

PRACTICING AND TEACHING SCIENCE AS A SERVICE TO HUMANITY

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My training at MIT and Harvard taught me that scientists should be self-assured, never admitting when they don't know something. The goal of every scientist is to be famous, which one does by expounding a novel theory and then proving it by experiment. Furthermore, science is incredibly competitive, so only those who can convince others that they are the best will make it. Is it possible to be a scientist and yet be heroically humble? How does heroic humility fit into a culture of science where the biggest egos seem to reign? Blessed Josemaría taught that humility is not incompatible with being the best, on the contrary it is false humility not to achieve all that we are capable of. In this presentation, I would like to concentrate on ways of practicing and teaching humility and a spirit of service in the world of cutting edge scientific research. How can we foster that «good pride» of being children of God, as Blessed Josemaría taught, by doing science with a spirit of humility and seeking the truth?

Science is a wonderful career because every new discovery brings awe at creation and an ever deeper appreciation of how great God is. Blessed Josemaría taught that our goal as scientists with faith is to discover and understand better God's creation and to

work together with God to finish creation. Indeed, our intelligence is a spark of the divine intelligence, and so, when we do science, we are really discovering a bit of God's intelligence by examining what he has designed. I have met many scientists who were taught that science and faith are contradictory, but this is not true. If we take the approach that we are discovering God's creation, there can be no contradictions! Blessed Josemaría led me by example to have a great confidence in the perfect harmony between man's intelligence and God's intelligence. If we ever seem to find a contradiction, we need to study more, and we will find out that the contradiction was only apparent because of our lack of knowledge. He also taught us that we have to study our faith as deeply as we study our science, otherwise we will not have the knowledge we need of both in order to find the harmony between them.

Is the goal of doing science to promote one's own fame and to win competitions or to discover the depths of God's creation so as to work with him to finish it? Whether we choose one goal or the other depends on whether we approach our scientific endeavors with humility. The conviction that we are working with God on his creation enables a scientist to approach the unknown with confidence in God,

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an attitude I learned from Blessed Josemaría. In apostolic endeavors, he never waited till he had all the required funds and personnel to start something, he went ahead trusting that God would provide what was needed. When I look back at 10 years of my scientific career, I see the providential hand of God working at every step of the way. I was sure I was not worthy of the offer of a tenure-track position at a top-ten Biochemistry program, but I accepted the job convinced that God wanted me to try. After four years, we had no publications and things looked very uncertain for my tenure but somehow I was able to publish seven papers in that last year before tenure. All throughout my career, whenever we were without another experimental avenue, a paper describing the experiment we needed would be published, or we would have an idea that would give us the clue we needed at that moment... I have tried to foster this confidence in the providence of God in my students. They have certainly experienced it in their own work. The only student in my lab who got his paper accepted on the first try was the one who would have been scooped if his paper had been delayed! I am convinced that no one fails in science if they try their best, work hard, keep their eyes open for the clues that they need along the way, and are willing to change direction whenever necessary. It is only when they close their minds to other approaches or ways of thinking that they get stuck and can fail.

I have discovered that this is the key to doing good science, yet it is not the paradigm under which most scientists work. It was my postdoctoral advisor at Harvard who taught me this valuable lesson. One day he asked another student in the lab whether he had gotten the result they were both waiting for. The student answered that he had indeed gotten the result but it wasn't the one my advisor wanted. My advisor responded dogmatically that he did not want

any particular result, he simply wanted the truth. Humility, which is truth, is extremely important in doing good science. Either one is searching for the truth, and designing experiments that will probe the system deeply, or one is hoping to prove one's own theory. I would venture to say that science done with humility is likely to be better science because God's creation is much greater and more fascinating than we can imagine. I have experienced this in my own career. When I was still an un-tenured assistant professor, we characterized the disulfide-bonding pattern of the 5th EGF-like domain from thrombomodulin. To our surprise, the active form did not have the expected disulfide-bonding pattern based on other EGF-like domains. I was lucky enough to have colleagues who were willing to support me in publishing this surprising result, but they would ask me often whether I was still right about it. I would simply say that chemistry doesn't lie, bonds are bonds, and they don't change at will. It wasn't easy going against an accepted paradigm. It has been five years since we first made this discovery and finally an independent group has confirmed it. The head scientist from this group telephoned me just to tell me that he was so sure they were going to prove us wrong and he just had to tell me how surprised he was that we were actually right. In our case, we had nothing to prove, we were simply characterizing the bonding of the molecule, and we stumbled upon this result. It frightened me to think that if I have not had the humility to recognize the truth, I would have sent my student back to the lab to continue repeating the experiment because he must have gotten it wrong.

Doing science with humility has several consequences. One important consequence is that we will need to admit that we don't know a lot of things. While admitting we don't know something

sounds like a negative consequence, I have found that it is a key to success in the new world of collaborative, interdisciplinary science. One of my students once commented that it amazed her that I did not seem to care at all what others thought of me. Thinking about this comment later that day I realized that it was true, and I had learned this attitude from Blessed Josemaría. He used to say that the only opinion that we should care about is God's, the opinion of others will come and go and we should not give it too much importance. My student was probably referring to the discussion we had had that day in which I had admitted in front of several famous scientists that we didn't know how to do one of the experiments she needed to do. In approaching her project, we chose an important problem, but we didn't know how to do most of the experiments that needed to be done to solve it. We found other scientists who knew how to do the right experiments, and were able in some cases to work together with them, or we asked them to teach us how to do the experiments. Although some may think it is humiliating to admit that one does not know something, objectively speaking, we are all out of date less than a year after we finish our degrees, so if one is to continue to be a cutting edge scientist, one has to continually learn new experiments. It will be the humble scientist, the one who is not afraid to admit that they don't know how to do something and to be taught, who will be able to stay on the cutting edge.

Is it possible or desirable to train students in how to do science with humility? In my experience, it is not only possible, it is desirable, and it is a project that lasts the entire time a student is with you in the lab. Certainly, the thesis proposal defense examination is designed to teach each budding young scientist a lesson in humility. In this examination, it is the goal

of the committee to show the student just how little he or she really knows, a humiliating experience for sure. Some students react to this experience by fighting back with ever more study and work so that they are never humiliated again. I encourage my students to maintain their new-found humility, as it will serve them well in science. Humility is learned by example. I learned it from my advisors, who were willing to share with me their lacks of confidence, and the fact that most of their good ideas actually were their students' ideas. Students learn it when they see their advisors admit mistakes, and apologize. I see this as a key apostolate where I can really make a difference in students' lives. I help them to see that God made a better world than we can guess, and it is more fun to figure out what He did, than to try to make it fit into what our small minds can imagine. As one of my first students said, you cannot study biochemistry and not believe in God! We all like to make rules so we can predict the future, but in God's creation, there are many surprises, and His ways are much more interesting...

A second way to train in humility is to foster a collaborative rather than competitive spirit in the lab. This has to be carefully done, because most students are naturally competitive. They need clear definitions of what their project is, and how the advisor distinguishes it from that of the other students in the lab. Labs where there are not well-defined projects and everyone works on closely related aspects tend to foster competition rather than collaboration. Just as in society, the family is the place where everyone is accepted for who they are, the lab has to be an environment where there is no competition, and people can share ideas openly. Often in my lab, it is the undergraduate students who know something that a new incoming postdoctoral fellow needs to learn, so they must also not be afraid to learn from

someone who is lower than them in the hierarchy. This creates an atmosphere of openness and everyone feels free to admit ignorance as well as mistakes. It is a critical role of the advisor to manage the competitive spirits in the lab and foster collaboration, catching small incidents of unhealthy competition before they get out of hand. Blessed Josemaría taught that petty jealousies, feelings of not being noticed, and hurt feelings due to pride are like termites that can ruin the foundation of a building, and it is important to «kill» these termites quickly. The advisor must make sure that every student is respected and feels their project is important and that they get the help they need to make progress. Also, by establishing an atmosphere of collaboration, students experience the joy of contributing to the common good. I learned this from my advisors also, that each student should have a task that they are responsible for and that helps the entire lab. This is the way Blessed Josemaría treated the young people who came to the center. Each one, no matter how new to the enterprise, was made to feel that their efforts were an important contribution to the success of the whole operation. When each one has responsibilities that other's work depends on, they will learn how to practice a spirit of service towards others.

Another way to foster humility is to build a broad cultural base within the lab. My postdoctoral advisor always had one postdoc from Japan, one from Germany, one from Israel, one from England, and one woman. I was lucky enough to apply when the slot for the one woman was opening up...It certainly was educational to learn how to work together with such a diverse group, and I have tried to encourage diversity in my lab as well. My first experience with people of different cultures was in Bayridge Residence, a large student residence run by Opus

Dei in Boston, Massachusetts. Students came from all parts of the world to study in Boston and to live at Bayridge. The director worked hard to make sure that there were not too many who spoke the same foreign language, so that everyone would need to communicate with each other. She also taught me to have an open mind about other ways of doing things, when it was a matter of opinion. She taught me even to enjoy how people from some cultures can be so relaxed and do things more slowly than I was accustomed to. I am very glad to have learned how to be open to different cultural biases and ways of doing things. Students spend a lot of time together in the lab, and such an intense amount of contact with someone very different from themselves is wonderful training in humility. They learn that there are lots of good ways to do things, theirs is not the only way that works. They learn about other religions and cultures and how each fosters certain virtues that promote the common good. An important aspect of humility is that one is not wedded to one's own way of doing things. I try to foster this aspect of humility by encouraging students to take initiatives in their experiments. This can sometimes be difficult because biochemistry and biophysics is very exacting, and freedom is not usually conducive to good experimentation. On the other hand, better science is done when one knows WHY certain things are done a certain way. A humble research advisor is open and honest, admitting they don't always know the best way, and allowing the student to take initiatives. Either both student and professor will learn the reason behind the practice, or they will learn a better way to do it. Oftentimes better ways of doing things are discovered by the students exploring their own initiatives.

Blessed Josemaría taught us that since pride comes as a result of thinking about ourselves, humility is

fostered by the practice of being concerned for others. A good way to foster humility is to foster a spirit of service in the lab. The older students help the younger ones to study for exams and to prepare their oral presentations. They help each other with their experiments, and teach one another new techniques. I also try to organize charitable projects that students can work together on. These projects are a wonderful way for students to get out of their everyday world to broaden their horizons. They also see an example of someone who has not made science their entire life. Each year the students in my lab prepare demonstrations for local grade school and high school students who are educated at home so they can experience science at a more advanced level. The «home schoolers» day now serves some 65 children from around the San Diego area. Students from my lab also help with service projects in Tijuana, Mexico. At Christmas time last year, some 30 students from the university, many who were graduate students in Chemistry and Biochemistry, staged a complete Posada, including the traditional songs and piñatas. Many of these students are not Catholic, and this was their first experience in learning the «Christmas story». One student said to me afterwards «Now I understand why they always show the figures of Jesus, Mary and Joseph in a *barn*!»

Teaching a spirit of service by example means showing respect for the needs of the students. Science is moving very fast these days, and everyone has too much to do. Still, it is important that the students see that we put their needs before our own. Faculty are often faced with the decision to do something themselves, which would be faster and easier, or to let the student do it, which would be more educational. Often, because of a lack of humility, and concern for the education of the student, we decide to just do it ourselves. Again,

Blessed Josemaría gave a tremendous example in this. He put less-experienced people in charge of things that he knew much better how to do. He told them later that it was for their education that he did this. For me, the struggle to wait while education happens is a key aspect of my struggle to sanctify science and I often ask Blessed Josemaría for patience knowing that he probably struggled with in this area and became a saint as a result. I am often saddened when I hear that students are waiting to graduate because their advisor has not had time to read their thesis, or edit their papers. It is important to let the students write their own papers, and to edit them quickly and thoroughly so that they learn to write well. It would certainly be easier to ask for the data and write the paper myself, but this would not allow the students to learn how to write well themselves. Working together in this way, the students experience a one-on-one care and respect that they will want to emulate when they are professors themselves someday.

Finally, in the fast moving scientific world we live in, I always remember what Blessed Josemaría said about being a sower of peace and joy. There is certainly not much peace or joy in cutting edge science today. Even Nobel prize winners get their papers rejected without review, and the grant review process is not much more reliable than a lottery. Everyone faces uncertainty and frequent rejection. As Blessed Josemaría also said, we cannot be «hot house plants» we need to face the difficulties squarely and try to find Christian solutions to today's problems. This means that we cannot protect students from the realities of science in today's world. We need to help them to face rejection with a supernatural outlook and humility, learning from the negative comments. A colleague of mine criticized me for showing an unfair review to my student who

had written a paper that got rejected. I had already learned, and tried to teach my student, that one needs to read the review carefully and learn from it. It is not constructive to get angry and just send the paper to another journal. The person who did the review is a scientific peer, so if he or she appears not to have understood what was described in the paper, it is probably because it was poorly explained. I always tell my students that they should be grateful for the reviewers' efforts, and try to improve as much as they can from the criticisms. In this way, even in the midst of difficulties, an atmosphere of peace and joy is maintained.

In summary, Blessed Josemaría taught us that in every field it is possible to live all of the virtues heroically. He also taught that when one lives the virtues heroically, one will be better at their profession, and this has certainly proven true in my

personal experience as a scientist. The humble scientist is open to the surprising truths of God's creation and works with God to discover them. These discoveries are always more interesting than we could have imagined. Contrary to expectations, the humble scientist has more confidence because he or she only cares what God thinks. The humble scientist is not afraid to admit ignorance and is therefore more able to stay at the cutting edge. The humble scientist works well with others and fosters unity that promotes the common good. This will be more and more essential as science becomes more interdisciplinary. Finally, it is important that we foster humility in our students through encouraging a spirit of service so that we will have more humble scientists in the future. In this way, despite the frequent rejections, science can be done in an atmosphere of peace and joy built on a deep confidence in God.