Quantum Weirdness

A reading play for the whole class about the discovery of quantum mechanics and quantum weirdness and its application to gravitational wave detectors.

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Abstract

This play explores the history of understanding light and quantum mechanics from Newton to the modern era of quantum computers and gravity wave detectors. It features a few of the key characters in this process of discovery. Most children in a typical class can participate. The *kid* roles can be spread (extra kids) or concentrated depending on class size.

Props required: Computer keyboard, frames to simulate computer screens for Timeskype conversations, black cloth or curtains to aid disappearance at end. Costume wigs, coats, moustaches, beards etc and large font name tags.

The Characters in order of appearance

Question kid 1
Dad
Mum
Grandad
Nerdy 1
Nerdy 2
Isaac Newton
Question kid 2
Kid 1
Augustin-Jean Fresnel
Smartypants
Nerdy2
Max Planck
Albert Einstein
Werner Heisenberg
Niels Bohr
Smartypants 2
Alain Aspect
Modern physics PhD student

The play begins with Question kid 1 sitting down at the computer doing his homework, family sitting having tea, reading a magazine and cooking, while other kids slowly walk up to the kids desk to join in the conversation. One or two large frames are the “computer screens” where historical characters appear as they are accessed by Timeskype.

Question kid 1: Hey Dad, what's light?

Dad: I don't really know….stuff that comes out of lights and the Sun

Question kid 1: Hey Mum, what is light?

Mum: I think it is some sort of tiny waves…I'm not quite sure really

Question kid 1: Hey Grandad, what is light?

Grandad: When I was a boy I asked my Grandad the same question. He said it was things called corpuscles: some sort of things like tiny little wet bags of jelly that bounce around like little bouncy balls.

Question kid 1: Do you mean little bags of jelly are going into my eyes?

Grandad: Well I think we had better find some experts:

Nerdy1: That's easy…. I just installed TimeSkype – its really cool! It lets you talk to real oldtimers: who do you want me to call?

Nerdy 2: Lets ask Isaac Newton….(*punches away at keyboard*) Hey Isaac, is that you? Is that Mr Isaac Newton, the one who likes to sit under apple trees?

Newton: *Sir Isaac* if you please! But yes, I do like to think in the orchard.

Nerdy2: My teacher told me you had found out about light.

Newton: Well, I can tell you about light: I did lots of experiments. I found out how to make really powerful telescopes…but look at this…it is made of lots of different colours.

Question kid 2 : Yeah, that's pretty…but what *are* those colours

Newton: Well they are different coloured corpuscles

Kid1: I don't like the idea of corpuscles: it sounds sticky and yukky. I don't want corpuscles going into my eyes!

Newton: Well there's an old fellow called Christian Huygens in Holland: and Robert Hooke: they both disagree with me…they say light is a wave.

Kid1: Well did anybody find out for sure?

Newton: Well you could ask Mr Augustin-Jean Fresnel, the one who invented lighthouse lenses

Nerdy2: He's on TimeSkype too. Just a moment. *(bends over keyboard)*

Question kid 2: Hey, is that Mr Fresnel. Can we ask you a question for our school project?

Augustin-Jean Fresnel: Oui, oui, oui…. it would be a pleasure to help!

Question kid 2: We want to know what light is. We asked Mr Newton and he said it is made of yukky corpuscles. But he said that you had a different idea.

Augustin-Jean Fresnel: Oui, oui, oui…I found lots of ways light acts like a wave…how it expands out through little holes, how light waves can cancel out just like ripples in a pond, how lights sparkle when you look through your eyelashes.

Question kid 2: Can that only happen if light is a wave?

Augustin-Jean Fresnel: Absolutement, absolutement! If it acts like a wave it must be a wave!

Nerdy2: Well you can't argue with that!

Augustin-Jean Fresnel: With my theory I could explain why light bends when it goes through glass.
I used it to invent lenses for light houses ; lights with my lenses can be seen from 30 kilometers away! Without my lenses lots of ships would have been wrecked.

Smartypants: Yes but the world would have been destroyed if light was a wave like you say.

Augustin-Jean Fresnel: What do you mean?

Smartypants: I think Max Planck could explain it to you…hey Nerdy, is Max Planck on the time net?

Nerdy 1: Just a moment…Yes he is! Hey Mr Planck, could we ask you an important question: why did you say light wasn't a wave?

Max Planck: Hello there! I didn't actually say that.

Question kid: Well what did you say Mr Planck?

Max Planck: I told everyone that if light is just a wave then the smaller the wavelength the more energy it would have.
It just does not make sense for light to be a wave, because if it was we would be fried by the sun. You can only explain why the sun does not fry us in ultraviolet light if light comes in packets of energy. But I didn't think it could possibly mean that light is really a stream of little bullets.

Question kid 1: But I heard that there *really are* things called photons!

Max Planck: well that's a long story. I kept arguing that they were wrong. But then Mr Einstein explained Heinrich Hertz's mysterious discovery that electricity is made

when light shines on metals. From that time on Mr Einstein started to argue incessantly that light came as particle things called photons.

Question kid 1: So now you believe it, do you?

Max Planck: Well it wasn't as easy as that. But after Einstein published his theory of relativity I was really impressed. I wrote to him quite often and after a while I found him a job in Berlin. That was great.
We used to play music together and have huge arguments! In the end he convinced me that photons were real. Lets get him on the line so he can tell you himself!

Einstein suddenly appears on the screen.

Question kid 2: Hi, Mr Einstein! Max Planck just told us you convinced him that photons were real! Is that really true?

Einstein: Vell, I could explain many things if light came in packets. It all seemed so beautiful, so perfect, so true. It explained how electricity comes off metals according to the colour of the light. And it even explains how metals get hotter when you heat them up. What a pity, what a pity! *Starts to sob*

Question kid 1: Oh Mr Einstein, what is the matter?

Einstein *sobbing:* It was that pesky Danish fellow Niels Bohr and then Werner Heisenberg in Germany. Zay spoilt it all! Zay started to interfere. Zay caused me so much grief! Zay claimed all sorts of weirdness if light comes as photons. I don't see why you can't have photons without everything going weird.

Question Kid 2: Like what Mr Einstein?

Einstein: Vell…there is no need to ask me. You have zis timeskype thing. Why don't you ask Herr Heisenberg!

Nerdy 1: Is that Herr Werner Heisenberg. Mr Einstein said we should call you. He says you spoilt his theory!

Werner Heisenberg: We didn't spoil his theory. I just showed him the consequences of his discovery of photons.
Einstein agrees with me that photons have momentum. But he seems to hate the fact that the momentum must always cause uncertainty when you measure something.
He is supposed to be a genius! Why can't he see that when you measure where something is, you must always move it. Then it won't be in the same place. We call it the uncertainty principle!

Einstein: Humph: you are saying that God plays dice. That's nonsense. It must be just that you don't quite understand your measurement.

Werner Heisenberg: I don't think so! Niels Bohr agrees with me.

Niels Bohr: Yes I do. The uncertainty also means that things can be in two places at once.

Einstein: Now you are saying that there is some sort of spooky action at a distance…all this weirdness…zee world can't be like that.

Nerdy2: Well Mr Einstein you were the one that said that light comes as photons. I have another question for you:

Einstein: yeees? Go ahead.

Nerdy2: do things look the same when the light is really dim. Is the pattern on a butterfly wing still the same when you look at it in the dark?

Einstein: Yes of course!

Nerdy2: And would it be the same colour except for being a bit dim?

Einstein: Yes of course!

Smartypants: But that colour comes because some of the light waves cancel out: Mr Fresnel showed that. Where a butterfly wing is blue the red and yellow have cancelled out. Isn't that right Mr Einstein.

Einstein: Zat is quite right Mr Smartypants.

Smartypants: But if the lights are very dim, the photons are so, so, so far apart! They travel so fast that only one photon can be nearby at a time…I worked out for dim starlight the photons coming into my eye are 1000 km apart…so how could there ever be two photons close enough together at the butterfly wing to cancel out. - It must take two photons to cancel themselves out.

Einstein: That is a pretty convincing argument Mr Smartypants. Something else must make the photons cancel themselves out.

Niels Bohr: You are right Albert…I worked out what it is. I admit it's weird. I think there is a thing called a wavefunction….it looks like a wave. The wavefunction is what does the cancelling out, but when you make a measurement it suddenly vanishes and turns into a photon!

Smartypants 2: That is really really weird! But has anyone ever seen a wavefunction Mr Bohr.

Niels Bohr: Well, I must admit, they haven't. In my theory you can't see the wavefunction.

Smartypants: Ok! Then why don't you call it a tooth fairy. Tooth fairies turn teeth into money and nobody sees them!

Neils Bohr: Please don't make fun of me Mr Smartypants. In my theory, when you measure something the wavefunction collapses like I said..This is what makes photons appear in the right place at the right time. That is my theory: I call it quantum mechanics.

Smartypants 2: has anyone proved that your theory is right Mr Bohr.

Niels Bohr: Lots of people have tried to prove it was wrong! First Einstein and his friends tried to prove that is was absurd because if it was true, then a crazy thing called photon entanglement was possible. This means that if you measured the colour of one photon, you could instantaneously tell the colour of another one, however far away it was, without even measuring it.

Smartypants: Wow! That must have killed your theory!

Niels Bohr: No way! Einstein was right. The theory is absurd! But it is correct. People started to do cool experiments with photons to test my predictions. Why don't you ask Messieur Aspect. I'll call him up for you! *Scrunches over keyboard and types*
Alain Aspect. Hello Mr Bohr. It was very exciting to test your theory. I used every hi-tech trick in the book to try to disprove your theory!

Smartypants 1: And did you succeed Messieur Aspect?

Alain Aspect: Well, Einstein's entanglement that he thought proved that quantum mechanics was nonsense was there plain to see. Every experiment showed that spooky action at a distance is real. ….Einstein said it was all because of missing data. He was wrong! … The universe really is weird!

Smartypants: I don't mind the weirdness but I don't like the wavefunctions.

Alain Aspect: You don't need to worry about the wavefunctions. Photons follow different mathematics. Quantum physics follows the maths of adding up arrows. For numbers 1+1 = 2 but for arrows 1+1 can equal zero if the arrows point in opposite directions.

Smartypants: Wow, that sounds more fun than plain old numbers.

Question kid 1(*putting up his hand excitedly*) Mr Aspect, is all this weirdness useful in any way?

Modern physics PhD student *(shoving to the front):* Absolutely: there are so many new things we can do now that we understand that all this spooky stuff is real. Using the maths we can harness the theory to make all sorts of cool gadgets, such as quantum computers and gravity wave detectors.

Nerdy 1: Quantum computers makes sense but not gravity wave detectors!

Modern physics PhD student: In gravity wave detectors we have to measure the tiny motions of huge heavy mirrors due to gravity waves. But even these huge things are

affected by quantum uncertainty. If we use quantum entanglement we can break the quantum measurement barrier.

Question Kid 1: Well, that sounds pretty cool! But can you make a teleporter?

Modern Physics PhD student: Sure we can! Here is my virtual teleporter….it is based on timeskype but uses the dimensions of space! Only works for small things so far!

Smartypants2: No one told me about this technology!

Modern Physics PhD student: Come over here! Stand straight! Arms out, palms up! Hold your breath! Watch this card: *places Ace of Hearts card on his hand* Smartypants….On the count of 3 press the escape key! …one, two, three! *Shouting:* Beam it up Scottie!

Lights out, Smartypants vanishes! Grandad suddenly appears holding the card

Modern Physics PhD student: *grumbling over the keyboard*: Damn, damn, damn! There seems to be a malfunction!

The End

Notes from internet sources

Fresnel was the son of an architect, born at Broglie (Eure). His early progress in learning was slow, and he still could not read when he was eight years old. At thirteen he entered the École Centrale in Caen, and at sixteen and a half the École Polytechnique, where he acquitted himself with distinction.

The Munich physics professor Philipp von Jolly advised Planck against going into physics, saying, "in this field, almost everything is already discovered, and all that remains is to fill a few holes." Planck replied that he did not wish to discover new things, but only to understand the known fundamentals of the field, and so began his studies in 1874 at the University of Munich.

Black Body radiation 1899: As Planck was deeply suspicious of the philosophical and physical implications of such an interpretation of Boltzmann's approach, his recourse to them was, as he later put it, "an act of despair ... I was ready to sacrifice any of my previous convictions about physics."[9]

The philosopher and historian of science Thomas Kuhn argued that Einstein should be given credit for quantum theory more so than Planck, since Planck did not understand in a deep sense that he was "introducing the quantum" as a real physical entity.[10] Be that as it may, it was in recognition of Planck's monumental accomplishment that he was awarded the Nobel Prize in Physics in 1918.

The discovery of Planck's constant enabled him to define a new universal set of physical units (such as the Planck length and the Planck mass), all based on fundamental physical constants.

Subsequently, Planck tried to grasp the meaning of energy quanta, but to no avail. "My unavailing attempts to somehow reintegrate the action quantum into classical theory extended over several years and caused me much trouble." Even several years later, other physicists like Rayleigh, Jeans, and Lorentz set Planck's constant to zero in order to align with classical physics, but Planck knew well that this constant had a precise nonzero value. "I am unable to understand Jeans' stubbornness — he is an example of a theoretician as should never be existing, the same as Hegel was for philosophy. So much the worse for the facts if they don't fit."[11]

Max Born wrote about Planck: "He was by nature and by the tradition of his family conservative, averse to revolutionary novelties and skeptical towards speculations. But his belief in the imperative power of logical thinking based on facts was so strong that he did not hesitate to express a claim contradicting to all tradition, because he had convinced himself that no other resort was possible."[12]

In 1905 the three epochal papers of the hitherto completely unknown Albert Einstein were published in the journal *Annalen der Physik*. Planck was among the few who immediately recognized the significance of the special theory of relativity. Thanks to his influence this theory was soon widely accepted in Germany. Planck also contributed considerably to extend the special theory of relativity.

Einstein's hypothesis of light *quanta* (photons), based on Heinrich Hertz's discovery of the photoelectric effect, (later explored by Philipp Lenard), was initially rejected by Planck. He was unwilling to discard completely Maxwell's theory of electrodynamics. "The theory of light would be thrown back not by decades, but by centuries, into the age when Christian Huygens dared to fight against the mighty emission theory of Isaac Newton ..."

In 1910 Einstein pointed out the anomalous behavior of specific heat at low temperatures as another example of a phenomenon which defies explanation by classical physics. Planck and Nernst, seeking to clarify the increasing number of contradictions, organized the First Solvay Conference (Brussels 1911). At this meeting Einstein was able to convince Planck.

Meanwhile Planck had been appointed dean of Berlin University, whereby it was possible for him to call Einstein to Berlin and establish a new professorship for him (1914). Soon the two scientists became close friends and met frequently to play music together.

At the end of the 1920s Bohr, Heisenberg and Pauli had worked out the Copenhagen interpretation of quantum mechanics, but it was rejected by Planck, as well as Schrödinger, Laue, and Einstein. Planck expected that wave mechanics would soon render quantum theory—his own child—unnecessary. This was not to be the case, however. Further work only cemented quantum theory, even against his and Einstein's philosophical revulsions. Planck experienced the truth of his own earlier observation from his struggle with the older views in his younger years: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it."[16]