Abstract

The purpose of this paper is to explore the possibility of using the principle of *superposition of states* (commonly illustrated by Schrödinger's Cat experiment) to understand the process of using standardized testing to measure a student's learning. Comparisons from literature, neuroscience, and Schema Theory will be used to expound upon the principle of superposition at the micro and macro scale. In addition, a challenge to "open the lid" on a new way of thinking about the issues of high stakes testing and accountability is presented.

Chaos and Complexities Theories

Superposition and Standardized Testing: Are We Coming or Going?

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Lifting the Lid on Standardized Testing

Introduction

I became intrigued with the quantum principle of superposition after reading an article in a discarded magazine on an airplane seat. Although I remembered the principle from earlier study, several metaphorical applications of this principle occurred to me during this on-flight reading. I empathize with the scientists who cringe when scientific thought is snatched from its contextual purity, applied metaphorically (and often incorrectly) and utilized in situations that seem inconsistent with its original meaning and purpose. But I do not apologize for making meaning of the world with the tools and information I have available to me. I am not the first and I likely will not be the last to raid the closets of science in search of meaning applicable to an individual life.

Theoretical Framework

Quantum physics presents many unsettling and seemingly absurd notions. Even Einstein had difficulty accepting how radically different matter behaved at the subatomic level as compared to Newton's classical laws of physics used to describe the everyday world. "'*God does not play dice!*' exclaimed Einstein"(Lindley, 2004, p. 18) in reaction to the seemingly random (even absurd) qualities of quantum theories. However absurd they may sound, quantum theories are finding their way into the explanations of how all matter behaves, regardless of scale.

In this paper, I will explore the applicability of the quantum principle of *superposition* as a way to envision the process of measuring *learning.* According to Niels Bohr, *nothing is real until it is observed*. However, at the same time, he noted that the act

of measurement limits an object to a single possibility. Both of these observations are incorporated in the principle of *superposition.* In simple terms, the principle of superposition states "quantum mechanics requires that a system exist in a range of possible states…until a measurement is made, at which point one of those states takes on a definite reality" (Lindley, 1997, p.18). Objects exist in multiple states simultaneously. When an observer attempts to measure the object, however, its multiple states collapse, limiting it to a single possibility. "This state…is something quantum objects enter quite readily. Electrons can occupy several energy levels, or orbitals, simultaneously; a single photon, after passing through a beam splitter, appears to traverse two paths at the same time"(Yam, 1997, p.37). Though Bohr was describing the behavior of subatomic particles, he believed that superposition existed at much larger scales than the atomic. However, measurement made with classical (Newtonian) devices prevented the boundary between quantum and classical laws to interact seamlessly. Classical tools were insufficient for meeting the needs of quantum theory at a greater scale.

Because of measurement difficulties, it was difficult to convince skeptical classical physicists that superposition was feasible. The best-known challenge of this principle at a macroscopic level came in 1935, when Erwin Schrödinger created a hypothetical scenario. Though physicists are loathe to apply theory from the micro *quantum* world to the macro *everyday* world, Schrödinger nonetheless illustrated the absurdity of such a strange notion by developing an experiment in the macro world commonly referred to as *Schrödinger's Cat*. Theoretically, a cat is placed into a lead box with a vial of poison. The box is sealed. Once sealed, the contents of the box cannot be observed. It is impossible to know for certain whether the cat is dead or alive. Since the

state of the cat is unknown to the observer, it must be assumed to exist in both states simultaneously - alive and dead - in a state of superposition. But that defies reason. A cat cannot be both dead and alive at the same time. It is only when the box is opened that the cat's state can be discerned by the observer. Yet, in the act of measurement (opening the box), all possibilities collapse. Only one condition remains, the cat is either dead or alive. Thus, the superposition is destroyed. This is the paradox, and the absurdity, that Schrödinger hoped others would acknowledge (Gribbin, 1984).

An Alternate Version of Schrödinger's Cat

Nothing is real until it is observed. Ursula LeGuin (1998), in a short story entitled *Schrödinger's Cat,* grapples with our need to determine meaning through observation. One of the story's characters replicates *Schrödinger's* famous experiment. After the cat is sealed in the box, in the state of superposition, he explains to his companion:

> "We cannot predict the behavior of the [cat], and thus, once it has behaved, we cannot predict the state of the system it has determined. We cannot predict it! God plays dice with the world! So it is beautifully demonstrated that if you desire certainty, any certainty, you must create it yourself!
>
> "How?"
>
> "By lifting the lid of the box, of course…" (p. 523)

Nothing is real until it is observed. Can our own learning be real if not observed? Can we ourselves be real? During the course of the story, LeGuin confounds the two observers:

> I went to the box, and with a rather dramatic gesture, flung the lid back. Rover staggered up from his knees, gasping, to look. The cat, of course, was not there.
>
> Rover neither barked, nor fainted nor cursed, nor wept. He really took it very well.
>
> "Where is the cat?" he asked at last.
>
> "Where is the box?"
>
> "Here."
>
> "Where's here?"
>
> "Here is now."
>
> "We used to think so," I said, "but really we could use bigger boxes."
>
> He gazed about him in mute bewilderment, and did not flinch even when the roof of the house was lifted off just like the lid of the box, letting in the unconscionable, inordinate light of the stars. He had just time to breathe, "Oh, wow!" (p. 524)

Here LeGuin adds another wrinkle to the story. When the lid is lifted the cat is not dead and the cat is not alive. Rather, she introduces the possibility that the cat no longer exists at all, a third state of existence. *Nothing is real until it is observed*. Finally, author LeGuin presents a third character, that of an anonymous observer, who opens the roof from the box in which the other two characters have existed in their own states of superposition. LeGuin closes with one of the characters musing, "I shall miss the cat. I wonder if he found what it was we lost" (p. 524).

My Visions of Superposition

LeGuin's story inspired me to consider the impact the principle of superposition might have *on* my life and *in* my life. I began with the idea of my life itself. It is not a stretch to understand that within myself, within my very cellular structure, I am in a continuous state of superposition. I was reminded of an image from a short story by Sandra Cisneros (1992) wherein she described herself as a nesting doll. Like her, I simultaneously *contain* my inner 5-year-old self, as well as my rebellious teenager, and even my mature grandmotherly self to name just a few. *I* am these *selves* always. Which of these selves the observer sees, depends upon which *self* the observer summons. Does the act of observing/measuring itself limit the complexity of the selves I experience? Does the act of observing/measuring give a false sense of the whole?

Reading the article on superposition from the vantage point of a seat on an airplane, I considered my personal position in space. I found myself in an interesting situation. Although, to observers seated around me on the plane I appeared to be sitting quite still in my seat, my body was in fact hurtling through space. Observers seated along the runway as the plane landed could attest to seeing me through a window and could verify the speed at which I was moving. If they checked their watches they might find that I was moving rapidly at precisely the same moment that observers within the plane testified to seeing me sit perfectly still!

Obviously, this paradox became more complex when I considered the implications of my standing up and walking to the back of the plane while the plane was moving forward. I would then be observed going backwards by some, while going forward by others. If you added observers from outside the earth's orbit, I could be

observed orbiting the sun going one direction, while taxing on the tarmac going in another direction, while walking in the plane going yet another direction. In effect, when asked if I was coming or going, I would have to answer "yes". In this state of superposition, how would one measure something as simple as my movement? Does the act of observing/measuring itself limit the complexity of the movements I experience? Does the act of observing/measuring give a false sense of the whole?

I am in the states of both living and dying simultaneously. Is the glass – is my life - half full or half empty? Determination is a matter of how the observer chooses to measure it. In the case of my body, there is ample evidence that I am dying. At the age of 53, there is little in my physical self that could be considered anything but deteriorating. I may be able to hide some visible ravages of aging. I may be in good health for "someone my age". But the harsh fact of the matter is, as an organism, each day brings me closer to my inevitable death. Yet, there is also ample evidence that I am living. I breathe, my heart pumps, my muscles move - I think, therefore I am still alive. I consist of living cells, dying cells and dead cells simultaneously and this arrangement is a process in constant flux. Does the act of observing/measuring itself limit the complexity of the life/death I experience? Does the act of observing/measuring give a false sense of the whole?

I recognize a state of superposition in my memory, especially as I have grown older. Sometimes I remember information and sometimes I do not remember information. But even when I do not remember information, I do remember knowing that I know the information. I know the information is there – somewhere, but momentarily irretrievable. Still, it exists. Perhaps information is stored in a range of possible states and, as our

information networks become more complex, these paths get crossed or congested or traffic is halted or rerouted. Whatever the rate, however, the information eventually arrives. Does the act of observing/measuring itself limit the complexity of the memories I experience? Does the act of observing/measuring give a false sense of the whole?

As an educator, it was inevitable that the more I considered the complexities of superposition, the more I considered its implications for learning theory. And the more I thought about learning, the more I was drawn into the current American educational obsession: standardized testing.

Purpose

What occurs when an individual is asked to complete a standardized test, or any test for that matter? Does the act of *observing/measuring* limit (or otherwise influence) the possibilities of what is learned or not learned? Can something as complex as *learning* be assessed? Can *learning* be assessed fairly among diverse populations? Do our *observations/measures* prove advantageous to some and not others? What are we really *observing/measuring?* Is it fair to assess schools using these observations/measurements?

Unfortunately, within the parameters of one paper, it is not possible to present a complete exploration of all these questions. The purpose of this paper is not to answer the questions previously posed, but rather to *grapple* with questions about testing as envisioned through the lens of the superposition metaphor. This perspective may help pose questions differently, more usefully.

Lifting the Lid on Standardized Testing

How is an individual student in a testing situation analogous to Schrödinger's paradoxical cat-in-the-box? Prior to observation/measurement (i.e. taking a test), it is

unclear to the observer if the child *has learned or has not learned.* (It may be unclear to the child as well.) A child may *have learned* much about a topic, but to proponents of testing n*othing is real until it is observed*. The process of standards based testing is an attempt to take the lid off the box (so to speak) and see whether or not learning exists within the child. It presupposes that learning is inert, static, and quantifiable. I suggest that *learning* is a dynamic process that is always in a state of superposition. That is, at any given moment a person has both *learned* and *not learned* many things about a given topic. *Both* conditions exist simultaneously, locked away within the learner, unseen by any observer and often not completely recognized by the individual learner in question.

Superposition and Neuroscience

Taking the lid off during a learning situation may be an actual possibility in the near future. Through medical science, with advances in imaging procedures, it is already possible to observe the human brain react during learning sessions. However, it is not always clear exactly what is being observed. Today, it is possible to see particular areas of the brain *light up* when specific tasks are being completed, but the implications of these reactions are not altogether clear. One day soon, implications for assessment may be more conclusive (Casey, 2002).

We can actually see the physical effects of learning occur in the brain when dyes are released to highlight neural networks during learning sessions. *Learning* is a dynamic, organic process that takes place in a constantly changing brain filled with millions of interconnected tree root-like fractals. Billions of neurons (brain nerve cells) spew out fibrous dendrites filled with electrical impulses. When two of these fibrous finger touch (synapse), an electrochemical action moves an electric charge from the spine of one nerve

cell to the spine of another and learning occurs. Dendrites grow and new connections are made continuously. Each brain produces trillions of synaptic connections. The brain is dynamic, organic, and ever-changing. New connections are constantly occurring and old connections are being rerouted (Casey, 2002).

Nothing is real until it is observed so say the politicians who would have no children left untested. Their argument is that unless all are tested in some standardized fashion, there is no reason to believe their learning is real. Superposition suggests that an organism exists in more that one state at any given time. Neuroscience suggests that learning exists in more than one state at any given time. It is conceivable that an individual has a tremendous neural network of learning about some particular topic but is just one tiny synaptic connection away from answering a test question correctly. By the same token, something about the test question itself might be the impetus to create the synapse that connects two neurons and in effect develops new learning and a correct answer to the test question. Conversely, a connection that was made during the previous week might presently have become entangled and disconnected due to new learning in another area. Eventually, it will once again find its way back but perhaps through a new, rerouted connection. A test taken at any time during this procedure would miss the complexity of such a subtle, extended learning process. Learning, in effect, exists complexly in multiple states simultaneously. When an observer attempts to measure the learning, however, its multiple states collapse, limiting it to a single simplistic possibility. It is simply recorded as either *learned* or *not learned*. Complex learning processes are not recorded or even acknowledged.

Superposition and Piaget

Without the advantages of technological advances, Piaget envisioned a similarly complex brain when he described the construction of schema in the learning process. Schemata are representations of things we have learned; constructs or building blocks for future learning. A schema is the element or characteristic that, together with other schemata, defines the concepts we *learn*. We have schemata that allow us to differentiate between different plants and animals, as well as schemata that help us identify places and behaviors (Smilkstein, 1991).

In my classes, I have students read the following selection and then attempt to answer comprehension questions based on the material read.

> The procedure is quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one can never tell. After the procedure is completed one arranges the materials into different groups again. They can be put into their appropriate places. Eventually they will be used once more, and the whole cycle will then have to be repeated. However, this is part of life. (Vacca, et al., 2003, p. 16)

They find this task very daunting until I give them the word, *laundry*. With that key, we can then discuss how schemata help us to understand what we read. In this selection, initially it is usually unclear to students what the subject of this writing is. Without knowing the topic, the material is difficult to understand. Once the topic is known, the passage instantly becomes comprehensible. Its complexity is reduced. The schema, *laundry*, helped connect this material to a body of information already learned, aiding comprehension.

Schemata lay the foundation for future learning to build upon. These are analogous to the neural networks that hold together our new synaptic connections. Schemata, too, are dynamic, organic, and ever-changing.

Nothing is real until it is observed. Again, superposition suggests that an organism exists in more that one state at any given time. Piaget's schema theory suggests that learning exists in more than one state at any given time. Schemata related to a particular topic may be highly developed but if a key piece of information is missing, it can easily cause the learner to appear to be unknowing. Likewise, when the single key piece of information is presented, much more complex learning falls into place immediately. In effect, the student is in a position of learning and not learning simultaneously. It is presence of the measurement that collapses any possibility that the child might learn.

A recent newspaper article illustrates this concept. A reporter for *The Dallas Morning News* set out to investigate credibility of the Texas state TAKS writing test. He was invited to the headquarters of a major testing company and was given the opportunity of "taking the test" that was to be administered to state 10th graders. The essay test he

completed was machine graded and netted him a score of a below average 10th grader. It seems the problem was that he wrote a "bright, engaging essay that didn't follow the dry structure" (Benton, 2005, p. B8) rewarded by the testing criteria. Considering that this individual makes his living as a professional writer, it is interesting that he failed to meet the minimum standards for his profession. Is it conceivable that he is not alone?

What Is Lost When We Lift The Lid?

In our compulsion to know every morsel of information about the cat, about an organism, or about another human being, do we inadvertently alter reality? Do we describe a reality that doesn't exist at all? I suggest that the *portrait* of learning we get from any test is misleading. It gives us snapshot of *something*, a stagnant reality, but it does not give us a panorama of possible, simultaneous realities. Just as a single frame from a video clip of a dancer performing gives us *something;* it definitely does not present the whole dance. To suggest that the single image *is* the dance is to alter reality entirely. It is a mockery.

Suppose you are asked to assess a child's learning. You are given several options for assessing the child. The first option is to observe a child for one day. You will follow the child through the day at home, at school, at play, and again at home. Your second option is to view a film of the child. On this film you will see scenes at home, at school, at play, and then at home again. Your third option is to view one frame of film of the child at home, one frame of film of the child at school, one frame of film of the child at play and then one frame of film of the child at home again. Which of these options would enable the most accurate assessment of the child's learning? Which of these options

would produce the least accurate assessment of the child's learning? Which of these options is most like a test?

Testing situations in effect lift the lid on an individual's learning. It stops the process. It collapses all possibilities to a single moment in time. To suggest that a response issued in an instant reflects the *learning* amassed by the individual is simplistic at best.

Why must we open the box? According to Niels Bohr, *nothing is real until it is observed*. But how much of the observation is dependent on the observer's act of observing? In the case of superposition, the observation may actually create a *false* sense of reality. Even at the quantum level, objects exist in multiple states simultaneously. It is *only when they are measured* that they collapse a single possibility. *"Only when they are measured"* is not a natural state. It is an unnatural state triggered by the observer. Perhaps a truer statement would be *nothing is real while it is being observed*.

What is lost during the process of observation? In terms of the testing and learning, I think a great deal is lost. The first casualty is reality itself. Americans have embraced a distorted sense of what children know and can do. They see American children as failures. They perceive American schools to be failures. If children are not passing the tests, they are not learning. This is ridiculous. American children learn more today than children have learned in the history of the world! But reality itself has been distorted by our processes of observation.

Time, money, and resources that are badly needed by schools have been diverted by the process of observation. Instructional time is taken to prepare for tests and to administer tests. Billions of dollars in needed funding is redirected into the coffers of

testing companies for materials and grading. Resources are purchased to improve testing performance rather than instruction and, no, they are not the same thing.

Most seriously, the process of observation has too often destroyed the self-worth of our children and their teachers while limiting the vision and mission of our schools. How often has the process of observation led people to simple and quietly given up?

If we must open the box, why must we insist on testing as the lever? Can a test in fact open the box of learning? Computer science may provide some insight. In the development of artificial intelligence, computer science has attempted to duplicate human learning. Artificial Neural Networks (ANNs) are being developed that can predict difficulty levels of questions used on standardized tests, such as those used in reading comprehension assessments. ANNs are composed of non-linear processing elements that attempt to emulate learning and generalization much like the brain. Interestingly, many of these programs employ the principle of superposition to layer interconnected networks as information is processed. This enables test developers to determine how the difficulty level of some questions is affected by particular variables (Perkins, 1994). This is a first step. It is an acknowledgement of the complexities involved in assessing different levels of learning.

Can we not observe learning in a hundred other ways? Maybe this is where we should start. Why testing? Why are Americans enamored with testing? Why have we allowed test makers to sell us this bill of goods?

Conclusion

If politicians required the performance of a football team to be determined by measurements acquired from a snapshot/photograph taken during a time interval

arbitrarily selected by state department employees, the sport-loving public would charge they had lost their marbles. Is that scenario any more absurd than what politicians are asking of our public schools with No Child Left Behind testing? In comparison to the complexities of the learning process, I suggest there is no difference at all.

Einstein had two disagreements with quantum theory and both have to do with measurement. First, he thought that quantum theory relied on *statistical* predictions rather than *precise* prediction for the outcomes of individual processes. Secondly, he could see no way to objectively measure the quantum world without observer interference. In other words, that quantum world could not be seen "as it is in itself" (Smolin, 2004, p.38). Is learning any different? Can we *precisely* measure learning with any known tool? Can we measure any part of learning *as it is in itself* without observer *interference?*

Recommendations for Further Study

I suggest that until such questions about measurement and observation are adequately addressed, we should resolve to rescind the current wave of standards-based assessment. As applied to our airplane analogy, these measures are not yet capable of telling us if we are coming or going.

Because standardized testing is the focal point of educational reform, it is imperative that we know what we are doing! What do these assessments actually reveal? How does the act of measurement itself influence results? And perhaps most importantly, what is the actual relationship between assessment and learning? Although I've provided no definitive answers to these important questions, I hope that *opening the lid* will lead to more productive conversations about the relationship of learning, testing, and evaluation.

Additional study should also be done to uncover the interesting superposition of the financial interests of those who created the No Child Left Behind movement in Texas that later became a national movement in the United States. One individual in particular, Sandy Kress, is worth noting as he appears to represent the standards movement and those who tend to profit by its failure *multiple states simultaneously.* As evidenced in a recent *Dallas Morning News* story, Mr. Kress has simultaneously served as advisor to President Bush in pushing the No Child Left Behind laws through Congress while serving in roles as consultant/lobbyist/advisor to high stakes testing companies, home-school curriula companies, and companies developing alternative campuses and charter schools (Parks, 2005). Perhaps this movement has little to do with reform after all.

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