QUANTUM EDUCATION THEORY (Just an idea)

1. A very simplistic introduction…

As humans over time we have discovered that our everyday environment involves the interaction between Energy and Mass (we have developed different names for Energy such as waves and fields and for Mass different names such as matter and structure). We have used these two fundamental properties of our very existence to a greater and greater advantage as we have 'developed' our knowledge and understanding of how they 'interact' over the centuries whilst at the same time philosophising about their very meaning and existence.

Classical scientists even managed to find ways to explain and predict these two fundamental properties of our Universe. Newton managed to create equations that described the interaction of mass, from the motion of planets down to the motion of simple everyday objects such as rocks and stones. Maxwell then managed to create equations that described the interaction of energy or 'waves' such as light and electricity.

But there was a problem. As we humans became more and more 'advanced' and 'knowledgeable' it became clear around the turn of the 20th Century that this was a very simple outlook on how Energy and Matter interacted and it wasn't keeping up with a number of new things scientists were beginning to observe and measure, things that didn't make sense according to our current 'classical' understanding of how Energy and Matter 'interacted'.

It became clear that what we humble humans were observing in the interaction between Energy and Mass and therefore how we interpreted how our World worked was not by any means the complete picture, that in fact there was a lot more to it than we thought, things were clearly going on between Energy and Mass that were hidden from our everyday ability to view them but that had a fundamental bearing on the outcome of how our visible world appeared to us.

The first clue to understanding what was going on was Einstein's deduction that Matter (M) and Energy (E) were in fact one and the same thing and that they were related to each other by the equation $E = Mc^2$ where c^2 was equal to the speed of light squared. But the biggest problem with this was that as humble Humans we couldn't observe or see this relationship using our own personal measuring devices such as our eyes, ears or nose. So we had to leave it to 'boffins' or scientists to do that for us using the complicated language of Maths, Physics and engineering to see if Einstein's postulate was indeed correct. They proved it was correct to devastating effect in 1945 by dropping a Nuclear bomb over Hiroshima and then Nagasaki. So we now have the ability to destroy our planet in less than a day by making practical use of this previously hidden relationship between Energy and Mass.

Getting to this point took a great deal of imagination, creativity and leaps of faith on the part of very intelligent, resourceful and lateral thinking scientists and engineers. Not to mention huge political risk and billions and billions of dollars.

But there was more. Even though we could literally destroy our planet by making sense of this 'hidden' and strange relationship between Energy and Matter that Einstein had postulated, our boffins had already found even stranger things going on and which couldn't be explained by the current

scientific equations and observations available to them, not even $E = Mc^2$. They had observed the behaviour of small particles of mass behaving as a particle and a wave (with no mass) at the same time. And further more they had discovered that when they tried to accurately observe this behaviour the particles behaved differently than when they didn't try to measure it. It was as though the particles were aware they were being watched!

This was preposterous, how could a physical thing be a non-physical thing (energy wave) at the same time and more so how could the very act of observing this phenomenon change the way this particle or wave behaved? We had never seen or observed anything like this before. This wasn't possible, it defied logic according to our human intuition and understanding of what could or should happen in the 'real predictable world'.

It had to be wrong; our scientists (boffins) must have been doing the experiments incorrectly. But over time they realised they weren't wrong and that our intuitive or 'classical' way of trying to explain this discovery of another type of 'hidden' interaction between Energy and Matter just couldn't keep up. It just couldn't make allowances for or predict this type of behaviour, nor provide any answers as to how to measure it. Newton's, Maxwell's and indeed all the what we term 'classical' equations, long held to be the ubiquitous equations of our Universe had to allow a new and fundamentally different way of explaining the Universe to be developed. This development or movement became known as Quantum Mechanics.

If you are reading this on a smart phone, laptop, tablet, virtual reality headset or desktop via wireless connected to the internet, streaming live or using GPS whilst driving or a satellite phone whilst on Skype, using internet radio, on social media or just watching television you are experiencing how our scientists found the answer to this problem, through the language of Quantum Mechanics.

But there was a problem (and there still is), the language of Quantum Mechanics goes against everything we as humble humans believe is possible and even more so allows pretty much everything and anything to theoretically occur. It requires difficult to understand concepts such as imaginary numbers, differentiation, Hamiltonian operators, Dirac notation, matrices and more, it requires a highly-advanced level of mathematical understanding and comprehension, it takes away our long held common sense belief that we can measure things 100% accurately and instead it replaces the concept of accurate measurement with potential and probability and even removes the dearly held notion of 100% predictability. It has pretty much turned our own human view of the world upside down in every sense. Even Einstein tried to argue against some of its interpretations of the world and how it worked. But it has proved to be the most successful explanation of our universe to date and look what it has given us. Everything you and your children do in this previously unimaginable electronic world we now find ourselves in is thanks in many ways to the discovery and use of Quantum Mechanics and its language.

So here is my question. As educators, can we find a way to harness this technological revolution by embracing the same language that has created this revolution – Quantum Physics. Can we come to understand how the mechanics of this observation process actually works, how we actually record and measure it in order to adapt to this new world and take advantage of it for the benefit of our students. Simply put, can we take Quantum Mechanics and implement it into the very fabric of how we operate schools…? Here's my own attempt….

2. Quantum Mechanics: An example of what is on offer:

Quantum Mechanics has an equation called the Schrodinger equation (it has sooooo many more equations but I felt this was the 'simplest' one to consider for conceptualization purposes…). This is a fundamental equation that everything has to fit into in order to have the possibility of 'existing', it looks like this in its simplest form:

$$i\hbar\frac{\partial}{\partial t}\Psi = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi + V(x,t)\Psi$$ (not very nice is it!)

The key to understanding the equation is as follows:

- Ψ describes something that is trying to exist (a thing of Mass and Energy combined)
- $i\hbar\frac{\partial}{\partial t} = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x,t)$ describes the 'environment' that Ψ is trying to exist in.
- Ψ has to fit into the equation $i\hbar\frac{\partial}{\partial t} = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x,t)$

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in order for it and the environment it is in to exist. Notice Ψ has to fit into three different places; each place in the equation describes a different action or operator acting on Ψ.

This Ψ is known in the Quantum Language as a 'Wave Function'. A Wave Function is the name given to an equation that provides the most complete description that is possible to have of a 'thing'. The simplest form of a Wave Function is as follows:

$$\Psi = \cos\left(\frac{px - Et}{\hbar} - \phi\right) + i\sin\left(\frac{px - Et}{\hbar} - \phi\right)$$

The key to understanding this equation is as follows:

- $\cos\left(\frac{px - Et}{\hbar} - \phi\right)$ describes the REAL 'oscillating' or changing part (the bit we can see and measure) of the Energy and Mass interaction that is manifesting itself into the 'thing'. It is an interaction between momentum (p), position (x), Energy (E), time (t), a constant of life (ħ) and a phase constant (ϕ).

- $i\sin\left(\frac{px-Et}{\hbar}-\phi\right)$ describes the IMAGINARY (i) 'oscillating' or changing part (the bit we can't see or measure) of the Energy and Mass interaction that is manifesting itself into the 'thing'. It is an interaction between imaginary momentum (ip), imaginary position (ix), imaginary Energy (iE), imaginary time (it), an imaginary constant of life (iħ) and an imaginary phase constant (iϕ).

So you have something described by Ψ that has a real element of oscillating Energy and Mass and an imaginary (or invisible to us humans) element of oscillating Energy and Mass combining together to manifest itself into a 'thing' that in order to exist has to adapt itself to fit into an environment described by

$$i\hbar\frac{\partial}{\partial t} = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x,t)$$

which itself is changing over time and itself has an imaginary component.

In Summary

The Wave Function is an equation that provides the most complete description that is possible to have of a 'thing'. It is made up of Real and Imaginary components. These Real and Imaginary components combine with each other in a multitude of ways to become the 'thing' and this 'thing' then either fits into and continually adapts to a changing environment and therefore exists and survives (and as a consequence so does the environment it is in) or it doesn't fit in or adapt to the changing environment and therefore doesn't exist or survive (and as a consequence nor does the environment):

"To be or not to be"

3. One of the many ways that Quantum Mechanics make sense of or 'interprets' this equation

Some definitions first

Lets take the scenario where this 'thing' Ψ is managing to 'exist' and adapt to an environment it finds itself in.

Firstly as explained earlier we have the environment it is in described by:

$$i\hbar\frac{\partial}{\partial t} = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x,t)$$

and secondly we have the thing Ψ trying to 'survive' in it:

$$i\hbar\frac{\partial}{\partial t}\Psi = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi + V(x,t)\Psi$$

We now need to try to find a way of finding out any information about what the 'thing' Ψ does or even 'will do' when things 'happen' to it in the environment it is trying to 'exist' in and by doing that we may be able to gain more information about the 'thing'.

But before we do that we have to define how we make sense of the 'thing'. We have to find a way to measure this 'thing' in order to be able to describe the 'thing'. We do this by a combination of its position or 'x' (where is it in the environment) and time or 't' (at what point in time is it in the environment). Mathematically we then say we are measuring or 'observing' the thing Ψ as a 'function' of location 'x' and time 't' together and we write this down as follows:

$$\Psi(x,t)$$

We then insert this 'thing' into its environment as before but this time with the notation $\Psi(x,t)$ to tell us we are measuring it as a 'function' of both position and time together:

$$-i\hbar\frac{\partial}{\partial t}\Psi(x,t) = \frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) + V(x,t)\Psi(x,t)$$

giving us a more complete version of the famous Schrödinger Equation:

$$i\hbar\frac{\partial}{\partial t}\Psi(x,t) = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) + V(x,t)\Psi(x,t)$$

Now some mathematical manipulation

There still isn't very much we can do with this. So we use a mathematical technique called 'separation of variables' which basically says we will 'notionally' split this thing $\Psi(x,t)$ into two distinct and independent measurements of the 'thing', one measurement of the 'thing' using the measurement of position only, so we use the notation $\psi(x)$ and one measurement of the 'thing' using the measurement of time only, so we use the notation $\psi(t)$. So we now have the 'thing' described by two separate measurements each completely independent of each other but that must both be able to fit back together at some point in the mathematical process in order to make sense and therefore 'exist'. We therefore show we are making this change as follows:

$$\Psi(x,t) = \psi(x)\psi(t)$$

Then we put this new way of viewing the 'thing' back into its environment as before:

$$i\hbar\frac{\partial}{\partial t}\psi(x)\psi(t) = \frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\psi(x)\psi(t) + V(x,t)\psi(x)\psi(t)$$

Then we rearrange it into a more useable form giving us

$$\frac{1}{\psi(t)}i\hbar\frac{\partial}{\partial t}\psi(t) = \frac{1}{\psi(x)}\frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\psi(x) + \frac{1}{\psi(x)}V(x)\psi(x)$$ (doesn't feel useable at the moment does it!!)

The golden rule of mathematics is that the value of the LHS of the equation must always equal the value of the RHS of the equation. Sounds obvious but in this case the LHS of the equation is all a function of time (t) whilst the RHS of the equation is all a function of position (x). This is a problem, it is going to be very difficult to find a way of getting both sides to equal each other when one side depends on the passage of time only and the other depends on the position in space only.

But this rearrangement of the equation has been done on purpose (even though it doesn't feel like it yet).

In order for the 'thing' to be able to exist both sides will have to match up (have the same value) or else it won't be able to exist (by that we mean the equations won't have a solution). Only when it does all match up (and we will find out how this happens next) can the thing $\psi(x)\psi(t)$ exist and only then will we get an observable 'value' to show us that the 'thing' is existing in the environment and reacting in a certain way in order to keep existing in the environment. (Now you know why Quantum Physics language hasn't become mainstream…!)

So we can write the equation as follows:

$$\frac{1}{\psi(t)} i\hbar \frac{\partial}{\partial t}\psi(t) = \text{"value"} = \frac{1}{\psi(x)} \frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2}\psi(x) + \frac{1}{\psi(x)} V(x)\psi(x)$$

We give this "value" a name but ONLY when both sides are equal and therefore the 'thing' is 'existing'. The name we give it is 'Energy' and this Energy turns out to have very discrete or 'specific' quantized numerical values depending on the environment the 'thing' is in. What has become known as the quantisation of Energy.

So we now write the equation as follows with Energy denoted by E:

$$\frac{1}{\psi(t)} i\hbar \frac{\partial}{\partial t}\psi(t) = \downarrow E = \frac{1}{\psi(x)} \frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2}\psi(x) + \frac{1}{\psi(x)} V(x)\psi(x)$$

This now allows us to deal with the LHS and RHS equations on their own as follows:

- $\frac{1}{\psi(t)} i\hbar \frac{\partial}{\partial t}\psi(t) = E$
- $E = \frac{1}{\psi(x)} \frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2}\psi(x) + \frac{1}{\psi(x)} V(x)\psi(x)$

We are nearly there….! So lets deal with the LHS equation first

LHS EQUATION

$$\frac{1}{\psi(t)} i\hbar \frac{\partial}{\partial t}\psi(t) = E$$

now we rearrange the equation ever so slightly to get

$$i\hbar \frac{\partial}{\partial t}\psi(t) = E\psi(t)$$

giving us what is known as the "Time **Dependent** Schrodinger Equation".

Now for the RHS equation:

RHS EQUATION

$$E = \frac{1}{\psi(x)} \frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \psi(x) + \frac{1}{\psi(x)} V(x)\psi(x)$$

again we just rearrange the equation to get

$$\frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \psi(x) + V(x)\psi(x) = E\psi(x)$$

giving us what is known as the "Time **Independent** Schrodinger Equation".

These two equations have come from one unifying equation and we must remember to ensure that at any time we use one that the resulting 'E' from that one equation must also be able to work in the other one in order to have any meaning.

Now to use these equations to effect

Lets look at what we have called the Time **Independent** Schrodinger Equation first.

$$\frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \psi(x) + V(x)\psi(x) = E\psi(x)$$

This equation is in a format that is known as an Eigenvalue and Eigenfunction equation and these types of 'Eigenevalue' equations occur throughout physics and applied mathematics extensively, not just in Quantum Physics. Usually, neither the eigenfunctions nor the associated eigenvalues are known at the outset, but by a process of elimination sense can start to be made of them as I hope I will be able to demonstrate over the coming pages. I will do this by trying to offer an analogy of what they represent.

Consider the environment of an examination hall that has a desk, chair, invigilator and an examination paper in it all described by the 'environment' part of the Time **Independent** Schrodinger Equation below:

$$\frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \qquad +V(x) \qquad =$$

Now lets put a student into this environment. It doesn't matter when we put the student in as there is no 'time' element in this equation (but we will need to bring time into it later using the other 'Time **Dependent** Schrodinger equation). This student is described by the 'thing' $\psi(x)$. Now remember $\psi(x)$ provides the most complete description that is possible to have of the student as a function of position only. Lets rewrite that phrase replacing 'position' as follows: *"Now remember* $\psi(x)$

*provides the most complete description that is possible to have of the student as a function of what the student **possesses** as a function of his position only".*

So lets put the student $\psi(x)$ into the examination hall remembering he has to adapt in order to satisfy his 'survival'! Also note in this equation that the environment equation is a bit simpler thanks to the previous steps of mathematical manipulation; the environment expression is only on one side of the equation now, in this case on the LHS:

$$\frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\uparrow_{\psi(x)} \quad +V(x)\uparrow_{\psi(x)} \quad =$$

Now what happens? Well in 'reality' what happens is the student needs to try to adapt to the environment in order to 'survive'.

The equation now looks like this; the student is now 'in' the environment or 'in' the examination hall:

$$\frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\psi(x)+V(x)\psi(x)=$$

But the equation isn't complete yet. What follows is the KEY to one way (there are many) Quantum Mechanics observes and hence measures how things with both a real and imaginary component react. The student now realizes that in order to survive he needs to make use of all the stuff that he possesses, stuff that he was born with, stuff that he has learnt to use and that has grown around him (his maturing body), stuff he has experienced and learnt at home from his parents, relatives, friends, even enemies during the period he has been 'growing up' and of course stuff he has experienced and subsequently 'learnt' in school. He does this by using everything he 'possesses' to expend energy (E) to write on an examination paper. If the student does that we can say he has managed to 'survive' by having adapted to what he came across in that examination hall environment.

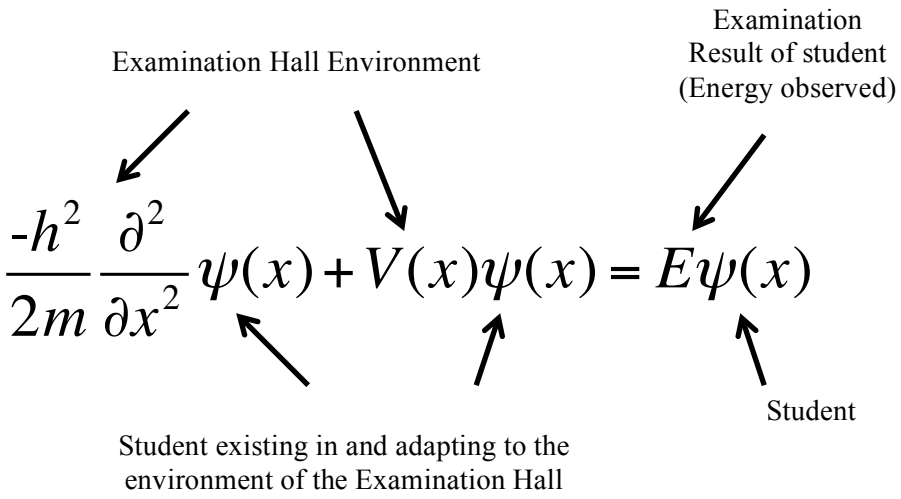
But what actual measurable value do we get from this 'interaction' between the examination hall and the student. We get an observable value from the student in the form of this observable energy (E) that the student has expended in order to survive using his real and imaginary properties that are unique to that student.

$$\frac{-\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\psi(x)+V(x)\psi(x)=\downarrow E\psi(x)$$

We then process this Energy that was a product of this students 'survival' in the examination hall and that is unique to the student and ultimately give it a value or grade and we assign it a discrete or 'specific' quantized numerical value such as a mark out of something, percentage or even a grade A, B, C etc… In this case lets give a grade of 60 out of 100 and equate that to a 'B' grade student.

This is an example of eigenfunctions and eigenvalues in play. Lets try and summarise it.

The environment of the examination hall 'acted' on or 'operated' on the student by making it 'adapt'. This action on the student made of real and imaginary properties and the student's subsequent 'reaction' resulted in the creation of an 'observable' value of energy produced or expended by the student and unique to the student, in this case a completed exam paper that we were able to then 'measure'.



It appears that the tried and tested method (traditional or classical method) of 'examining' students in schools in order to measure a resulting production of energy of the student (in this case predominantly memory and information processing energy) is analogous to this Quantum Mechanical eigenvalue process being played out in front of our very eyes. The Examination result or grade is a result of that student adapting to his or her environment and producing an energy that is both measureable and quantifiable. What's interesting is the Quantum Mechanical function $\psi(x)$, is designated by both real and **imaginary** properties. Is it too naive to try and interpret this imaginary property as the 'inside' properties of the student? Character (that's invisible), Motivation (that's invisible), Feelings (those are invisible), Emotions (those are invisible)…. Maybe that's a bit much to ask, but it's worth a try!

4. Comparing this Quantum Mechanical Framework with our current Framework in schools.

Remember this E value we have observed and measured as an energy output of the student and defined its value by way of a grade? Well we still need be able to see if this observable E value can fit into the Time-**Dependent**-Schrodinger-Equation in order for us to fully satisfy the mathematical rules that allowed us to manipulate one equation into two equations in the first place. If we can do this, then and only then, can we definitively say that the student 'existed' and therefore 'adapted' to the environment they found themselves in. If we can do this then we will be able to deduce some more useful information about the student.

So we take the Time **Dependent** Schrodinger Equation

$$i\hbar\frac{\partial}{\partial t}\psi(t) = E\psi(t)$$

and insert the value 60 in place of E as this has already been observed in the examination hall of the other equation as the Energy that was a product of this students 'survival', the students grade of 60 out of 100. Remember we do this because this E value has to be the same for both of the original LHS and RHS equations that we split up in order for them and therefore this whole process to make sense:

$$i\hbar\frac{\partial}{\partial t}\psi(t) = 60\psi(t)$$

Now all that needs to happen is the description of the student $\psi(t)$ needs to match up in a way that allows the equation to make sense or to have a 'solution'. But the description of the student $\psi(t)$ in this equation now only relies on a function of time hence the (t) bit, so the description of the existence of the student will need to be as a function of 'time', we could interpret this as the students 'age'. So we could interpret the whole process that in order for the student to produce an observable energy or grade of 60 in the environment that we put them in, they would need to be within a certain age range for that Energy value to be produced.

Furthermore the two environment equations are intertwined as are the two descriptions of the student $\psi(t)\ and\ \psi(x)$ and so it becomes a very fluid and adaptable situation. In essence the student descriptors $\psi(t)\ and\ \psi(x)$ will always vary for each student (we are all unique) but they will always have to combine together to allow for the mark of 60 to be produced. In essence one student can be a different age with a different ability to another student and still produce the same Energy output or grade in the examination hall, something we experience in schools all the time.

4. Conclusion

We have become very good at this ability to say "at age so and so a student should be able to get this mark in this exam" and if they get more or less then we can define them as more or less clever. In fact we have become so good at it that we have developed it as the 'defining' way we measure a child's success at school (not to mention the success of the school). That's fine and understandable. But when schools and teachers want to focus on the Human side of their students in order to help improve their exam grades or 'measured success' at school then it becomes very hard to do so unless the Ethos or 'character' of the school hierarchy and society allows this, which is very rare. Those teaching in a 'British Ethos' school, such as mine as an example, are very fortunate on the whole as this focus is allowed, even expected and anecdotally we see great progress and results. KIPP schools in the USA are another example. Yet for most schools this is not the case even though paradoxically the last 20 years or so of research in a multitude of disciplines keeps highlighting that this 'human' or 'Invisible' side such as mindset, character, emotion and the like has a huge impact on determining future success and achievement of children. Something many teachers would agree with and would have anecdotal evidence to suggest yet struggle to articulate to an at times highly skeptical audience.

So could the language of Quantum Physics be the answer? It would be nice to find out or at least find others who are considering it, if only to know…. Yes or No!

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