Calling All Physics Teachers: We Have a Physics Legacy Crisis

by Jesse Ruiz, July 2018
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Attention all Arizona physics teachers, this is for you. A crisis is happening in the world of physics and it involves our legacy. The number of students taking physics has decreased drastically in recent years, in Arizona. As of 2018, of all the high school students in Arizona, only 20% of them are taking a physics course, half of the national average of 40% (1). Even worse than that is, almost 20% of Arizona's public comprehensive high schools no longer offer physics (2). If we don't have physics teachers, we can't teach the students, and if we want more physics instructors we need more students entering the field of physics in general. To increase these numbers, we need to hit the students as soon as we can at the high school level, and possibly even the middle school.

Before we get too much into how to solve this problem, we need to discuss why this problem needs to be solved in the first place.

If we look at data of jobs being created in the 21st century, STEM employment will increase by 9 million jobs from 2012 to 2022 (1). These jobs are in high demand and supply good salaries, benefits, with great job security. In order for students to have these kinds of opportunities, they need to have the skills and background that many of these jobs require. By taking physics, students are 2-3 times more likely to pursue a STEM degree (1). Most students who choose to skip this class never enter the STEM pipeline to begin with (3). From my own personal experience, I never took physics at the high school level and instead went the alternative route by taking anatomy and physiology. I was planning on entering the arts by obtaining a Film degree and told myself, "I didn't need physics or math any more," even though I was talented in both science and math fields. After a few semesters, I switched my major and pursued an associate in science. I didn't know what I wanted to do but I knew I was good at it. I took my first physics course at the community college as my science elective and it changed the course of my education path. I continued on to the second physics course and third and soon transferred to Arizona State University where I majored in physics and eventually got my degree. This little exposure to the laws of nature inspired me to pursue this field. If it can work for me, I know it can work for our students.

There is a problem. Physics is dying. There is a reason. Physics is needed. So now we must discuss what paths we can take to solve this issue. To start, we must identify where the problem originates. It might be almost too obvious but it comes down to the students' choice. They are at the age where they are starting to make their own decisions but still impressionable enough to take advice from their elders. The students might have the choice, but the adults have the power of persuasion they can use to inform these students about the benefits of physics. The students have many adult role models they look up to and take advice from. There are three main sources I would like to identify as the primary influences in students' educational choices: their parents, the school counselors, and their teachers.

In July 2017, the results from a research survey that was received from 75 Arizona high school counselors showed several skewed viewpoints about physics as a class. This survey, sent out by Earl Barrett and Larry Dukerich, both well-seasoned physics teachers, was created to investigate the crisis at the school level (3). The conclusion stated that the majority of counselors believe that students require a high level of math skills and the intention of entering the engineering field if they want to take physics.

The following year, Toni Gagliardi, a physics student at the Barrett Honors College at Arizona State University, performed an additional study using the same survey questions as Barrett and Dukerich the previous year, with a few additional questions she added (4). This time however, she sent the survey to a closer source to the issue: the 190 physics teachers in comprehensive district high schools. 116 teachers responded, 103 of whom teach physics as a junior and senior level class. She came to the conclusion that the physics teachers know about the problem, yet not enough action is being taken to spread the word of physics.

I took Toni Gagliardi's data and dug deeper to find other correlations relating to this cause. The following data taken from her study did not use the 13 "physics first" teachers who teach the subject to freshman, before the typical biology and chemistry courses. There are also several extremely large high schools that have multiple physics teachers who responded to the questions, which inflate some of the numbers dealing with physics students. I would like to start with the least influential and end with what I believe to be the most crucial individuals to help with solving our physics problem.

PARENTS: First we have our parents. As the parents, they have the deepest connection with the students and have the predisposition of already influencing the students up to now in their life. One of the questions asked the teachers to select which individuals have the responsibility to share information about the future to the students. Below shows the results from Gagliardi's question.

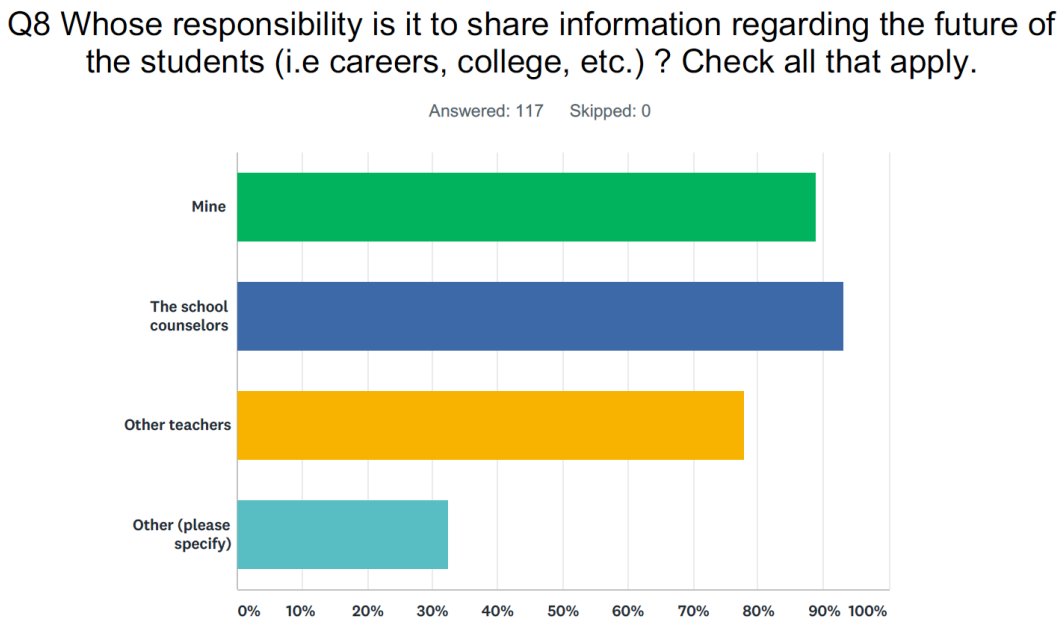

Figure 1: Question from Gagliardi's research to physics teachers in Arizona.

An interesting piece here was the number of teachers who selected "Other". Reading through the responses revealed a fourth of them agreed that parents and family have a large influence over the student's future college and career choices. This gives us something to think about. Knowing our parents have this ability, what can we do to use this to our advantage? As physics teachers, we need to reach out to the parents. We need to show the parents and make them understand the benefits of taking physics in high school and how it can help their child develop crucial critical thinking skills for their future college and career. There are several ways to contact parents including a monthly newsletter, parent-teacher night, or through an online profile.

A newsletter can be sent out electronically and on paper to students and staff to spread the word of what's happening in physics. It can include projects or labs being performed in the class to help entice the fun that physics can possess. But most importantly there should be a message about the importance of what is being learned and why the content is useful in the real world. Sending them out to parents is great but sending it to staff is also beneficial, especially the chemistry teacher. Supplying the chemistry students with the newsletter might help pique their interest for taking physics the following year. This can be a quick and easy way to get the news out to the parents, but if you want face-to-face interactions with them, you can take advantage of your school's parent-teacher night. The parents who do come must have an interest in their child's classes, and it shows they want to know more about the class and how their student can benefit or be successful.

Just as with the newsletter, talking with the chemistry and biology teachers about a student's track can be advantageous. Many parents want to know if their child is on the right track in their science classes and which classes will come next. If we have our biology and chemistry teachers on our side, they can help promote and

inform the parents about the benefits and necessity for their child to continue onto physics.

Finally, having an online profile is also another small but effective way to get the news out to the parents about physics. Many schools provide a website for each of their staff members to post class information, schedules, and more. For the physics teachers, they can really dress up their profile with pictures and information all about the class. You can include everything you did in your newsletter and more with the openness a website can provide. This information can be kept year around and show everything the class entails, plus the future benefits for students who sign up for your class.

GUIDANCE COUNSELORS: While the parents are guiding their kids at home, the school has their own guidance counselors who are responsible for advising the students about their schedule and science track they are on. This can be alarming, as many counselors might convey their own fears or experiences about physics and misguide the students (5). They also have the misguiding viewpoint that Barrett and Dukerich's study revealed about the students needing to have high math abilities to be successful. Physics is not about the math but about the concepts and the skills we use to reach our conclusions. We, as the physics teachers, have the sole responsibility in contacting our school's counselors and informing them of how our class can be appropriate for any student background. Physics supplies students with the quantitative and analytical skills that help math make sense (3).

This is where Gagliardi's survey revealed some interesting viewpoints several physics teachers have about their communication and beliefs towards their school counselors. Looking back at *Figure 1* on the question about the responsibility for students' future, counselors were ranked number one. Another question from the survey asked the instructors how often they have contact with their school counselors. Taking these 93% of physics teachers who agreed that counselors have a large impact on a student's future, many of them admitted they only contact them once or twice per year or not even at all.

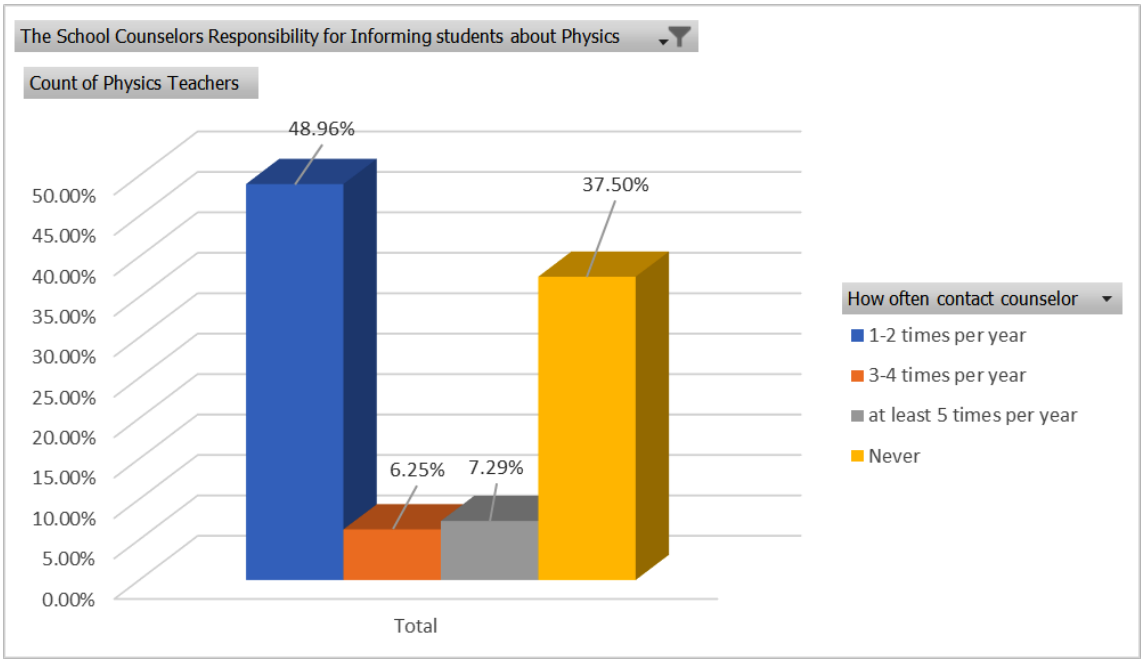

Figure 2: Physics teachers who agree counselors share responsibility and how often they see the counselor.

This figure shows that 37% of these physics teachers never have contact with their counselors and almost 50% of them only contact them once or twice each year. This is not enough for the job we have. When taking a closer look into those teachers who have significant contact with their school counselors, we can also look at how many students are being affected by these physics teachers in the following figure.

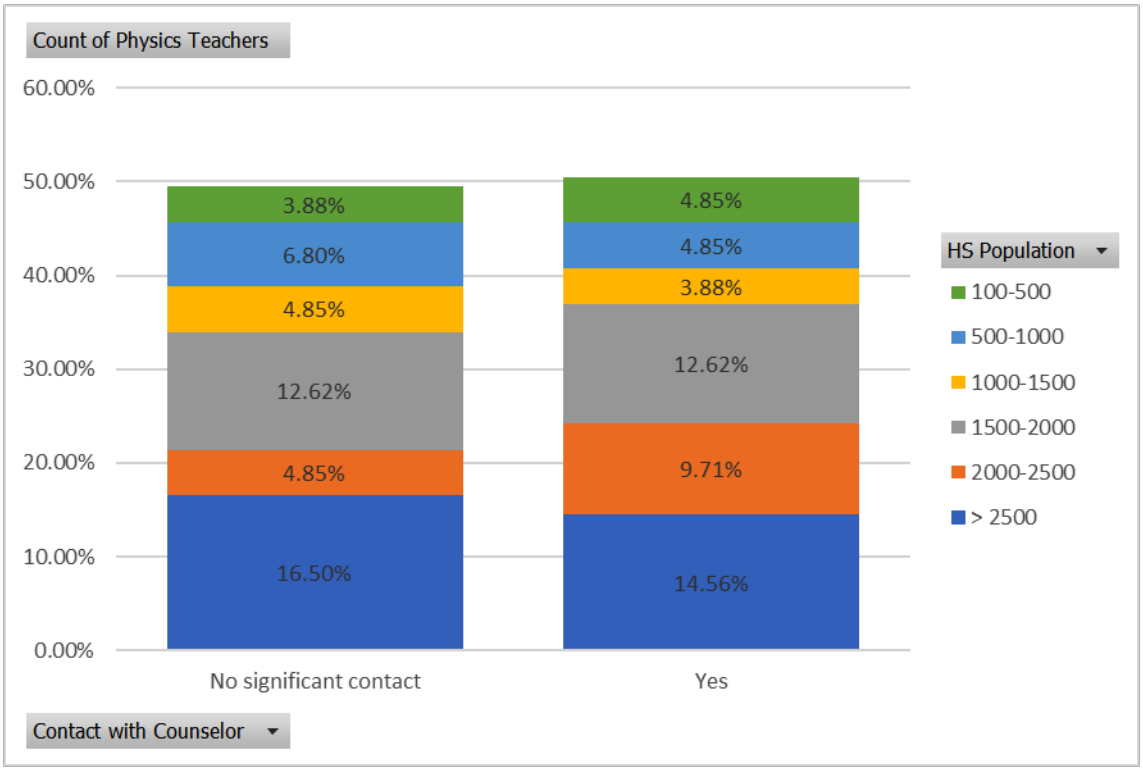

Figure 3: The percentage of physics teachers who do or do not have significant contact with their school counselors with how large their school is.

This is quite shocking to see that nearly 50% of physics instructors have no significant contact at all with their counselors at their school. We can see that there are nearly 34% of teachers who are in schools with a population of more than 1500 students and who do not talk to their counselors about the importance of physics. These numbers account for thousands of students every year who slip between the cracks of high school without ever being exposed to any physics at all. Since taking physics increases the likelihood of a student pursuing a STEM field in college and career, Gagliardi asked another Likert scale question regarding this idea. Over a third of the teachers who agreed or strongly agreed that physics helps with a student's post high school career, have no significant contact with their counselor.

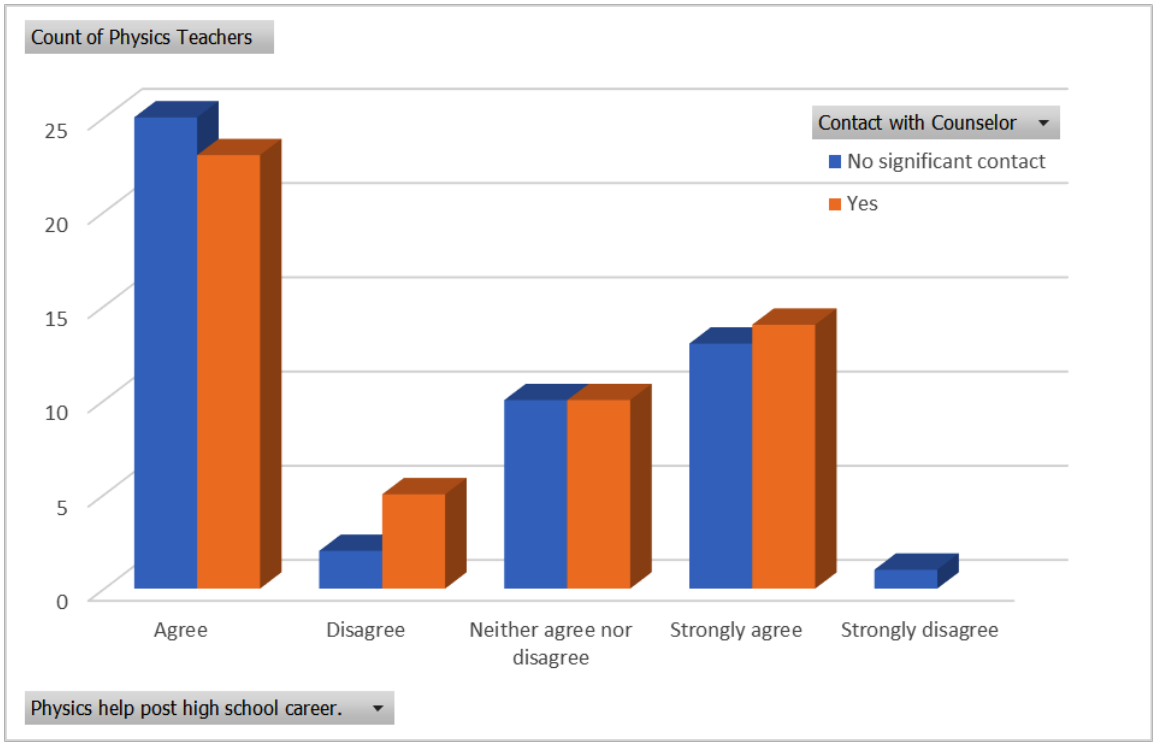

Figure 4: The number of physics teachers who felt physics would help with a post high school career and how often they had contact with their school counselors.

The logic here does not make sense. The physics teachers believe their content will help the students in their future, and a large majority believe counselors are the main source of advice when it comes to informing the students about their future, yet only 50% of these teachers can say they have had a significant relationship with their counselor about the class.

If our physics student numbers are hurting from the counselors, what are they advising the students? The following two figures come from two answers that the Gagliardi survey gave the physics teachers in a Likert scale form. The questions asked if they thought counselors were advising the students that physics was only needed for those who were interested in an engineering track in college. They also asked if they believed the counselors were advising the students to take alternative science classes. The following shows the results of the responses, while splitting each choice into those teachers who do and do not communicate with their counselors.

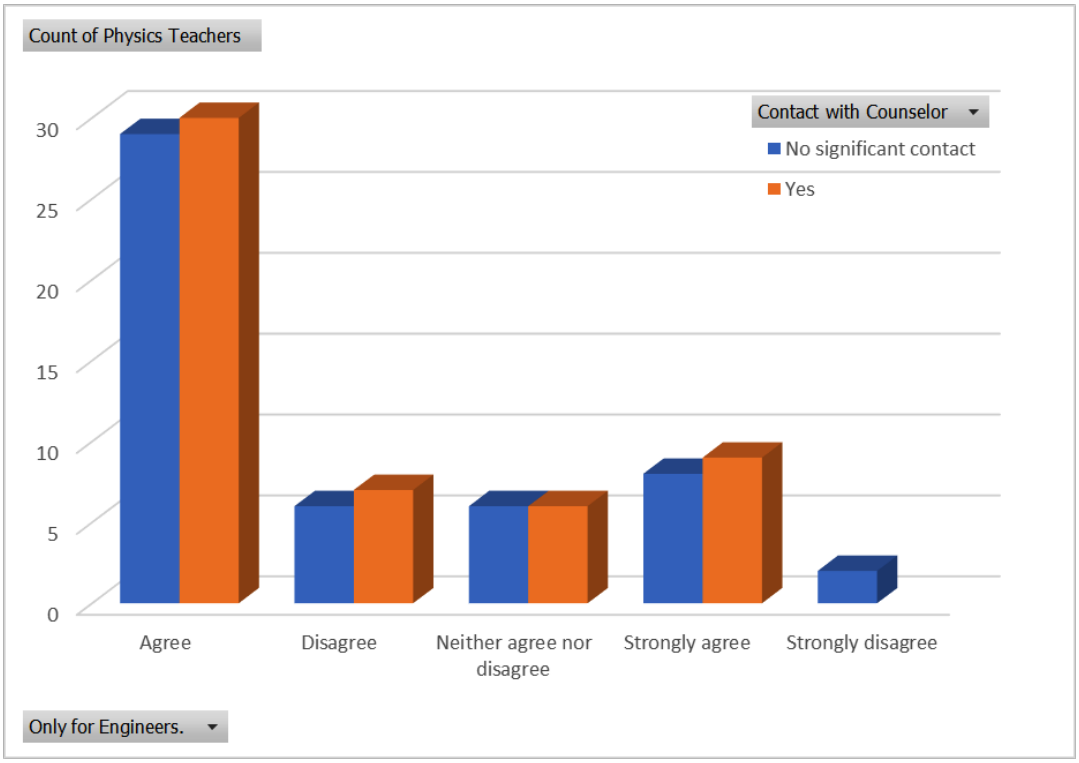

Figure 5: The number of physics teachers who felt the reason for low physics numbers was the idea it is only for engineers and their contact with the school counselor.

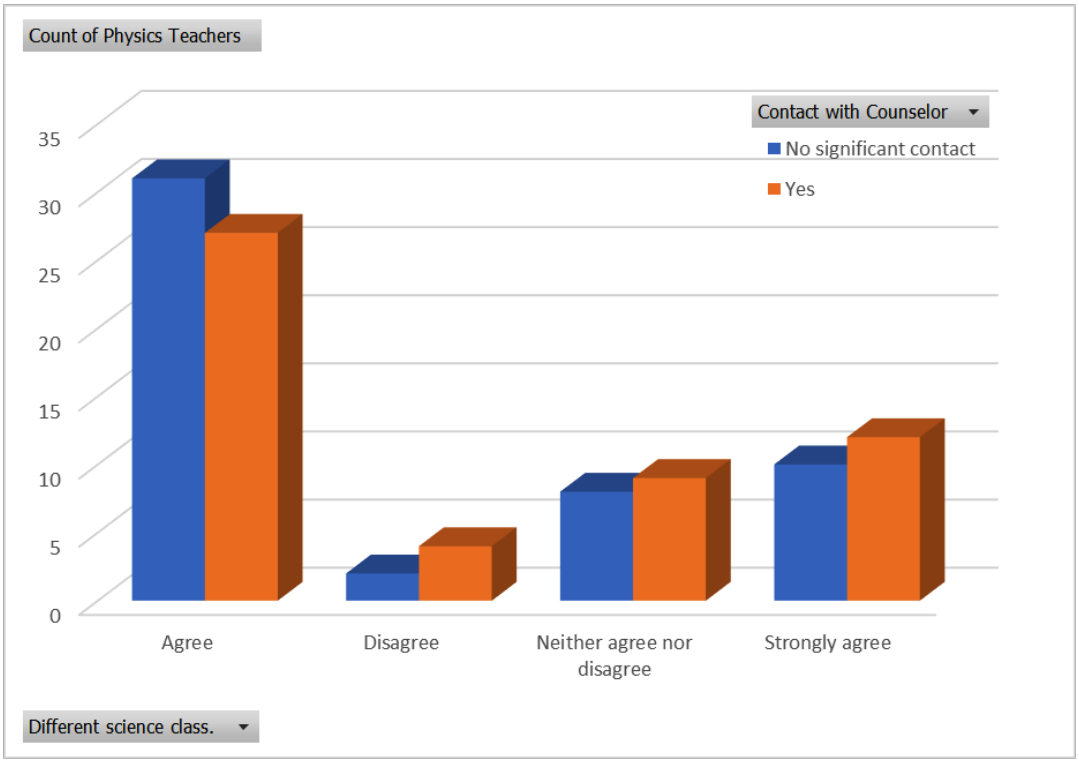

Figure 6: The number of physics teachers who felt the reason for low physics numbers was counselors suggesting other science classes and their contact with the school counselor.

I believe we are seeing a trend here. The counselors do have a lot of power in helping a student decide his or her future and college path, yet it seems that physics teachers are not doing much to communicate with their counselors about the benefits these students can gain from taking this course. From my own experience, the counselors are very helpful not only to the students but to the teachers as well. If I needed one of my own high school counselors to help with a scheduling or tracking issue, they always are more than happy to listen. They are always open to new ideas and listening to the teachers' inputs on a student's schedule.

PHYSICS TEACHERS: It now comes down to our main source of influence when helping grow our physics programs: the physics teacher. Much of the responsibility for getting our physics numbers up has been blamed on the parents for not informing their child, and the counselors for not giving accurate advice, but the only person who can fix these viewpoints and start working towards growing a physics program is the physics teacher. I have had my own experiences in growing programs for a different topic. In my first year as a teacher, our calculus program was almost non-existent. At our school, we had one section with 6 students. I couldn't believe this to be true and started inquiring amongst the sophomores and juniors about where they were headed in their math career. Since I was teaching pre-calculus at the time, I had access to many students' opinions about calculus. I found that just by having a conversation with the students, I could tell them about the usefulness and amazing world of math by using calculus. I was able to talk to students in the Honors Algebra 2 classes who were exceeding beyond their requirements, the Honors Pre-Calculus class, and the College Algebra and Trigonometry classes to start recruiting for a larger calculus program. By the time registration was done, I was given two sections to teach the following year and had over 60 students signed up and enthusiastic about learning calculus. Just by my awareness, and putting myself out there with recruitment, I saved a dying program. Going into my fourth year of teaching next year, I will have another 60 plus students exceeding above their graduation requirements and pursuing higher level mathematics. Saving our physics classes can be just as easy; we just need a plan, and then execute it with full force (pun intended).

First thing we can do is recruit, just as I had done for my calculus course. We have to get to the chemistry classes and talk to these students about how fun and interesting physics is. We should bring in fun demos and toys to show the students, or even past projects to show off. If we coordinate with the chemistry teacher about these students' schedules and get them on board, we can ensure the chemistry teacher is encouraging the students to move on towards physics throughout the year.

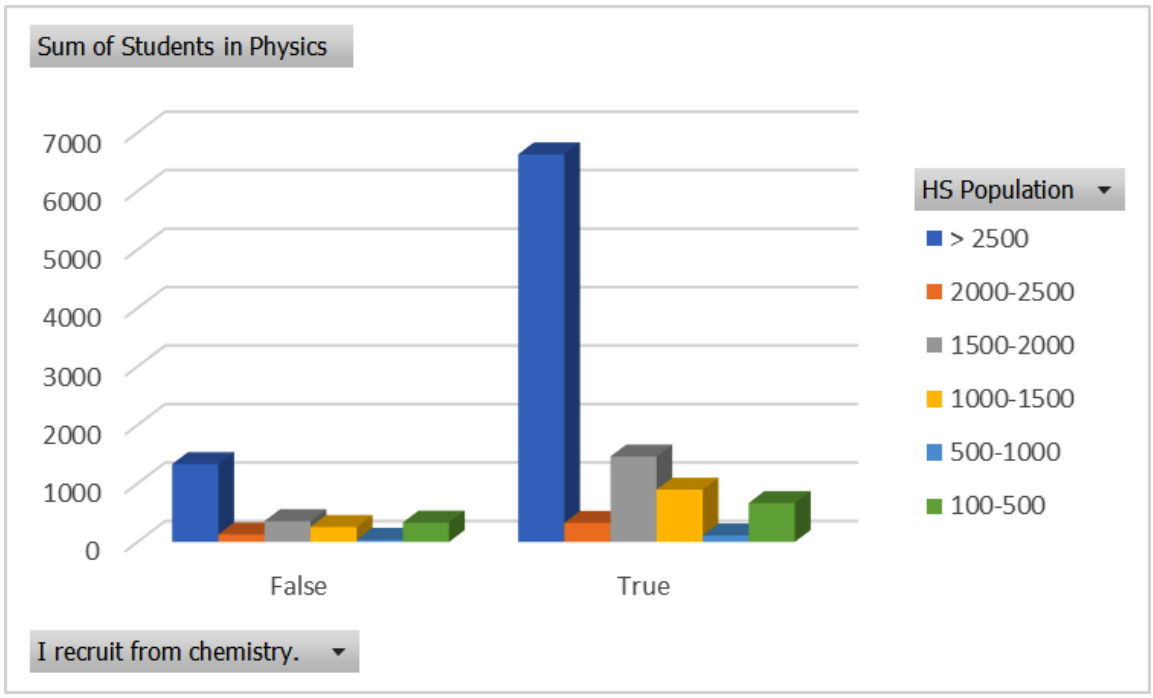

Figure 7: The number of physics students in each high school population and whether the physics teacher recruits from the chemistry class.

Each physics teacher was asked if they recruit from their chemistry courses and how many physics students they have enrolled in their classes. Each group was also split by the size of their high school. Recruiting works. There should be no physics teacher who does not. As we can see in *Figure 7*, the schools that do not recruit have a very low physics enrollment. This should not stop at chemistry but also reach down even lower to the biology or 9th grade science level. If we can reach the kids at an earlier age, we can make sure it is in the back of every student's head by the time they get to registration.

There have been leaps in physics education using a new pedagogy for the subject known as Modeling Instruction. The use of the modeling pedagogy helps open the door to all students and might even help the ones struggling in their own math courses**. There has been a lot of research on the modeling method that proves its worth as a pedagogy that has a significant positive effect on student achievement in a physics classroom (6).** It can even be shown that it attracts more students to the classroom, looking at the following figure.

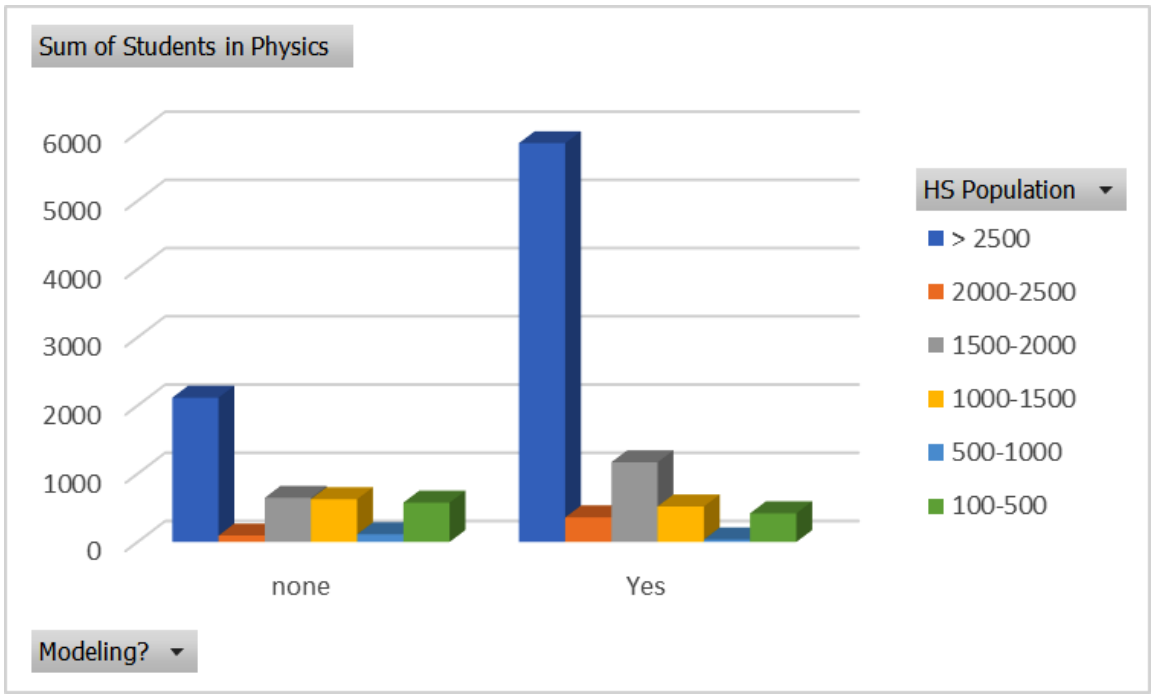

Figure 8: The number of physics students enrolled in physics at their respective high school size and whether the physics teacher has taken modeling courses.

In almost every size school, there is a significant amount more students that are enrolled in classes where the teacher has taken modeling courses. Modeling Instruction is a fun interactive way to teach that gets the students more involved in the learning process. It is our responsibility as physics instructors to keep on top of our teaching techniques to find new ways that engage the students and help them reach high achievement.

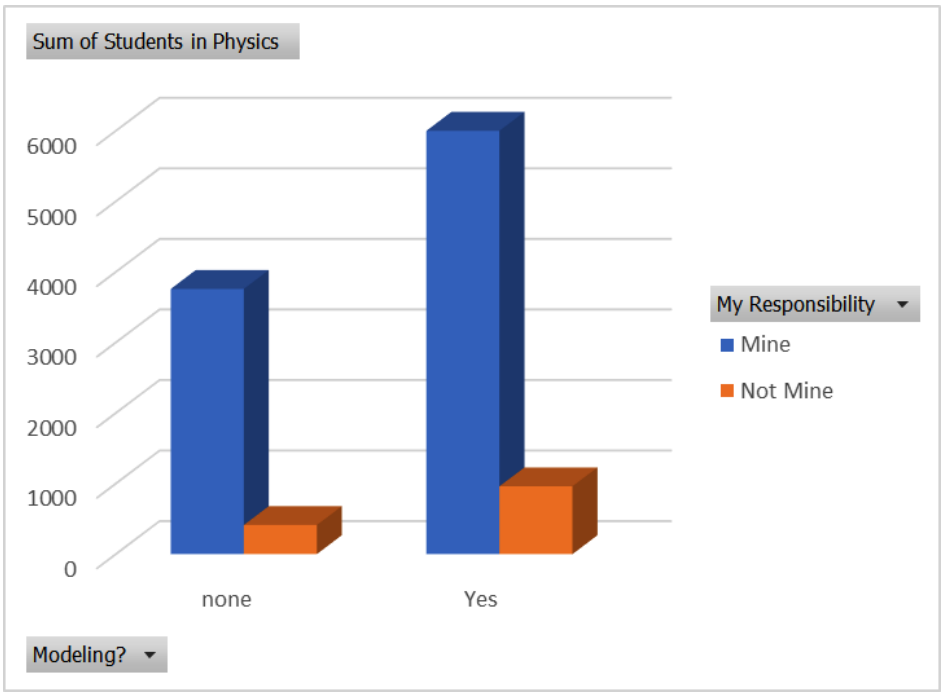

Figure 9: The sum of students enrolled in physics class and whether their instructor has taken modeling and believes they share responsibility for a student's future.

This figure shows that teachers who have taken Modeling Workshop courses have a higher enrollment of students in their physics courses, whether or not they feel they share the responsibility for influencing student's future. This reveals two major points. First it confirms that physics teachers who take modeling courses have a much higher enrollment of physics students. It also shows that those teachers who feel they share that responsibility also have higher student enrollment.

In conclusion, we have many outlets to work with, for helping grow our physics courses. These are just a few of many ideas that researchers have come up with to help with this problem. We have to take it to the root cause and reach the students any way we can. We have to find ways to communicate with their parents and family, informing the school counselors about our program, and helping ourselves by recruitment or improving our own pedagogy skills to make the class more engaging and interactive. Again, these are just a few ideas for what we can do and we shouldn't limit ourselves to spreading the word about physics to these simple ideas. We have to stay in touch with all of our faculty, and not just limit ourselves to the science department. Talk to administration, coaches, technology teachers, and math teachers about your program and invite them over when you have a cool demonstration, project, or lab to show off. We can even go higher up to the district level and get involved in any professional development or curriculum work. There has been talk about possibly using physics as a senior level math class credit for a student's graduation requirement. Even around our schools there are many facets to spread the word of physics. We can ask the yearbook club to come in and take photos, join in to be a part of the pep assemblies, create a physics and

astronomy club, host astronomy nights if you have access to a telescope at your school, or even take the students on field trips to fun exciting places that apply the many topics of physics to the real world. In the end, we just need to be involved in our school in any way possible. Putting the effort out there is the first step to reviving our program and bringing physics back to life.

Bibliography (all resources are available for download and/or viewing at http://modeling.asu.edu)

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