Teaching Philosophy Statement – Michael E. Summers

Being a teacher is what I am, it's not a philosophy that I have. My first memories are of my father reading to me and enthusiastically explaining what he was reading. I was so mesmerized by his wonder of the world that I knew from age 5 that I would be "some sort" of scientist and/or teacher. To me they are different sides of the same planet – one cannot exist without the other. I have always had an intense curiosity about the universe around me, and that has driven me as a scientist in many endeavors in physics, astronomy and space exploration. But I exist to be able to talk about the magnificent emergence of complexity that we see in a universe that comes about from a few very simply laws and principles. You can see this in a glass of water, a blade of grass, or a Hubble picture of a grand galaxy of stars. It's all one enormous story, all intimately connected in time and space, and it's the story of life in the universe. It's a story played out on the grandest stage of all – the stage of the entire universe.

I got my first telescope at age six. The first object I looked at, just by chance, turned out to be the planet Saturn. Seeing the rings of Saturn was so amazing that I can still visualize in my mind exactly what I saw at that moment. And to know that the planet around which those rings (which we now know are millions of tiny moonlets) revolve is a gas giant planet 90 times as big as the Earth, yet light enough to float on water, is a wonder that I still can't fathom. I immediately had to show this to my brother, sisters, parents, cousins and everyone I knew, and try to explain to them what it was and what it meant. That was my first teaching experience. And I feel the same sense of wonder now about the universe that I felt then, but now with a far greater depth of understanding of how it works, but with a hugely magnified sense of the necessity of humility about what we don't understand. I have an almost insatiable desire is to share the things I do understand. That desire to teach and explain is sometimes overwhelming and guides my decisions more than my scientific endeavors. I can't not teach, or at least not with any peace of mind.

By the time I was in High School I was tutoring science and math to other students. I led science class groups on telescope observing sessions in the lake regions of Kentucky, where it is so dark at night that you can truly see thousands of stars. And now we know that each of those stars has on average several planets, with many probably habitable for life as we know and understand it on Earth. This makes an already powerful story so much more real when I explain its significance to us as humans. In that context, finding teachable moments is trivial.

I'm constantly looking for such teachable moments. I try to get my children to look at the world from unusual perspectives and ask questions from those perspectives. Once while in our car I asked my son how long it would take to get to Pluto at the speed I was driving (over the speed limit unfortunately). He worked it out – 60,000 years! But I teach adults as well. I'm one of the lead scientists on the New Horizons NASA Pluto mission that will reach Pluto in 2015, just two years from now. To get there in 8 years meant we had to launch it faster than any object that had ever previously left Earth. How do you do that? I spent 17 years studying Pluto and teaching other scientists about it, and then teaching the engineers who designed the spacecraft how to build a robotic instrument to get to Pluto in a timeframe that was reasonable, and then teach both the engineers and scientific investigators how to investigate Pluto in order to learn its story as a planet. I've given over 100 talks on Pluto alone, about half to the public and half to scientists and engineers. So you can see how scientific investigation and teaching go hand in hand in the work that I do.

That has been my role in the more than 8 NASA space missions on which I've collaborated and/or been science team leads. I suspect I've done it well as I've won 4 NASA Group Achievement Awards for this. But whether it's Mars, Pluto, Jupiter and its moons, the upper atmosphere of the Earth, or as I've been doing recently, studying planets around other stars, my role is always the same. To first understand the planet in as much depth as possible – that's the science & analysis part, and afterward to teach others (whether scientists or engineers, or future scientists and engineers) how to further explore it – to get involved in the discovery part of science. And no matter how much we think we understand a planet, comet, or star, we are nevertheless always, always surprised at what we find. The universe is always more complex than we expect, and I truly expect it is more complex than we are capable of expecting, or maybe even believing.

In college, my department faculty instructors quickly recognized me as a good teacher even while I was a student. So as a sophomore I was teaching 3 astronomy labs a week, and running the observatory, as well as being the school's science photographer, while mentoring students to make some money on the side. Teaching those older than I was a challenging and intimidating experience, especially in a culture such as Kentucky that is quite different from DC. Kentucky is a world of generally low income and poor education, and with very fundamentalist religious views, and is a place with a very free gun ownership culture. That is my heritage. So instead of taking positions on these issues in my discussions with people, I used my cultural heritage to teach the college students and others about science. For example, the issue of science and God is almost always one to engage people, especially so in a culture that distrusted science and concepts such as evolution. But by showing them the wonders of science, it got them to question what they'd been taught.

As another example, I used my background in the gun culture of Kentucky to ask questions such as "what happens to a bullet shot through a galaxy of 400 billion stars." I've always tried to use the background of the audience as a springboard to understanding. And just about everyone is awed by the vast scale of the universe and wants to understand our place in it. Two years ago I gave a conference keynote address, along with Francis Collins now Director of NIH, on the religious aspects of science. It turned out to be the highlight of the conference and I had questions for almost 2 hours afterwards. Science tied to religion is always an opening for teachable moments. Whether it's evolution, the age of the universe, or climate science, the key is to ask penetrating questions from an angle that the person you target already understands and appreciates. You have to avoid making people defensive or they quickly become close-minded and difficult to reach.

In college I obtained majors in Physics, Math, Russian language, and minors in Astronomy and Russian History. Such a combination may seem odd, but to me it's all part of the same story, each just one topic in a tiny fraction of the story of the universe and how to communicate that story. In college I also was awarded a student semester exchange program in Russia. This was in 1975 during the height of the cold war, and our group of 30 US students was one of the first groups allowed into Russia with such an arrangement. But even there I tutored Russian to my fellow US students, and encouraged all of us to speak Russian even when we were in private.

But science won out in my life once I read Richard Feynman's Lectures on Physics. He is well known as the Noble Prize winner for his work in Quantum Electrodynamics, but even more notable as a teacher of physics – perhaps the best physics teacher ever. I chose the California Institute of Technology (Caltech) for my graduate school simply because he was there and I wanted to study and work with him. I had the honor of taking several courses, including General Relativity, with Feynman. Watching him teach was like watching true magic. I simply cannot imagine anyone understanding physics better than he did. For me, it was the first time I understood how little we really understand about the universe. But I also learned from him just how powerful science is at helping us figure things out about the universe. And Feynman taught it so well! I use his techniques at every chance I have to teach. And my physics students are in awe of the ways of intuiting physical systems that Feynman taught me, and that I pass on to them.

By 1991 I was a senior scientist at the Naval Research Laboratory in the Space Science Division, but teaching at George Mason University, always at least one course a semester, but in the evenings. I developed three courses at Mason during that time, including PHYS 575/CSI 655 Atmospheric Physics, ASTR 703 Planetary Sciences, and PHYS 676 Atmospheric Dynamics, as well as several specialty topics such as one on Cloud Physics, and one in Climate Change. I trained 8 Mason Ph.D. students in the 1990's, along with mentoring numerous undergraduates and high school students, including Dan Quayle's son who spent a summer with me at NRL. I did this all while only an Adjunct in the Physics department and a full time demanding job at NRL.

I decided to leave NRL in 2000 in order to focus more on teaching and space exploration. My reputation as a scientist was very solid, having published in the very top journals Nature and Science, and collaborated with Noble Prize winners, worked on several NASA space missions, and as project scientist for two space shuttle missions. I joined Mason and immediately started to work on the physics and astronomy curriculum, and helped design and develop the ASTR B.S. and B.A. degree programs. I also helped develop the PHYS Ph.D. program. All told, I've graduated over 20 Ph.D. students from Mason, and mentored many dozens of other graduate students, undergraduate students, and high school students. The student evaluations of my first 10 courses I taught at Mason were all 5.0 on the overall evaluations. I've never had below 4.75, except on courses where I co-teach and mentor other teachers, which I've done quite a bit of over the past 6 years. The highlight of my course development was developing ASTR 301 Astrobiology. Astrobiology is the most multi-disciplinary science in existence and so a bit difficult to teach. But the students love it. It brings together all the traditional sciences to show that you can start at any place in science, and via a few clever questions get to fundamental mysteries about the universe that we still don't understand. In this particular course, which is indeed difficult for students used to studying one discipline at a time, I give them real science projects.

One particularly difficult aspect of astrobiology is that it is always on the frontier of science. There is a new astrobiology story in the news every week. So I must be constantly learning just like the students. Every year the course must be updated and sometimes changed significantly. In one course I had the students plan and design a planetary space mission, but following the same planning and selection process that NASA uses to select mission to fund and fly to other planets. I know this process well as I have gone through it many times in my planetary mission projects. In another course that I taught more recently I had students select one of the hundreds of recently discovered planets around other stars, and had each person become the world's expert on that star system. I took them even further down this road of discovery, and had them try to determine whether their chosen planet was habitable for life, at least for life as we understand it on Earth. It was the most amazing and I believe successful experience of teaching I've ever had. Most good students don't want simple make-work. They want to do things of significance. And they will learn orders of magnitude more by doing so. This was real science taking place in a 300 level course!

Working with Mason undergraduates has been the most fulfilling part of my career. Sometimes wonderful science can come as a result of the mentorship. In 2002 a sophomore student wrote a paper with me about the survivability of certain microbes in the soil of Mars. We predicted that if such microbes were there, then methane should be in the atmosphere and thus it would be an indirect indicator of life beneath the surface. This was only an interesting speculation at the time, at least until methane was discovered on Mars about a year later. This had huge implications for the planning of subsequent Mars surface and orbital spacecraft missions and experimental designs, and even shaped the mission goals of the Curiosity Rover now on Mars. It put me once again in a position of teaching engineers about the atmosphere of Mars so that they could then design an airplane to fly in that very unusual atmosphere. This was the ARES Mars Airplane Mission, still under development but unfortunately now unfunded (congress!). I taught the engineers about the meteorology of Mars so they could design an airplane with sufficient lift, control, and stability to fly over the surface and make precise measurements of the surface, atmosphere, and simultaneously search for methane as a biomarker of subsurface life. I've had several students work with me on this project.

I have an open door policy, even as Director of SPACS, so that students can see me any time. I always work with them in a way that I believe a learning community should work. We are all students and learners, but each at different places on our own learning curve. The current hierarchy in traditional departmental structures has had a very counterproductive influence on realizing such a learning community. But learning communities will eventually happen, because information technology is the ultimate equalizer in information access and usage. It is now almost impossible to fence off information and hide it from others. It's impossible to have general information and knowledge in privileged hands. Having information and knowledge online is not enough for learning. For learning we will always need community, because the problems we now face in the world are much more complex than a single person can solve. In truth, it does take a bit more to make the learning community model viable. We must be willing to let go of our intellectual ego. I have all my students, undergraduate and graduate, call me Mike. I want them to feel comfortable communicating with me. That is a more accurate form of communication, and allows a more accurate assessment of where someone is on his or her own personal learning curve.

About 5 years ago I started teaching groups of Korean Science High School teachers (TJ like schools). That then evolved into weekend workshops on astrobiology, planetary science, and climate science for Korean high school and middle school students. Then it expanded into week-long camps where the students had to design and plan space robotic missions to search for life on other worlds, much like I do in ASTR 301. It took me a while to understand the important cultural differences between Korean and US students, but once I caught on to their competitiveness, and how to get them to loosen up around me as the instructor (instructors are nearly unapproachable in Korea, and never questioned!), we began to have some extremely successful camps. I would use the students' relative English, Physics, and Math skills to select groups with comparable overall ability. Then I would let each group team select a planet for which to develop an astrobiology mission, and let them compete on developing the most original and scientifically credible space mission. Some of the concepts that resulted from these camps were just as clever as any NASA has designed mission I've seen. This summer hobby of mine has now becomes so popular that every summer I have 4 to 6 middle and high schools asking for me to give summer camps for them. It did strike a cord with the Principles of several of the Korean Science High Schools and Minister of Education in Korea, who told me they wanted my program as a part of the Mason Songdo campus project. We have yet to work out the details on that.

During my career I've given, conservatively, over 500 public talks to non-scientists, many to young students in 2nd to 4th grade, through middle, high school, and continuing education groups. Last week I spoke to about 90 6th grade students at Herndon McNair Middle School, and as a prop I took along a few pieces of the Chelyabinsk meteorite that exploded over Siberia in Feb. 15 of this year. The students got to hold a small piece of the meteorite that is 4.5 billion years old - older than the Earth, and they will never forget holding a rock older than the Earth. The teachers said I had inspired the whole class. I've also given several talks to OLLI over the years. They have recently asked me to organize a special SPACS course on "Recent developments in Physics at SPACS" for their OLLI Spring 2014 semester. I gave one of the first TEDx talks on "Astrobiology and Beyond" last year, and speculated on whether we were even asking the right questions in our search for life beyond Earth. Maybe life is just one end point in an infinite spectrum of emergent complexity, and even more complex systems exist, and which are self-aware, that wouldn't even meet the criteria for life as we know it on Earth.

About 4 years ago I became Associate Chair of the Physics and Astronomy Department at Mason. This was my first experience at administration, and going beyond pure scholarship and teaching. But I saw a field ripe for exciting change. I immediately created a student lounge, and a student advisory committee for student feedback on the department's culture on a regular basis, and I continue to do so. Student feedback is essential both in and out of the classroom. I also started working on getting the faculty to look at distance education options and using technology for teaching with simulations, large data bases, and gaming. After one semester I then stepped up to Chair of the Dept. of Physics and Astronomy, a position I held for one year before I led the merger of the Dept. of Physics and Astronomy with the Dept. of Computational and Data Sciences to form the School of Physics, Astronomy and Computational Sciences (SPACS), of which I'm the founding and current Director. Ironically, teaching faculty members is much more difficult than teaching students. And changing course and curricula material is even more difficult. But it can be done, albeit slowly, by sowing seeds of ideas that grow, and then allow the faculty members to jointly claim credit for the seeds and the successes.

Before I became Chair, the Physics department had taught physics the same way for 50 years, i.e., the faculty members were teaching students to become like themselves. I noted immediately that this approach ignores about 99.5% of the market for physics majors. By making that slight change in emphasis, although difficult at first to persuade the faculty members, we had great successes. We have more than doubled the number of physics majors in SPACS in three years. And our FTE growth has been about 45% during this same period. SPACS was chosen as an innovative department to be featured at the international American Institute of Physics conference this year, primarily for our teaching and research innovations. By combining the successful components of the popular flipped classroom, with collaborative learning using high technology for in-person and online collaboration, as well as an enquiry-based approach to instruction, we have seen enormous success at decreased failure rates and increasing the numbers of A students in our introductory physics and astronomy courses. We were awarded time by the Provost's Office to carry out these instructional experiments in the ALT classroom in Exploratory Hall. The results appear amazing, but still tentative. We need more and better statistics. Assessment with typical tools and pre and post-assessment is not complete. Our instructional approach I just described came to the attention of the 4-VA consortium, and SPACS recently receive a significant grant to implement more such experiments and for longer periods of time. We are also looking at on-line collaborative hybrid laboratory sections, which would appear to most students as playing computer games, but using real physical world principles. This may lead to a capability to significantly scale our teaching to larger numbers of students, but without increasing resource needs which is the big challenge with such scaling classes to larger numbers of students. But again, assessment is incomplete. And we have already learned of ways for improvement, by following students individually and groups in these experiments.

But the dirty little secret in my overall teaching approach is the recognition that physics, chemistry and biology don't really exist. At least they don't exist as the discrete fields the way we have historically taught them. The universe just doesn't work that way. Nowhere do you see these sciences separated in the world around us. The universe is much like life, a continuum of increasingly more complex emergent phenomena as you go from smaller to larger scales. The terms physics, chemistry and biology are just flags that we planted in scholarship domains over the past few hundred years when there were particular problems we either wanted or needed to solve, and had suitable technology at the time to solve them. Examples are easy to find. Astronomy and the telescope were both required for astronomy to get on track as a science that went beyond our normal senses. Galileo's two balls of differing weights, dropped from high on a leaning tower (he also dropped chickens) and the precise timing of their fall began physics in earnest. Optical spectroscopy and chemistry led to the periodic table and thus chemistry. The microscope and the biology of cells went hand in hand. It could easily have been other combinations of technology and/or problems, where we might have called physics what we now call physical chemistry. Or we might have called biology what we now call biochemistry. Or we might have called chemistry what we now call physics. But the traditional approach did serve us well when the problems were narrowly focused and by our modern perspective very simple. But the world is truly much more complex than we then assumed.

The point is that all the traditional disciplines of physics, chemistry and biology overlap in a continuum fashion from the small to the large, and from the simple to the complex. By not seeing that, and by not teaching science as such, we are depriving our students of a major insight into reality. Other than a few very fundamental problems such as particle physics and cosmology, the truly big scientific problems we face now are all interdisciplinary and/or multidisciplinary simply because they overlap all of these domains of the traditional science arenas. The days are long gone when we could do individual research and pick the low hanging fruit of science. Today science deals with enormously difficult problems such as understanding the brain and consciousness, understanding climate and human influences, understanding the origin of life, and the search for life beyond Earth. To deal with these extraordinarily difficult and interdisciplinary problems, we must teach students to think of these problems as multidisciplinary systems. We need to recognize that continuing to teach science as individual disciplines we are actually hindering the ability of the students to understand complex systems and make advances by working with large multidisciplinary teams of scientists.

Perhaps that is why I am so enthusiastic about astrobiology, which naturally integrates all the disciplines of science and shows how the story of life is connected to all of reality. And the science of astrobiology is producing amazing results. We find planets made entirely of water, and some of metal. We find planets where it rains glass, and other planets that are composed of diamond, at the center of which the pressure is so high that the diamond flows as a liquid. Just telling people about these things does more to awaken their interest in science and motivates more learning that any amount of make-work problem sets.

So back to my teaching philosophy - if pressed to define one I would say "I constantly look for teachable moments and use whatever is at hand to exploit those moments." And it's easy to do. I learned to do this early on, and now I do it naturally at just about every encounter I have with people. I look for ways to teach people about their part in the story of the universe. Over 80% of the elements in our bodies were formed in the nuclear fusion reactions of stars that lived and died 5-10 billion years ago. The water we drink came from impacting comets 4 billion years ago. Evolution is driven in part by cosmic rays damaging DNA strands; cosmic rays coming from neutron stars falling into massive black holes on the other side of the universe. We truly are star stuff as Carl Sagan was wont to say, and we are intimately connected to the entire universe in time and space. Teaching science the way I do it is simply telling that story.

And if, perchance, you haven't guessed by now, this statement is a teachable moment.