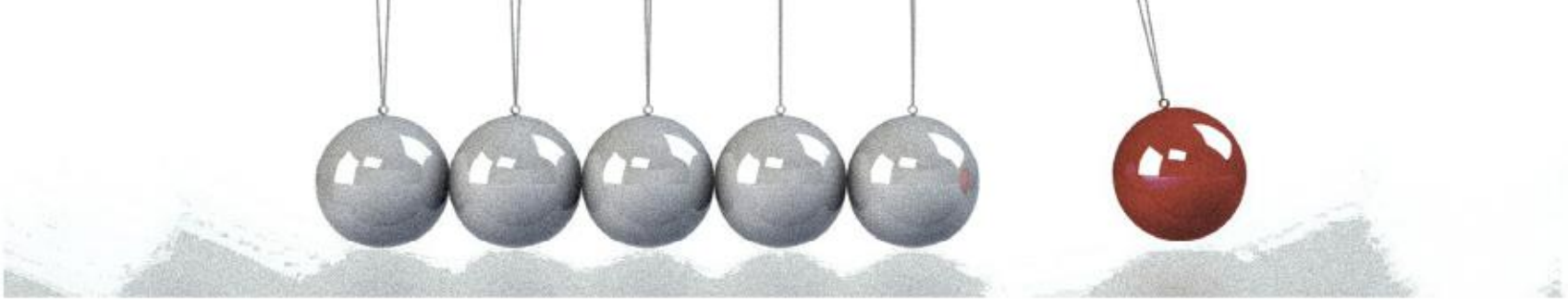


UiO : Department of Physics
University of Oslo

ReleQuant – Improving teaching and learning in modern physics in upper secondary school

Budapest 2015

Carl Angell
Professor of physics education

ReleQuant - Improving teaching and learning in quantum physics (and relativity)

Modern physics in upper secondary school (age 17-19):

- Modern physics is fascinating but challenging
- the Norwegian curriculum requires *qualitative* discussions of how quantum physics represents a break with classical physics, and epistemological consequences
- ReleQuant aims at developing web-based teaching modules in quantum physics (and relativity), to create varied and student-active teaching and improve students' understanding

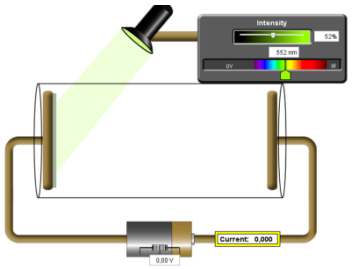
ReleQuant - Improving teaching and learning in quantum physics (and relativity)

The research approach chosen in ReleQuant is Educational Design Research (EDR), where web-based teaching resources are developed and adjusted in several cycles in close collaboration with practicing teachers.

The resources contain short text sequences, video clips, animations, simulations, discussion problems, multiple choice problems, and questions to be answered in writing. They are meant for use in full class teaching, combining individual and small-group work and teacher-led full-class discussions.

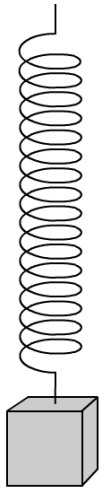
Quantum physics represents a break with the principles of classical physics

- **Module 1: A new physics is needed**
- Module 2: Photoelectric effect
- Module 3: X-rays and Compton scattering
- Module 4: Heisenberg uncertainty principle
- Module 5: Entangled photons

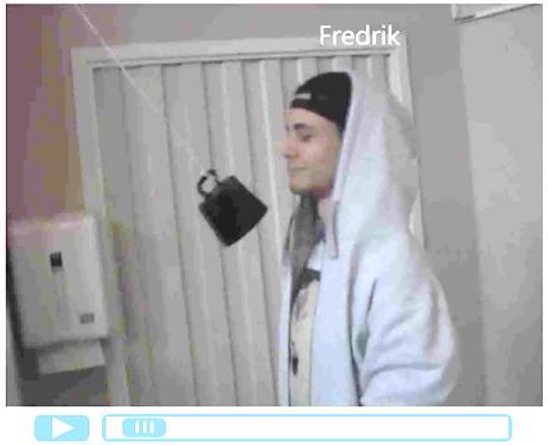


Principles of classical physics

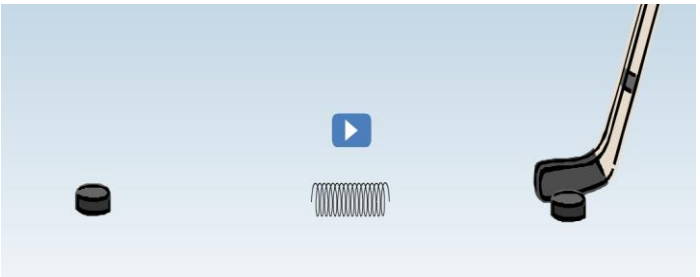
Continuity

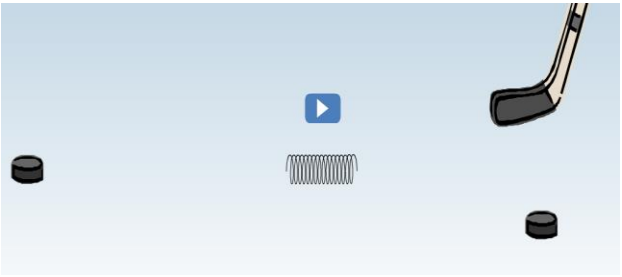


Determinism



Local reality





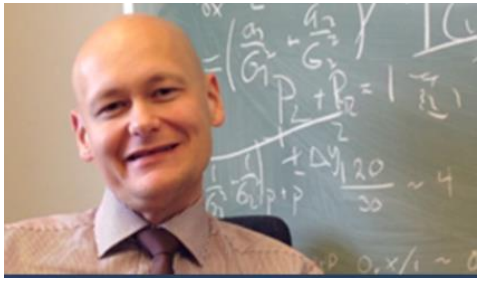
ReleQuant emphasize students' use of language in expressing their understanding in writing and in discussions with peers

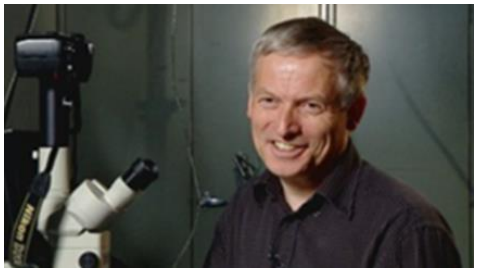
- Writing responses into the learning platform
- Discussing in pairs - recorded on the students' own cell phones
- Classroom discussions

Introducing light and photons

1. Start writing: What is light?
2. Talk with another student: Did you disagree about something? Did you write anything about photons? What is photons?
3. Ask a scientist: What is light and photons?

They do not agree!





«The particles move in «wave trajectories» through space»

"Light can be looked upon as waves and particles. As I have understood it, light is particles with wave properties. Hence particles move in a wave pattern."

Prevalent conception:
«Light is waves *and* particles»

Very few students recognise the contradiction between the two models

New sequence: Can light simultaneously be a particle *and* a wave?

Light – both wave and particle?

Talk with another student: Is it possible to imagine that light is BOTH wave and particle?

«….. that is the problem, isn't it? - that they can behave nicely as both. And both are valid whereas both also contradict themselves in a way, - it is paradoxical»

Inspiration from history
– the Solvay conference in 1927

viten.no

Viten is a web-based science curriculum designed for use in grades 8-13 science classrooms.

ReleQuant on viten.no

One example of preliminary results

Thought experiment “Schrodinger’s cat”

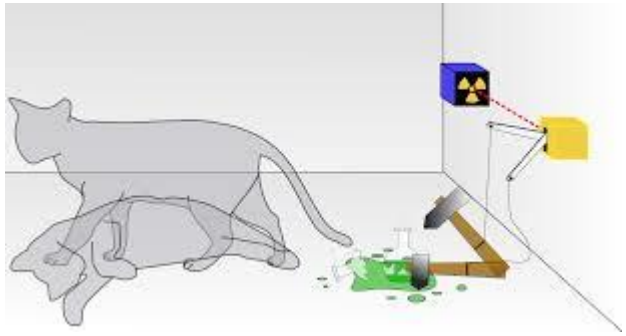
Schrodinger’s cat involves a cat sealed in a box, where the cat's life or death depends on the state of a subatomic particle. According to Schrödinger, the Copenhagen interpretation implies that the cat remains both alive and dead (to everyone outside the box) until the box is opened.

Three broad categories of student responses

- Trivial interpretations; we can't know if the cat is dead until we have looked into the box
- Schrödinger's cat can teach us something about quantum physics
- Critical voices: quantum physics is absurd

An example of trivial interpretation

First of all I think the use of a cat is brutal. But apart from that, it illustrates a good point. Because we don't know when the poison will be released or if it will be released, we cannot know if the cat is dead or alive before we test it out by opening the box.



Some students are positive to the macroscopic analogy

It is a good way of explaining what superposition means. It has been a little difficult to understand that observations and measurements determine the state of a particle, but when you think about it on a macroscopic level it is easier to understand.

A critical voice

I find quantum physics absurd and abstract. Things are what they are, right? Determinism is wrong?! I don't think so. Why should it make a difference whether you have a video recording going or not? How can particles behave differently depending on whether or not a camera, or a person, is standing there and watching? These are the problems I have with quantum physics at the moment. Also, cats are too cute to experiment with.

Talking physics

Focus group interviews with students revealed that some students valued the opportunity to talk and discuss different topics in order to understand difficult concepts. One student said:

> *Talking together did very well, because then we very easily found out if we had understood it or not. So if …. when trying to explain it, and you are not able to say anything, you realize that you have not understood it.*

About quantum physics …..

"I think now that quantum physics is even more *mind fuck* than I originally thought, and also actually even more exciting.
It also clarifies my suspicion that even that being able to touch the surface of quantum physics in Physics 2 is ambitious and that I probably need to take a closer look at this later in life."

Conclusion

We hope to demonstrate through ReleQuant how students' motivation and learning may be supported through carefully designed learning activities including discussions, writing tasks, visualisations and simulations to support not only conceptual understanding, but also philosophical and epistemological reflections, and to stimulate philosophical reflections in physics.

My e-mail: carl.angell@fys.uio.no

ReleQuant publications:

Bungum, B., Henriksen, E. K., Angell, C., Tellefsen, C. W., & Bøe, M. V. (2015). ReleQuant - Improving teaching and learning in quantum physics through educational design research. *NorDiNa - Nordic Studies in Science Education, 11*(2), 153-168.

Henriksen, E. K., Bungum, B., Angell, C., Tellefsen, C. W., Frågåt, T., & Bøe, M. V. (2014). Relativity, quantum physics and philosophy in the upper secondary curriculum: challenges, opportunities and proposed approaches. *Physics Education, 49*(6), 678.