract serious researchers who want to participate in the improvement of physics education, also. Instructor evaluations are very important but they should be more used to help committed teachers to determine the effectiveness of their teaching methods and should not be used as the sole criteria for the teacher’s job extension.

We will even recommend at least full-time temporary hiring instead of the adjunct position. Lab teaching could be handled by adjuncts but the full-
time teachers should preferably teach lectures so that they can give enough
time to students. In that case lab teaching can also be done by full-time
faculty and could be more organized and effective to attract more students
and improve the image of the subject itself. Moreover, better ways for the in-
structor evaluation procedure could be developed incorporating the student’s
interest in the subject in the evaluation procedures. We are already aware
of the fact that some colleges have very good evaluation procedure and the
obvious difference in the teaching standards could be easily observed. An-
other convenience could be achieved by introducing a comparatively uniform
procedure of instructor evaluation so that the instructor evaluations in dif-
ferent institutes could be compared. Some further research is required in this
direction. Undergraduate physics research programs are the effective ways
to promote physics among students.

VIII. RECOMMENDATIONS

In the end, we would like to give a few suggestions to secure our future
standards in technology and science. These are obviously some of the possi-
ble moves in the direction of the promotion of physics among the incoming
generation. We know that these are not very easy steps, especially to take
all at once. We understand the limitations of different policy making bodies
and are aware of the financial constraints. However, some of the improve-
ments are possible partially or completely. Consideration of these issues will
at least help to protect us from the further decline in standards of physics
education. This is the first needed move. We know some of these things are
already adopted by certain places, however we have to mention them here to
suggest it to everybody. Some of the recommendations are as follows:

1. Promotion of science interest in elementary schools, in particular by
developing calculation skill in math. We would recommend completely
banning the use of calculators in elementary schools. Even at higher-
level school students should be discouraged to use calculators for simple
numerical calculations.

2. School trips can be organized to some research labs and students could
be provided with opportunities to meet renowned scientists of the area.
Some other programs can be designed to involve college/university
teachers to work with school students.
3. Lesson the pressure for a high graduation rate. So, job security and promotion of teachers should be less dependent on a high graduation rate. They should be required to involve students in more practice in solving problems. State exams could be designed to accommodate the testing of student’s math practice and their broad knowledge.

4. In all high schools, those teachers who have degrees in the relevant subject should be teaching math and science courses. Preferably, M.S degree in the relevant subject and should be a requirement. Some of the schools already have these standards.

5. Community colleges and state colleges should give more full-time positions instead of hiring adjuncts for teaching those courses. So many highly qualified people are looking for physics jobs these days that it should not be difficult to hire one teacher who can teach for example every undergraduate course. Physics degree holders should preferably, do physics teaching. Preference should be given to doctorate degree holders.

6. Instructor evaluation by students should be considered as input data for further improvement in teaching and not the sole criteria for job extension.

7. The teaching load in colleges should be reduced to improve the quality of teaching. Teachers should have enough to organize lectures and design experiments properly.

8. Qualified technicians should also be provided to run physics labs properly. These technicians can take care of the equipment, which are never used by many colleges, just because teachers have no time. This expensive equipment could be used to introduce new experiments.

9. Research should not be discouraged in colleges at all. Actually college teachers should be encouraged to establish research collaboration with universities. In this way, they will also be more aware of the learning needs of students who want to transfer to other colleges to do research in basic sciences. They can play their role to promote basic sciences by getting new ideas and having discussions with their colleagues in research institutes.
10. Physics courses for engineers should be designed more clearly, so as to relate physics to engineering applications. Students should be able to learn and understand physical concepts so that they can properly apply them in their engineering courses.

11. Research grants should be given to contract teachers by colleges to involve undergraduate students in research.

12. More inter-disciplinary courses should be designed to make students more familiar with physics and other science courses. Especially, the courses, which can link natural sciences and social science together, could be very interesting. For this purpose, teachers with more than one master degree could be very helpful.

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