Messin' Around: The Role of Play In Middle Level Science Education

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Abstract

The authors propose a novel conceptual framework for a middle school physical science curriculum: play. They describe how play allows the integration of the I Wonder model, the K-12 Framework for Science education, the cross cutting concepts and the nature of science. They draw upon their own teaching experiences and theoretical constructs in the literature to outline a practical physical science curriculum at the middle level: Physical Prestidigitations and Chemical Conjurings. The authors also pay tribute to their mentor Fred Wilkin, Jr.

Key Words: Play, Cross Cutting Concepts, Nature of Science, Middle School Physical Science Curriculum

Preface

Flights of Fancy and Happy Plants
A Personal Tribute to Fred Wilkin, Jr.

> *Flights of Fancy*
> The idea was not to just fling airplanes. It was to perform and execute elegant flights. The planes were quite fragile.
> It meant going around in stocking feet, and slow walking. No running amuck. No bounding about. No shrieking. Maybe a few rousing cheers. Until the thing lands, stand still. Retrieve it slowly. Make sure that the gym is open and free for the period Mr. Wilkin expects these things to be done right.

> This all called for flight rules taking turns, and watching from the sidelines. The watching is as important as the flinging. Do not forget that!
> Assembly and adjustments were important. The wings had to be attached in a very special way. The number of windings for the rubber band was limited. Tossing-launching procedures had to be learned. You learned to do it right, or you did not get to do it at all. That is the way it would be.
> It was time to play.
> Wilkin (1974) p. 132

Play and the urge to learn are intimately woven into the fabric of wonder every child brings to school. It is also the essence of the practice of science! However, as schooling progresses, play becomes a leisure activity or a time to let the body have some freedom from the confines of the classroom. By the time students reach middle school, play is one of the few times when students are free to engage in what is most important to them–unstructured and lightly monitored social interactions with their friends. Play becomes synonymous with a break from learning.

Science begins with wondering that leads to exploration that results in a question. Learning how to formulate a good question is more important than finding the answer. Questions arise in science by playing–messin' around! The play is by no means unstructured. This can clearly be seen in the passage from Fred Wilkin's dissertation, *The Urge to Learn* (1971). Play is not let letting oneself go but is a centering activity where establishing the rules of procedure, designing a method of evaluation and acquiring the knowledge of what has been done before set the stage for scientific discovery and thought. And then there is the aesthetics of the experience. Eloquence and other tangible intangibles are as essential to the learning in science as the nuts and bolts of the investigation.

The Flights of Fancy is one example of classroom learning that is a joint venture between teacher and student. This joint venture in learning requires articulation of the expectations of the teacher and the students. One needs, as Fred puts it, to "expect learners to take part in revealing what they do in response to what I do in order to teach them something." Learning is not passive and responsibility for learning resides with the learner. Teaching becomes an act of calling out the extraordinary from the ordinary. Learning is the realization that what was mundane and ignored is wondrous and worthy of study. This teaching and learning paradigm is similar to what is outlined in the Framework for K-12 Science Education. (NRC, 2011) This is how I (Vito) have been teaching for over 35 years and Fred had been doing since the late 1950s.

Happy Plants

> A kid says something about wanting to see about plants growing better when they are happy.
> Another kid wonders about plant psychology. Must have been reading something. Plants react to someone's personality. How do polygraphs work? What's inside a lie detector? What is the means of connecting gadgets to plants to register sensations? Teacher doesn't know. Sensational.
> In two weeks the project has gotten nowhere. But still a design comes about involving alternating plants from the librarian's closet to the northside window. It called for equal shift with consideration of light/times hours and humidity. Some can up with an electric timer. Very timely. A variety of seeds were planted. Unkempt begonias were revived to use.
> Why no? No textbooks had helped. The newest encyclopedia still had no entries about this subject. Appetites were whetted for activity.

> How to go on with it? Now there were judges who could pick out and say that certain plants look better. The plants might indeed be happier. The investigators developed broader smiles for their exposure and maintenance times. Grandmas heard about the study. There was reading to find out, and there was lots of talk. People were going to sneak in and tell a couple of jokes to the deprived plants and "kid with them." Notes accumulated. Two girls shared the major responsibility. The class got progress reports. Copies went to school secretary. Other students went along to help the happy plants be happy. Some wanted to play happy songs.
>
> Wilkin (1974) p. 83

And it is time to play again! This scientific endeavor may seem different than Flights of Fancy; however, when learner and teacher are roles that flow and shift among the members of the classroom, this is as much a teacher directed activity as a child centered learning experience. The question is who is the teacher. This role seems to be taken on by different people depending on need, during the investigation. Again, this is what play in science is all about. It nourishes the urge to learn. It requires students to pay attention to what is going on around them as well as what is going on inside their own heads. Watching and participating in the science circus is a metaphor for acquiring skills needed to learn in a middle school science classroom. Doing nothing is not a choice. Science is not being taught–the kind of things (the practices of) scientists do is! Again Fred's work is far ahead of its time. One of the guiding assumptions of the Framework is connecting to students' interests and experiences. Happy Plants is certainly that! It also engages the students in some of the essential practices outlined in the Framework: asking questions and defining problems, planning and carrying out investigations, constructing explanations and designing solutions, engaging in argument from evidence and obtaining, evaluating and communicating information.

> In a classroom that emphasizes expectations and which openly sanction evaluations between learners, and where contributions to everyone's learning are counted on from individual efforts, students appear to try hard to do things for other reasons than those a teacher might invent. Students develop their own reasons
>
> Wilkin (1974) p. 40

The constructivist perspective changes from building and organizing the knowledge gained to formulating the motivation for doing, further doings, for communicating to others, to having purposes and detail and method and laughs and . . . However, a constructivist approach to learning is limited due to the counter intuitive nature of the science. A more practical approach is to consider students as designers of knowledge. (Turner & Dipinto, 1997). A sense of audience is established in this kind of learning environment. Indeed, collaboration among learners of all ages in a classroom is an essential element in building this audience. Ideas, results of work, musings, clowning around, reading, wonderings and wanderings are all part and parcel of the process of learning science. Science is not only done in school; it is part of what one does naturally "in order to find out what one wanted to know and become is able to do so."

The emphasis on Fred Wilkin's dissertation in this preface is a humble attempt to provide the reader with the foundation upon which I (Vito) began my own journey in teaching and learning science with middle school kids. I have, without reservation, adopted as my own (stolen might be a more accurate description) many of Fred's POLOs (perceptions of learning outcomes), both academic and non-academic. I owe a great deal both professionally and personally to Fred Wilkin. Professionally, his work has validated the kind of science teaching and learning that is the essential part of my own science education outside of schools. Personally, he has encouraged me to integrate my cosmic jester personality into that of my science teacher persona. Fred has provided me with many words and deeds of wisdom, which can best be summarized by the opening lines of his Urge to Learn.

"You did that?"
"Yes."
"How come?"
"I wanted to."

Wilkin (1974) p. 1

Fred died in November 2011. He influenced so many of us as we began and continue our teaching journeys. Bronson Davis (source unknown) wrote:

> Fred is a professor of education and free-spirit-in-residence at National College. In the classroom, he is a bit of Mr. Chips and a bit of Fred MacMurray's absent-minded professor. And his students are seldom unaffected by his unusual teaching methods. In addition, he is a rare professional bird–a practicing educational ethologist.

Fred and I spent many hours playing with all sorts of things: paper airplanes, tea bags, BTB and assorted junk. I cherish every minute of our playing or as we liked to call it:messin' around adventures. Fred was able to read most of this chapter before he died. He said the Urge to Learn Part Two was now in session. I will miss him!

Introduction

What follows is our attempt to indicate how we have played to learn in our middle school science classrooms. The interactions between play and the "urge to learn" in science education emphasizes how readily the scientific endeavor engages students in learning for its own sake. It has been our experience that this carries over to academic and nonacademic areas with middle school students. School becomes a place where learning is second nature to the student and not the agenda that is provided by the teacher. And it is now time to PLAY!

Playin' Around

What is play? The attempt to define play is an act—both pragmatic and enigmatic—that remains elusive. Poets, philosophers, clowns, painters, learning theorists, psychologists, doctoral students, and scientists have struggled over and debated about how to define play in order to study it, to ascertain its value in human development, and to understand why it is *so* difficult to define. Perhaps an obstacle to defining play, when applied to its formal study, is that play is both cognitive and affective. It is an interaction between these two domains as well as being a unique entity. The world of children's poetry and literature is a rich source of images that reflect some of the definitions of play. A. A. Milne in The House at Pooh Corner has Pooh formulating a strategy to unbounceTigger (Milne, 1956).

If Rabbit Was bigger
And fatter
And stronger
Or bigger
Than Tigger,
If Tigger was smaller,

Then Tigger's bad habit
Of bouncing at Rabbit
Would matter
No longer,
If Rabbit Was taller, (p. 112)

Pooh's solution to the problem is reminiscent of White's (1959) ideas of play as mastery over the environment. His interpretation of play establishes it as a vehicle by which an organism achieves adequate skills to survive and excel. This rhyme certainly adheres to Rubin's notion (Whalen, 1990) that play develops self-confidence while alleviating anxiety. While playing, attention is directed to a means not an end. Moreover, unbouncingTigger reflects Sutton-Smith's (1967) idea of play as a test of powers involving all domains of behavior. It exemplifies Singer's (1973) notion of how play is an aspect of divergent thinking. For Singer, play helps create additional possibilities for appreciating what we possess or for more actively improving and exploring what can exist in us.

Another of Milne's poems, *Us Two,* is about imaginative play (Milne, 1955).

Where I am, there's always Pooh,
There's always Pooh and Me.
Whatever I do, he wants to do,
"Where are you going today?" says Pooh.
"Well, that's very odd 'cos I was too.
Let's go together," says Pooh, says he. "Let's go together," say Pooh . . .
"Let's look for dragons," I said to Pooh. "
Yes, let's," said Pooh to Me.
We crossed the river and found a few—
"Yes, those are dragons all right," said Pooh.
"As soon as I saw their beaks I knew. That's what
they are," said Pooh, said he.
"That's what they are," said Pooh . . .
So wherever I am, there's always Pooh,
There's always Pooh and Me.
"What would I do?" I said to Pooh,
"If it wasn't for you," and Pooh said:
"True, it isn 't much fun for One but Two Can
stick together," says Pooh, says he.
"That how it is," says Pooh. (p. 35)

Bateson's notion of play (Herron & Sutton-Smith, 1971) as facilitating the understanding of roles is inherent in this poem. The importance of relationships and trust are two of the characteristics of these kinds of roles. It is by playing that an individual learns that there are categories of behavior. In Bateson's analysis of play we learn something about the whole structure of *not* objects. It becomes more than learning the specifics of any category; rather it is learning the "conceptual structuring of the universe." Christopher Robin exemplifies Baldwin (Lightfoot, 1990) and Vygotsky's (1978) views about the experimental nature of play and how both hypothetical and potential meaning can be found in the experience. Vygotsky describes how by playing children confront the difference between objects and their symbolic representations. Baldwin talks in terms of a child pursuing an interest that isolates the content from its external setting. Winnicott's model of play (Lightfoot (1990) in which a child uses elements of the external world to achieve some inner and personal goal can easily be seen in this poem. Lee's (1916) definition of play as an active project of what a child is and will become is vividly portrayed in *Us Two.* Finally, Einstein comments:

> When I examine myself and my methods of thought, I come to the conclusion that the gift of fantasy meant more to me than my talent for absorbing positive knowledge, (source unknown)

In **Messin Around** two science curricula are described. *Physical Prestidigitations* is a 10-week study of physics and *Chemical Conjurings* is a ten week study of chemistry. Together they constitute the Inquiry Project of an eighth grade physical science curriculum. Each draws on experiences in sixth grade science (astronomy and space science) and seventh grade science (life science). The italicized portions are the actual assignments given to students. It is important to realize that even students who have not had any inquiry science readily embrace these playful explorations. Each of these explorations leads to a Big Idea in physics or chemistry. The activities are designedusing the I Wonder Model of Science Teaching and Learning (Dipinto, 2013).

I Wonder
I Question
I Explore
I Investigate
I Analyze
I Share
I Act
I Inspire
I Wonder . . .

In addition the applicable Cross Cutting Concepts from A Framework for K-12 Science Education (Pratt, 2012) are indicated.

Messin' Around: The Role of Play in Science Education

Physical Prestidigitations

Last year we studied in detail human and specific mammal locomotion. But what are the physical laws governing motion? It is time to bring out my toys. Here are couple dozen windup toys. See what you can discover about motion playing with these toys. Identity some variables you can't control. What can you measure? How can you measure them? (Cause and Effect: Mechanism and Explanation)

Chemical Conjurings

Over here is the place for exploring chromatography. There are several different kinds of paper and a multitude of water-soluble markers. What can you discover about the nature of the color pigments in these markers? Give an operational definition of chromatography. Devise a procedure for someone to replicate your significant findings. Go mess around. (Patterns)

"It's time to play!" These closing words of *Flights of Fancy* may have disturbed your preconceived notions of what play is. Play is one of the characteristics that we share with all members of the class Mammalia. Play is an early learning experience that develops the synaptic networks in the brain so that each species of mammal can survive. For humans (and probably Cetaceans) play is critical in forming the biochemical processes that lead to both creativity and the acquisition of survival skills including cultural ones. Play is serious business. Because it has such an impact on the brain (less as we get older, but still significant), play is rule-bound and structured; this is because chemical reactions are not random or chaotic but proceed according to well-defined rules of structural compatibility and energy requirements. Unfettered playing is physically dangerous and maybe even psychologically harmful. Hawkins (1965) observes that when the mind is engaged in evolving abstraction that will lead to comprehension "all of us must cross the line between ignorance and insight many times before we truly understand." (p. 6) The structured nature of play makes it an ideal methodology for teaching and learning science by providing individual and collective maps to cross and recross the lines of ignorance and insight.

Cromer (1993) relates how object play develops mental structures for learning science. He contrasts the world of stuffed toys and soft fabrics with that of mechanical toys like model trains. In the soft and fluffy toy world no toys fit together and there is little that has straight lines. The world of toy trains, by the very nature of the toy, encourages a child to go beyond random imaginative play to become interested in connecting the tracks appropriately so that the cars roll from one place to another. Just like the stuffed toys, the toy train imposes its own reality on the play. Playing with toy trains, with its internally bounded reality, helps develop mental structures associated with line and connection. This enables the child to see the geometric similarities between real trains and toy trains. This insight lays the foundation for formal development of the concept of scale and proportionality, crucial ideas in learning science. Cromer emphatically states that students who have reached middle school without the relevant concrete experiences are unprepared for subjects like similarity of triangles or rates of time and distance that involve proportionality.

The windup toy example provides an experience that places taken-for- granted toys in a different context. The paper chromatography example places the use of familiar artistic and doodling tools into the role of valid objects for serious scientific investigation. These context changes are known as different frames of reference-another of those essential concepts in science. With every change in frame of reference new information is revealed. Torrance (1969) comments that changing the frame of reference by making the unfamiliar familiar or the familiar unfamiliar assists in increasing creativity. He provides an example of a chemist who imagined himself as a drop of paint struggling to hold onto a wall that was previously painted. This experience enabled him to define better the qualities of stickiness to previously painted surfaces. In Vito’s own work in his early teens as a chemist, he used a similar visualization technique to help develop one of the first binders in the manufacturing of latex based outdoor paints. He imagined himself as some alien shaking hands with a sentient water molecule and an equally sentient alkaloid white pigment that was incompatible with the water being. Imagining what each hand would need to look like to accomplish this task was the key to figuring out the structure of the chemical binder needed.

Physical Prestidigitations

Capselas are one of my favorite construction/motion toys. Here is a kit with some instructions on designing and making objects that go via battery power. Build some that are in the book. Then try your own designs. What tests can you devise to determine if your designs are better, worse, and/or more aesthetically pleasing than the ones in the kit? (Structure and Function)

Chemical Conjurings

All right. For those of you who think our senses are reliable, here is a playground for you. This playground consists of five white powders. You may touch and look but you must never <u>ever</u> taste these samples. Can you ascertain the physical and chemical properties of these kitchen chemicals? How can you use your tests to identify an unknown I will give you? By the way, science is the last period of the day today. Exit to home requires you to submit the identity of the unknown supported with the evidence from your tests. (Stability and Change)

Capsela construction and mystery powders are ways to engage the learner in convergent and divergent problem solving. Hughes (1991) summarizes some work done with large sample populations of preschoolers. (We found this true in our own practice teaching science to middle school students.) The control group was shown how to solve the problem. Their task was to duplicate it on their own. Or the teacher guided the students to the correct solution without allowing for too much error. In the experimental group the children were just given the rules of playing. In convergent problem activities, the experimental group demonstrated the ability to bring isolated pieces of information together to come up with the one correct solution. These students were not only successful problems solvers but were highly motivated to solve problems and worked more persistently than the control group. In the divergent problem solving activities, the experimental group was able to branch out from the starting point and consider a variety of possible solutions. This group was more flexible, particularly when playing with concrete objects (we call them toys) and their solutions were more original than those of the control group. These are the mental skills middle school students need to have in place to effectively explore the Capselas, especially when designing tests to establish criteria for value statements such as better, worse or more aesthetically pleasing. Mystery powders require students to use divergent problem solving methodology to devise tests to solve a convergent problem, i.e., the identity of an unknown.

Physical Prestidigitation

Twirling tops that may never stop can nourish the imagination. They can also make you nauseous if you are the top. Spin these objects to discover the motion you love in amusement parks–going round and round round and round. . . By the way, not all of these toys are obvious tops. Discover some notions of "topness."

(Energy and Matter: Flows, Cycles, and Conservation)

Chemical Conjurings

Here is some bubble solution. It consists of one part Dawn detergent and three parts water. It is fantastic elastic. You may use any item in the classroom that can get wet and then be cleaned. Explore "bubbleness."

(Systems and System Models)

Twirling tops and fantastic elastics are examples of playing with toys that can be used at any grade level. Vito initially conceived of the top tests as a set of structured experiences for a group of five years olds in his Montessori early childhood classroom. Twirling tops became a concrete representation of decentering their egotist notion of the world. These children could spin and twirl using the special magic that is within them. However, twirling tops requires learning the rules (or skill) of spinning objects. At the middle school level, asking kids to develop notions of "topness" is asking them to participate in the process of how innovation in science occurs. Arieti (1976) comments that many scientific discoveries are the result of "individualizing" a common characteristic or connection between some things that were deemed dissimilar or unrelated. However, an observation of similarity is not enough. Arieti uses Newton's experience with the falling apple to illustrate his point. When Newton saw a similarity between a falling apple and the orbiting moon, he created a new class of concepts in which there could be an indefinite number of members. It is the discovery of this class that reveals new ways of looking at the universe. Arieti's conceptualization of class is very similar to the conceptualization of frame of reference. When a new frame of reference or formation of a new class occurs, its importance transcends the immediate discovery. It leads to the discovery of additional properties hidden in the members of the new class. Eighth grade students may discover the properties hidden in the new members of the class "bubbleness."

Physical Prestidigitations

You know all those balls that I have confiscated from you over the past six years when you bounced them in the halls? Now you get to use them again. Bounce these balls, even in the hall. Roll those balls. Try a variety of surface textures and inclinations. Throw those balls. Drop 'em! Collide them! You are now playing in the fields of classical mechanics! (Cause and Effect: Mechanism and Explanation)

Chemical Conjurings
It's a gas! Bubble, Bubbles everywhere and there ain'tno soap involved. Explore the mysteries of chemical reactions that produce gases. However, these are invisible gases. How can you collect them? What kind of tests can you use to devise to make the invisible knowable? Hint: BTB could be your best friend conjuring with these chemicals. (Scale, Proportion and Quantity)

Bouncing Balls and *It's A Gas* provide concrete experiences which initiate students into the process of scientific ways of knowing and the *Chemical Conjuring* allow students and teacher to focus on the epistemological question (how) and the causal question (why). How to investigate these questions lies at the heart of scientific inquiry. How the resulting knowledge claims are verified provides experience in science's view of its own objectivity. Finally, how to adjudicate among the possible theoretical explanations that include looking at sources of error, numerous replication of findings by others, and the application to problems that either had no known solution or the solution was messy and ineloquent, flow easily from the constructed meaning-making experiences the students have with the rolling, bouncing, and colliding balls. Fantasy play is important in developing skills needed to stimulate this discourse. Fantasy play encourages intellectual flexibility through decentration (Hughes, 1991). Decentration involves the ability to simultaneously attempt to transform the attributes of objects and situations in one's environment and maintain an understanding of the original identities and states of these objects and situations. Hughes summarizes this decentration as imagining, at the same time, things as they are and things as they were, and we would add, things as they are speculated to be. Gardner (1991) discusses the empowerment which pretense or fantasy play gives to children. It allows them to move beyond the ability to think only about the world of experience. They are now able to envision a state of affairs contrary to the one that is sensed in every day experience. In other words, Gardner validates this kind of play as a way to learn the counter-intuitiveness of science. Montagu (1981) observes that in playing with ideas the imagination "realizes what realism obscures or bungles." (p. 155) Let kids fantasize while engaging in science learning with concrete objects. It is good for them! How else will they make the leap from colliding tennis balls to colliding atoms of gas? Or how will students ponder the significance of making the invisible visible?

Physical Prestidigitations
Your homework is to prepare an artifact using any medium you choose that is a metaphor for the science you learned from any of the various activities you learned the past weeks playing. (Patterns)

Chemical Conjurings
For all of you, your homework is to formulate questions that arise from your Messin' around. In addition, find some background information about these substances or techniques you have been playing with in these sessions. Present this information as a set of scientific icons. (Patterns)

The materials and activities described in *Chemical Conjuringsand* Physical *Prestidigitations* help to develop the imagination. When students are asked to transform idea into graphical (and we don't mean on a Cartesian plane) information, they are designing materials to enrich their personal imagery and those of their classmates and teachers. You must allow time for thinking and daydreaming. Torrance (1969) observes that many parents and teachers try to keep children so busy that they do not have time tothink. These adults become disturbed if children are not visibly busy. "It is almost illegal to be busy thinking." (p. 40). Homework assignments in science, like the two above, are designed to keep kids busy thinking.

The Pendulum sans Pit

Today you will engage your mind and your imagination with James Burke's Knowledge Web and in particular the Connections episode "The Wheel of Fortune". Focus on the pendulums, their antecedents and their progeny. Tomorrow you will play with a string/washer pendulum.

It's tomorrow. Here are string, washers, protractors, meter sticks, stop watches and the standard box of junk, or should I say scientific resource construction box! A swing of a pendulum is defined as when it returns to the side from which it was released. The pendulum's period is the number of swings per unit time. Play with your string pendulums. You cannot work alone. This adventure requires collaboration from the beginning. Tomorrow and tomorrow and, well, at this point you can explore any kind of pendulum you can imagine swinging in any place in the building (safety is always the first concern). Air is one fluid medium that you pendulum swings. What other fluid medium can you try? Design an exploration to do this!

The pendulum investigations capture all of the notions of play and the nature of science that can be discovered, transmitted and imagined. This is play *par excellance!* Most scientists view their work as nothing more than a continuation of their play as children (Montagu, 1981). Discoveries are made in play. Laurel (1991) comments that when there is a surprise–unexpected new information–discovery becomes more interesting. It raises more questions than answers. This is another example of the essence of scientific inquiry. Laurel continues to describe an event rarer and more powerful kind of surprise: an Aristotelian reversal. This is a surprise that reveals the opposite of what we expect to be true. These reversals help a learner to recognize the uncommon nature of science.

diSessa (Forman &Pufall, 1988) describes two kinds of microworlds to help children learn science. One is a mega-microworld. *Chemical Conjurings*and *Physical Prestidigitations* are of this type. A single perspective is almost never enough to build a well integrated and widely applicable understanding of the sort that would be called scientific. The most carefully crafted experience or investigation just won't do it by itself. A teacher needs to build clusters of these experiences so that the student becomes involved in many ways over an extended period of time. The other microworld is called a textured-microworld and this is where *Pendulum sans Pit* finds an identity. In a textured microworld the teacher has precise expectations about what the students will learn in a variety of contexts. These are the structures that, when well designed, allow the teacher to let students go off and play in it for a while.

Play is a scientific method. Wolpert(1993) summarizes the advice given by a host of famous scientists.

> try many things; do what makes your heart leap; think big; dare to explore where there is no light; challenge expectations; *cherchez le paradox;* be sloppy so that something unexpected happen, but not so sloppy that you can't tell what happened; turn it on its head; never solve a problem until you can guess the answer; precision encourages the imagination; seek simplicity; seek beauty . . . One could do no better than to try them all. (p. 108)

Sure sounds like play to us. Hawkins (1965) advises you to "turn on your heel with your head back until you see the ceiling turn the other way and don't fall over." (p. 5) Play as a learning tool in science is constrained by the real world just as the discipline of science is. Some people react to this grounding in reality as the antithesis of imagination, creativity, and speculation. In science you have to imagine the possible in order to discover the actual. If you can't imagine it, one of the mysteries of the cosmos could be in the palm of your hands but you can't "see" it. "I wonder . . ." is the beginning of a scientific investigation of everything! If there were a "The Scientific Method" we would say it is the Imagination–the laboratory of the mind. For the doubters among you, we suggest that you immerse yourselves in the theory and techniques of organic chemistry. Fill your pallets with colors and hues that are the denizens of the quantum world. And sculpt, ever so gently, a molecule that nature has not! The universe is a magical place. How wonderful that science gives us a little understanding of the magic so that we can practice it.

> The earth is out caste, animated with millions of singing birds and dancing butterflies, more marvelous than any Disney candlestick or teapot; its storms and tempests fill us with awe and its uniqueness and fragility fill us with reverence; reality has far more wonders than all the tales of Arabia giving us in return for our loss of omnipotence some knowledge of the external world, some control over and responsibility for our lives, and even a touch of humility. Gardner (1991) p. 207

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