

## Atomic Conversation Unabridged

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### WHAT AND WHY?

Last year when I was serving a residency at the Rice Model Lab at Lee High School, we got into an argument about whether students have an intrinsic desire to know. Since I learned more about teaching and learning in that one year than I learned in all my previous college years put together and multiplied by a lot, I have to say that probably there should be more arguing and less lecturing. Nonie Harcombe, the professor at the lab, never lectured to us even one time, I don't think. When she talked to us it was to set us up so we could argue about things. (And I have to say that your memory really can remember the things you hotly contest as opposed to the things you are told to remember so you can pass a test.)

I was holding out strongly for the notion that students have an inward yearning to be able to understand the universe and their place in it. The other three teachers were trying to convince me that students are not burdened with such baggage. And they were not kind in their analysis of the kind of dummy who would believe that students are philosophers and scientists. But I clearly remember the argument, and while I do not think that I was moved towards their position, I certainly had to mentally assess more definitively the basis for the assertions I was trying to bolster.

The fact is that my universe starts with me, and it is not enough to say that I think and therefore I must exist, one has to go a step further and say I think about who I am, and what I am, and why I am here, and what purpose my life has, if any, and how I arrived at this point, and since I think about these things and I have the same DNA as every other member of this species, humans must think about such things and be concerned with such things, and, therefore, my students are little seething masses of hormonally-charged inquiry just waiting for a chance to add answers to the big questions. They are willing and able and anxious to make strides in the direction of understanding their place in the grand scheme of things.

When I was in high school, forty years ago, gasp, I was working away at my worldview the whole time I was there, chiseling a bit off here and puttying around sharp edges there, revising, huffing and puffing. I remember the day the social studies teacher let me argue with him about evolution. It was glorious. Thank God for teachers like him who let students buck and pitch a little bit. And then during college, I was shifting around like a drunk duck. I threw away massive chunks one day and reinvented them the next. And I was actually timid about it. Were my parent's ideas sacred? Or were my parent's ideas theirs and I needed to either make them mine or discard them and replace them?

Now before you shake a long pedagogical finger at me and intone the truism that the schools should not be about teaching religion, let me offer a resounding "HOGWASH."

There is nothing more important than teaching religion in the public schools. After all, what is religion? It is a way of answering questions that is employed in those instances where science is on the default. And science my friends, is on the default 90% of the time. I learned more about religion in school than I ever learned in church. Religion is what people care about. It is what they get hot under the collar about.

Taking religion out of the schools is like taking the breath out of the body. It dies.

It is lifeless. Real teachers never allow that to happen to their classes.

Talk about boredom? That's gotta be the big ho-hum. How can we say to students, "Kids, we want you to learn these stale, sterile facts and then we want you to spit them back at us on a test and we will call that education?"

Please.

The fact is that as far as we know, Homo sapiens have always been the ones to insist on things being meaningful and you will find them religious to a fault. You may separate church and state, but you will never divide religion from education. Never. The whole essence of being human is wrapped up in the need to be more than a collection of cleverly organized organic molecules. This drive has energized the course of history more than some are willing to admit. Next time they call a war, try to notice the sequence of events, you know, the part where they have to come up with a bunch of high-sounding moral reasons why it is necessary to revert to barbarism? The part where all the little critters that are expected to become cannon fodder get invited to save the world for the higher good?

Religion has been used to build the case for racism, war, and regional strife; even internal familial differences have been defined and prolonged through the appeal to religious sentiment. Whether you want to include it or not, the element in man that seeks meaning and understanding and purpose is alive and well and ready to be employed as a blessing or a curse, a help or a hindrance. In education we can acknowledge and work with it or we can pretend it is not there and drone on as the students fall asleep.

For some it may not be a very natural transition to preface a science curriculum unit with these remarks. After all science is the non-religious subject. Wrong. Dead wrong.

My science classes over the years have influenced my worldview more than any other subject studied. In high school, back when Newtonian physics was the only physics considered appropriate for common fare (remember the dark ages?), I formed the view that science, given enough time, would eventually solve all the world's problems.

I put my hope for world peace, an end to hunger and sickness, you name it, in the careful and truthful application of the scientific method. I was a scientific socialist politically and a person who saw no real need for a supernatural God.

I hated to let God go because in my childhood I had seen my parents argue for His existence, and it was comfortable to keep Him around, but because of the science courses I was taking, I saw no real reason to. I decided that God was an idea that made some people feel better about the world and was, therefore, useful to some, but in my case, well, it just was not necessary. Then in my 30's, when my life was falling apart and science did not seem to have an answer, I began to really wish that I could reincorporate God into my world, but I couldn't until, well, until I started teaching at the High School for the Engineering Professions. That was a delightful experience because I was surrounded by a wonderful group of thoughtful nerdy little people who kept asking questions and forcing me to begin reading books like *The Dancing Wu Li Masters*. This book was written for the interested lay person, but it delves into the new physics, laying bare the foibles of the naughty little sub-atomic particles that have names like *beauty* and *truth* and which care not one whit for laws that Newton proclaimed as rulers over the seen realm and which act more like words than things and which bleep in and out of existence in a most unsettling manner. Scriptures taught to me in childhood began bubbling up out of my memory bank, Hebrews 11... *the worlds were framed by the Word of God so that things which are seen are not made of the things which do appear.*

The idea that the atom was just energy arranged a certain way began to take hold of me mentally because of what it meant to my worldview. Energy is just mass going really fast...slow it down enough and it becomes the stuff we see as particles, Newton's particles, stuff, things...and then think about the miracles of Jesus...and the miracles we see happening today...and listen to the accounts of those who experience those miracles...

"I felt a warmth go through me...(what is warmth but a speeding up of the stuff)..."

Energy to effect change, or healing, or mountains being moved into the midst of the sea or the storm being calmed or the food for the five thousand being manifested as things...yep. Like I said, science has literally influenced me more than anything, first to talk me out of God and then to talk me back into Him. And I said all that to say this...

when we talk about science with our students, if we squeeze the life out of it, we do so to our detriment. There is an intense, palpable desire in every human heart to know...

and if we try to work around that, we set ourselves back a considerable amount.

That is why in this unit I propose to bring to life the human conversation that has brought us to our current understanding of the atom. Students rarely get to see us conversing, or to put it bluntly, arguing. And yet, the things we care enough to argue about are precisely the things students show us, by their test scores, that they do not understand. We sit around in teacher's meetings and we opine the lack of ability to think critically on the part of our students, and then when we "teach" them, we don't let them critique anything.

We don't want to argue with them because arguing takes time and we are too busy covering material so we can answer to the hand-wringing administrators who will be changed out like burnt light bulbs if the kids don't pass the TAKS test.

Scientists argue. They always have and they always will. Their predecessors the natural philosophers argued. The alchemists argued. Everyone who cares about what they believe to be true argues. And people care most about what they consider to be religious truth which in turn is hopelessly intertwined and inevitably influenced by what scientists discover. Every shred of evidence tells a tale and plays into the grand scheme that each person is carefully developing and making sense out of as they plan their days.

At the Model Lab I was the only teacher who believed that, but a significant factor blurring the vision of my counterparts was their extreme youth, and young people are sometimes capable of doing something that they are not consciously doing. In high school I was not aware of the fact that I was sweating and slaving over my worldview because it was not until college that I even heard that term used.

Just because I didn't know I was developing a worldview doesn't mean I was not developing a worldview. To this day I am developing a worldview, and I love to tend it and nurture it and I will hotly contest its validity until through a preponderance of evidence it is forced to give way. I know my worldview. If I were to be tested over it right now, I could think critically about it and I could repeat it and I could ably compare it to other worldviews. If this is the case, then why would we want to step outside of this developing process to artificially present any discipline as divorced from anything meaningful and deeply felt. Why? Because we are terrified of discussing anything that might be remotely construed to have even a shred of religious content? Are we? In America we are terrified of arguing?

Well, then let us plunge into the atomic conversation and leave nothing out.

The atom got its name from two smart Greeks who had a lot of nerve because they argued about what the world must be made of. They must have argued hard and long because the remarks that are recorded as being the distillation of their talks, show a level of thinking that was

not significantly improved upon for 2000 years. Good old Leucippus, the teacher, and Democritus, the student, called the basic stuff of the universe *atomos*, extremely small particles that were conceived to be in constant random motion.

Hard core scientists don't like to call them scientists because, of course, science implies experimentation with many trials, but real science is often something that takes place as people just sit and contemplate what they have seen and heard—life being full of many, many experiments and trials, as we absorb data continuously, putting two and two together then taking them apart mentally. Mendeleyev sitting at his desk shuffling a deck of cards around until something clicks... Einstein mulling and cogitating until something clicks...and we allow them to be in the family of scientists even when they are just chewing their cud so to speak.

But I maintain that the conversation about the stuff of the universe is an argument that carries great import and without letting a chance to use a pun slip by, it matters.

When I read *The Dancing Wu Li Masters*, I was on pins and needles the whole time.

I had discarded the religion of my childhood and then when I found myself wishing I could have it back, I could not have it back because I was trapped in a Newtonian world where everything could be reduced to what we can see, touch, taste, hear and smell. I needed to hear somebody say, "The universe is not only stranger than we know; it may be stranger than we CAN know with the five senses." Whether that is true or not the issue is that I needed to see a crack in the impregnable edifice so that I could doubt science instead of science doubting me.

Democritus and Leucippus had just the opposite problem in that the political climate of their day was such that attributing witnessed phenomena to the workings of supernatural gods was A-ok, while stepping back and demanding that things stand to reason was not at all common. We look back at them and marvel because we do not see them giving in to the main stream. We see them boldly going a different road and it looks good to us from this end of the swamp. We mentally throw them into the same bin with other bold thinkers, some of whom lost their lives during the course of history, because they refused to turn their backs on the fact that perhaps the emperor was not clothed and was indeed sporting around in his underwear.

Believing that atoms exist is easy today because we have only to crank out a happy little atomic force microscope and look at them. Boom. There they are in plain view and we are forced to below the nano-level for our arguments about what the universe is made of and how it got here and what it means. We can no longer argue about whether the universe is one unified thing, instead of myriad small discrete particles, unless we want to try to nail down the hundreds of non-thing-like things that we see spewing from the atom when it is properly smashed. But the argument, just because the subjects got smaller, is far from over. It rages on. We still have physicists yearning for a unified theory that will explain everything handily. And, on the other hand, we still have the group who refuses to demand that the universe measure up to any kind of systematic application of human reason at all. And this same argument still gets people hot under the collar, and while burning dissidents at the stake is kind of frowned on in some circles, which is perhaps a sign of some sort of progress, persecution for alternative conceptions is alive and well almost everywhere, even right here in the self-proclaimed democracy capital of the world.

In fact, in this country we have come full circle in our religious passion in that what we at one time decried as unthinkable, humans having gradually developed from apes and, of course, originally having popped fortuitously from the ooze, we have now turned around and embraced with such fierce loyalty, it has become all but impossible to even discuss or hint at the possibility of their having been any evidence whatsoever for intelligent design. People froth at the mouth and display all kinds of emotion and in some cases fire you from your job if you dare to even let the rumor spread that there IS a debate on this issue. So we have the ludicrous, (Democritus and

Leucippus would NOT be proud of us) situation, where we cannot talk to students about a debate that adults are allowed to blabber on about on any street corner because we cannot trust ourselves to not grab students by the throat and shove our personal beliefs, if they happen to be not in the main stream, down their defenseless gullets. When was the last time you saw a public school hosting a forum on the topic of evolution? One in which scientists are allowed to point out the holes in the theory? I am not asking for a debate in which preachers and laypersons duke it out. I am asking for the real debate, the scientific one in which we allow students to see the reality of where we are in this all important, you know, the one that matters, the one we care about, argument. What is the evidence?

No, we keep a straight face and we faithfully mouth the party line and we bore them to distraction with the same story they fed me in high school. “We have it all figured out, or well, just give us a minute and we will get it all figured out.” Oh, the intellectual paucity of it all makes me want to vomit. What robbers we are as we strip away the meaning and feed them the processed, packaged, useless truth. No nutrition...no life in it. How do we ever expect them to jump into the human conversation if we deny them entrance at every turn? When will we ever become confident enough to tell students that we don’t have it all figured out? Why do we consistently insist on taking firm aim and shooting ourselves repeatedly in the foot?

Last year at the Rice Model Lab was such a breath of fresh air, such a treat. How we argued! It was like going back in time. When I got to college, it was not the classes that interested me, but rather it was the discussion among students. I remember talking ‘til the wee hours of the morning about anything and everything. Sometimes and on some campuses the professors would join in. It was rich and I remember being very alive during it. Nonie Harcombe (Rice Professor of Education who heads up the model labs), whose book on constructivist learning I have included for you in the bibliography, would hold forth for the notion that we do not see our students learning because we refuse to take the time necessary to find out what they think about things and then to let them confront the evidence in such a way as to change the way they think. We never really change the way our students think because we shy away from the debate. And, of course, discussion and debate are time consuming and in some cases taboo. It is easier, faster and cheaper to hand out a work sheet with the information we want them to know on it, all packaged and processed and regurgitated and dead. (Somebody ought to bury it.)

## **HOW?**

I mention the Rice Model Lab again also because the how of this unit is strongly influenced by my lab experience. Before I went to the lab, I would have probably done a whole bunch of research myself, and then I would have written a dialogue for each scientist perhaps, well, no, the fact that I want to write a dialogue is probably also a direct result of what I learned in the lab so well...my first vision of this unit was that I would have a stage production in which the first scene would be Democritus and Leucippus having a discussion. There they would be sitting looking very Greek, there would be at least one column, and they would have on their Greek thinker garb, and they would sit there and hold forth mightily in conversation answering their critics and putting forward their ideas with great gusto, and the students would see this production, and they would be thrilled, and they would learn. After the scene with Democritus and Leucippus, we would go to the next scene which would be John Dalton in his laboratory, and he would be carrying out his experiments right there on the stage and his experiments would lead him to intone that Democritus was right. Yes, there are atoms, and they combine in definite ratios to form compounds, and there we now have experimental evidence for the advanced reasonable thought of the early Greeks, finally after thousands of years. Hooray. And the next scene would be the contemporaries, Thomson (J.J.) finding the negative particles with his cathode ray tubes shouting “aha!” There is more to these atoms. They are not the tiny solid marbles that Democritus and Dalton put forward. “Thar’s negative particles in them thar hills.” And then Rutherford would

take him to task and say, “But wait, friend, the positive part of the atom is a whole lot smaller than your plum pudding idea, because look at those alpha particles barreling right through the piece of gold foil, with barely a deflection, indicating that the atom is mostly empty space, gasp what a concept.” And then here would come good old Niels Bohr with his evidence for the notion that the electrons are not just whizzing around in a purposeless and disorganized manner but are instead religiously finding the least energetic level of participation in any given atom, and finally de Broglie comes along and points out that if by any chance the idea that the electrons were orbiting obediently around the nucleus in a somehow planetary manner, that such a notion had to be dispelled quickly because anything as small as an electron going at nearly the speed of light in a space the size of which is so small as to be barely imaginable, such a particle, if indeed it can reasonably be called a particle, would be everywhere at once and nowhere in particular at any given moment but would rather have to be defined as being PROBABLY somewhere.

I had planned to call this production *Dead Men Talking*, and I made a flyer for it with a skeletal hand on it that kind of hinted at death. I hoped it would grab the attention of my students. Then I started reading about the men. I started learning things about them and their ideas. I thought, “This will be fun, writing all this dialogue, trying to get it to be historically correct if possible. I am going to really learn a lot here and isn’t that the point of Houston Teacher’s Institute, to keep me learning so I don’t get intellectual constipation?”

The whole thing really had me cheered up until I looked at what role I was assigning my students in it, that is, they would be actors on a stage carefully regurgitating what I had written. Hmmmm...so I changed the lesson plans to include students in the creative part. Instead of my writing the dialogue, I decided that I would do the research just so that I would have an idea of what would be the parameters of possible faithfulness to what happened historically but that the students would get to write the dialogue and figure out how they wanted to stage the production, so that the production itself would not be the totality of the learning experience but merely one part of it. That is Model Lab kind of thinking. That would mean that the students and I could argue about the dialogue...if they wrote something I could not agree with, I would have the responsibility of presenting them with what I thought, and they would have the responsibility of defending what they thought. Then, according to Nonie Harcombe, learning would be more likely to occur.

Bringing the students in on it makes it more difficult but better. I will learn more this way because I will have to defend myself and be able to critique others. And, oh yipes, with the students in on it, my plans may have to change, yep in fact they already have because as I am working on this unit, I am discussing it with this year’s students (even though I am not really supposed to teach this til next year). They have already let me know that things are probably going to change a whole lot; in fact, they did not like the idea of having to write dialogue for Democritus and Leucippus, or Thomson and Rutherford, as a matter of fact they said, “We don’t want to talk like the Greeks. We want to talk like ourselves. Why couldn’t it be a discussion among modern day students? Why can’t we be arguing about the assignment itself? Why can’t we be arguing with each other about what Democritus would say and what he was thinking? We could have the artistic kids draw a huge back drop for each discussion and they could show Democritus and Leucippus talking, or John Dalton in his lab, and we could be talking TO EACH OTHER about them?”

Of course, I had not thought of that but I really could see it working. It was kind of a brilliant idea. When I **first** thought of this unit, it was in response to the TAKS scores our students demonstrate in which the TAKS objective 4, (Atomic Structure) is almost always the one on which students score the lowest... this and my teaching experience in which the concept of the atom seems to slip from their grasp year to year. We teach it one year and then the next year they have forgotten that atoms really exist. My **first** thought was to get some smart grad students from

Rice and have them write and perform something that would demonstrate for our students the historical development of atomic theory. I fully intended to see that happen. Fortunately my initial attempts to bring that about were fruitless.

Then I noticed that the Houston Teacher's Institute at the University of Houston was offering a seminar with Professor Scott Perry called *Chemistry through the Ages*. I thought maybe if I could participate in the seminar, I might be able to come up with the material for the production myself, having an expert at hand to keep me on the straight and narrow. That thought kind of thrilled me to the core, and now the notion that my students will have a chance to do some original thinking as well...well, it just doesn't get any better than that.

The production itself then would be the only thing for those we might invite to attend, so I thought to make it more meaningful for the attendees by distributing and having all prospective audience members be required to complete a survey in which they must ask at least twenty DIFFERENT (not just students or teachers but clerks, bus drivers, crossing guards, etc.) people to respond to the question "Do you believe that the universe is made up of tiny particles called atoms? Why or why not?" And, when I test drove this survey/questionnaire, the results were heartening in terms of their usefulness in the classroom. Many many people who affirmed the existence of atoms when pressed to find out why they believed were honest enough to say that they had no objective evidence immediately in mind but were instead merely burping back a "truth" they had been told to espouse. And, many who did not believe said they were in doubt because no one had bothered to show them any concrete reasons for believing.

These surveys then were designed to get the students thinking about the same questions they would be hearing discussed in the production. Sort of a mind prep, I guess.

Sort of a way to get them to confront the notion that the human mind, when presented with evidence, tries to make sense out of it, or, just blindly accepts what it is told to believe with the second option being the less desirable.

My thinking was to make it an honors event, including only those students who were actually going to benefit from the discussion as opposed to those students who might use the event to further their careers as loud show-offs. I find that at the high school level, some students are mature and others will find that maturity, hopefully, further down the road. In the production then it would be helpful to have only those students who have demonstrated their ability to participate in public events without deliberately disrupting them. Teachers would be excellent judges of who should and should not be allowed to participate. Behavior would then be the only limiting factor not just for the sake of the attendees but for the sake of the performers who might have their hard work demeaned by impolite audience members. As adults I think it is important to protect our students from themselves and each other until such time as they can assume that task for themselves.

## LESSONS

### Lesson One

Lesson one in this unit might begin with the teachers being up-front with the students. (This would be out of character for us, but it could work.) The teachers might tell the students that as 9<sup>th</sup> graders they have been privileged to the news about atoms on numerous occasions without the beauty of the atomic theory really getting a hearing.

"You see, guys, the universe is made up of these tiny little particles, atoms, and you don't believe it for a minute. You prove that to us every time you take the standardized tests.

But, don't be discouraged, most people over the course of the history of the human race have not believed in the existence of atoms. You are part of the majority. However, we are now faced

with some really incontrovertible evidence. Yeah. Like right now we could whiz over to Rice University or the University of Houston, and we could fire up the atomic force microscope, and we could see atoms, sort of. Actually we could see the force field they throw, but, hey, either way we have to deal with the technology and the facts. Too bad you could not have been alive 400 years before Christ when as far as we know, Democritus and Leucippus first really began the atomic conversation. Then you could have been a thoroughly self-respecting doubter.

In fact, since most of you would have been more comfortable in that intellectual climate, let's head down to the library, hop onto the Internet and surf around and see what we can find. What kind of conversations DID take place in 400 B.C. concerning the stuff of the universe? Let's see if we can nail down what Democritus might have been caught on tape saying to the folks that did not agree with him? Would his ideas have scared people?

Why would his ideas have been controversial? Why would his ideas have been something that people even cared about? If he argued with people, would there have been any passion, any fireworks, any fist fights? Does it matter what the universe is made of?"

I tried this in the classroom and I had a contest. Groups of two worked together to generate written conversations. Each group had to present their conversation while the rest of the class critiqued and countered. In order to counter a bit of dialogue students had to say, "I do not think Democritus would have said that because...or I do not think someone living in 400 B.C. would have said that because..."

Fortunately the Internet is rife with Democritus/Leucippus stuff. The students began by trying to write down a lot of things about the two philosophers. It took some prodding to get them to begin sorting through and distilling out conversations. It was also helpful to get them to be specific about who was on the other end of the conversation. The thinker-philosophers of that day were (this shocked the students) deep and brilliant and relatively open to new ideas. The regular folk were for the most part caught up in a rather silly religion. I finally had to allow some students to let Democritus argue with modern students instead of his contemporaries because a percentage of my students were unable to make a go of the assignment at all and the only way I could reach them was to insist that they could hold their own in a conversation with an ancient Greek. While the students were on the computer I roamed around prodding and fussing and posing questions and trying to generate interest. One of the most challenging things we found was written by Hegel. It was kind of fascinating to hear a man with a brilliant mind, who lacked the objective evidence for the atomic theory, really give Democritus the once over. His arguments were philosophical only, not in the least scientific, heavily weighted with the jargon of the philosopher, but very perceptive.

Hegel saved the day because he used fighting words. He charged that the teaching of Democritus was *immature and incapable of giving satisfaction*. The students loved it. Go Hegel! Nonie Harcombe would have been proud of Hegel because he started an argument. Why would Hegel have laid such serious charges at the feet of a philosopher who gets his name printed in almost every science text while Hegel gets left out in the cold? What is immature and unsatisfactory about the teachings of the atomists?

If I told you that all of reality could be explained by the random bumping together of tiny marbles would you immediately become a believer? How would it affect your behavior if you found out that your entire future was already set, cast in stone and totally predictable based on the luck of the bump? Would it alter your behavior in any way? Would you still struggle to be honest, and kind? Would you ever darken another church door?

For Hegel, the logical extension of Democritian atomism fell far short of in any way explaining the complexity of the human experience. And, since in Hegel's day the atom was still



more theoretical than the respectable objectivity it has garnered in the present day, the boldness of Hegel's charges could be understood. Which philosophy is less jarring as it collides with the evidence we see all around us every day?

## **Lesson Two**

Lesson two would then be a closer look at the evidence as seen through the eyes of John Dalton. Why is he claimed by the scientific community while Democritus is not?

What did he see in his laboratory? What affect did his work have on the thinkers of his day? What steps forward did the atomic theory experience in his hands?

## **Lessons Three and Four**

Lesson three would see Thomson, Rutherford and Bohr fleshing out a more complex and electrical atom with no real move away from the philosophical implications and lesson four would open the door and let the human spirit back out to fly in an world of infinite possibilities with the wonderful uncertainty that most people require in order to stay sane and forward-looking. Last year I wrote a unit in which I likened de Broglie's cloud model to a cow in a pasture. When you go to find your cow, the most likely place to look would be where the grass is thick and rich; however, it is possible that your cow may be standing on top of a rocky crag singing the National Anthem. It is possible but it is not likely. Humans want the possibilities to be endless. Americans have especially made this a requirement and this notion is woven into the fabric of all that we do and say in this culture. Miracles have to be coded somewhere into our doctrine or we balk.

We don't mind rules as long as there can be exceptions. Our mind set is nothing if it does not spawn one story after another in which the impossible happens.

Allowing students to argue about the constructs of the universe and what they might mean to us individually is my prescription for changing low test scores in TAKS Objective 4. I have yet to look at a printout of scores for any school that did not have the lowest scores in this objective. My personal experience has been finding students in high school repeatedly lacking in an atomic theory that has been incorporated into their personal worldviews. It should be okay to tell students about the mental journeys that others have trod as scientific knowledge has come forward to change the way we think.

This summer I taught the Project Grad 9<sup>th</sup> grade academy in science. Those students were fun to be with. Evidently another Harry Potter book came out because one morning here they all came with their books in hand. Why are children so fascinated with Harry Potter? Why does the supernatural have such an appeal? I submit to you it is for the same reason that in my 30's I longed for the religion of my childhood. It is the same reason Hegel found the atomists inadequate. We strongly suspect that there is much more to the story then what we have discovered to date. The questions of who we are, what we are, why we are and even when we are, continue to drive us to think and study and experiment because we want to know. We need to let our students in on the fun.

Dr. Harcombe would say that they already are in the game. They have ideas already.

Are we afraid to let them bounce their ideas around?

## ANNOTATED BIBLIOGRAPHY

### Main Sources

For those of you who may be reading this without knowing about Houston Teachers Institute, be aware that the institute happens in the spring and is a once a week seminar in which inner city public school teachers are invited to spend time with experts in various fields of interest. In this case I attended a seminar called *Chemistry through the Ages* lead by Scott S. Perry, professor of chemistry and chemical engineering at the University of Houston, in which three books were assigned. They were delightful to read not only from the point of view of being sources of knowledge about chemistry, but they were liberally strewn with the philosophical implications of our knowledge of chemistry and conversely, the sometimes but not always adverse effects of philosophy on the developing science of chemistry.

Le Couteur, Penny and Burreson, Jay. *Napoleon's Buttons: 17 Molecules That Changed History*. New York: Penguin Books, 2003.

Morris, Richard. *The Last Sorcerers*. Washington: Joseph Henry Press, 2003.

Strathern, Paul. *Mendeleev's Dream: The Quest for the Elements*. New York: Berkley Books, 2000.

### Internet

The Internet is rich with material that pertains to this subject matter but I will cite two websites that really helped to crank up the debate. You will probably find many better ones but these can serve as an example of sparks that can get the students to argue.

*Hegel's History of Philosophy: Greek Philosophy: E. Empedocles, Leucippus and Democritus.*

<http://www.marxists.org/reference/archive/hegel/works/hp/hpdemocr.htm>

On this website some tough reading is presented with a lot of philosophical jargon but if you can encourage the students to plow through the stuff that sounds nonsensical 'til they get to the coherent part where the arguments are presented, then the debate can be enhanced. Can they identify with Hegel's complaint against the atomists in that he is holding out for a universe with a little more depth, substance and meaning?

Ledgerwood, Philip. *The Atomists: Leucippus and Democritus – Atomism and Christianity*. Partial completion of the requirements for PHI-201. <http://www.philledgerwood.com/atomists/christianity.html>

In this rather simply written document the author points out that the philosophical implications of the doctrines of the early atomists are basically that the universe is a big machine that is totally predictable; starts itself, stops itself. Randomness is impossible.

It is important when using web materials that the students realize that the people writing the documents are mostly expressing their own ideas and opinions. The trick is to get them to listen to everybody and then come up with the ideas they find most convincing.

### Additional Reference Reading

Asimov, Isaac. *Worlds within Worlds*. Seattle: University Press of the Pacific, 1980.

Atkins, P. W. *Atoms, Electrons and Change*. New York: Scientific American Library, 1991.

Badash, Lawrence. *Kapitza, Rutherford, and the Kremlin*. New Haven: The University Press, 1984.

Calder, Nigel. *The Key to the Universe*. New York: The Viking Press, 1977.

Chester, Michael. *Particles*. New York: Macmillan Publishing Company, 1978.

Cobb, Cathy and Harold Goldwhite. *Creations of Fire*. Cambridge, Mass.: Perseus Publishing, 1995.

Gallant, Roy A. *The Ever-Changing Atom*. New York: Marshall Cavendish, 2000.

Gell-Mann, Murray. *The Quark and the Jaguar*. New York: W. H. Freeman, 1994.

Pachter, Henry. M. *Magic into Science*. New York: Henry Schuman, 1951.

Pais, Abraham. *Inward Bound*. Oxford: Oxford University Press, 1986.

Trenn, Thaddeus. *The Splitting Atom*. London: Taylor and Francis Ltd. 1977.

### Educational Theory and Practice

I am including some reading material to support the pedagogy this unit espouses.

Dr. Nonie Harcombe, a Rice professor who heads up the pH Model Lab at Lee High School in Houston, Texas, introduced me to these books during the course of a year spent studying with her. Her work has affected me profoundly, more than any other person or school. It was under her tutelage that I discovered the lack of real learning

my efforts as a teacher often produce. Reading the book *The Power of Their Ideas (Meier)* can explain it for those who still labor under the delusion that teaching and learning are a natural outcome of there being a sincere hard-working teacher in a room with relatively cooperative students.

Gary Zukov. *The Dancing Wu Li Masters*. New York: Perennial Classics, 2001.

Gary Zukov is not a scientist. This is a good thing. He is smart though and he hung around with a bunch of scientists, questioning and questioning them until they were forced to express their discipline in lay terms. He kept at it 'til he understood what they were about, then, he wrote it down for the rest of us.

Meier, Deborah. *In Schools We Trust: Creating communities of learning in an era of testing and standardization*. Boston: Beacon Press, 2002.

---. *The Power of Their Ideas: Lessons for America from a small school in Harlem*. Boston: Beacon Press, 1995.

For additional authors see the works of TheodoreSizer, Joshua Cohen, Joel Rogers, and of course Nonie Harcombe. For information on purchasing the book Dr. Harcombe has written on constructivist learning as applied in the Model Lab contact her at [nonie@rice.edu](mailto:nonie@rice.edu).

Finally, I include the book that more than any other set me free from the mechanistic universe that had me by the throat as a result of the way science was taught to me in high school. This book has been reprinted lately and there are many others books on the new physics, which physics is no longer really new, of course, but then neither am I as I find myself pushing 60.