IOP Institute of Physics

# Optimization Of Simulations And Activities For A New Introductory Quantum Mechanics Curriculum

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600 YEARS

## INTRODUCTION

The Institute of Physics New Quantum Curriculum (quantumphysics.iop.org) consists of online texts and interactive simulations with accompanying activities for an introductory course in quantum mechanics starting from two-level systems. This approach immediately immerses students in the concepts of quantum mechanics by focusing on experiments that have no classical explanation. It allows from the start a discussion of the physical interpretations of quantum mechanics and recent developments such as quantum information theory. Texts have being written by researchers in quantum information theory and foundations of quantum mechanics. One of us (AK) designed the interactive simulations and activities (17 in total) that are part of this resource.

The New Quantum Curriculum simulations make use of principles of interface design from previous studies[1-4]. Activities were designed to promote guided exploration and sense-making. Aims of this study were to optimize the simulations and activities in terms of clarity, ease-of-use, promoting exploration, sense-making and linking of multiple representations. We also aimed to optimize the link between the simulations and activities.

## METHODOLOGY

We conducted 38 hours of observation sessions with 17 student volunteers from the University of St Andrews Quantum Physics course (roughly equivalent to US sophomore Modern Physics). In these sessions, students first freely explored a simulation and then worked on the activity associated with the simulation, in both case thinking aloud and describing what they were investigating and explaining what they understood or found confusing. They then answered survey questions and reflected on their experience.

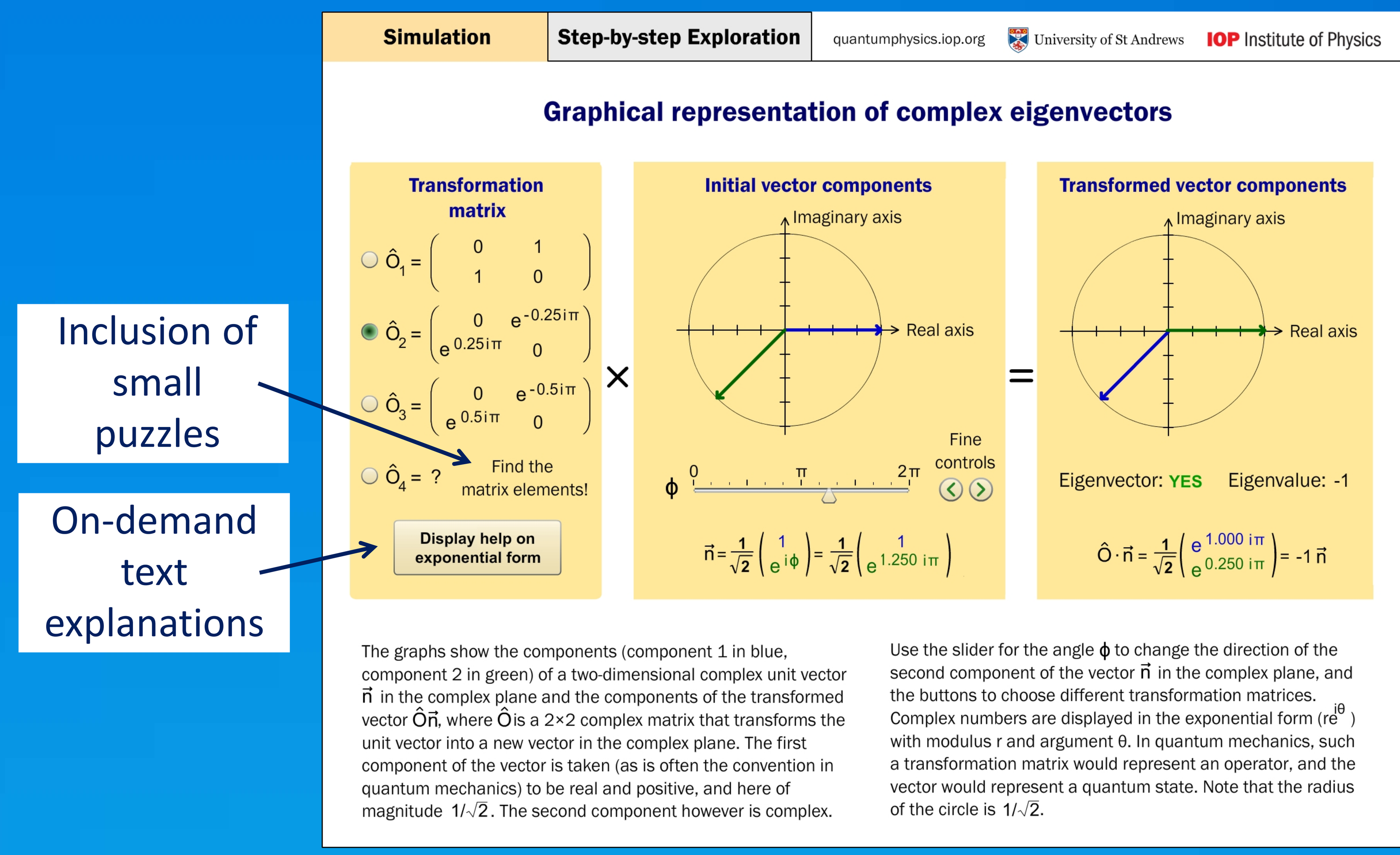
Sessions were audiorecorded with screencapture. We were able to trial all simulations and activities excepting one (16 in total) in these sessions, with 1 to 5 students interacting with each simulation. For a number of simulations there was sufficient time between trials for us to implement changes prior to testing the simulation with subsequent students. Where needed, we implemented changes to activities between trials.

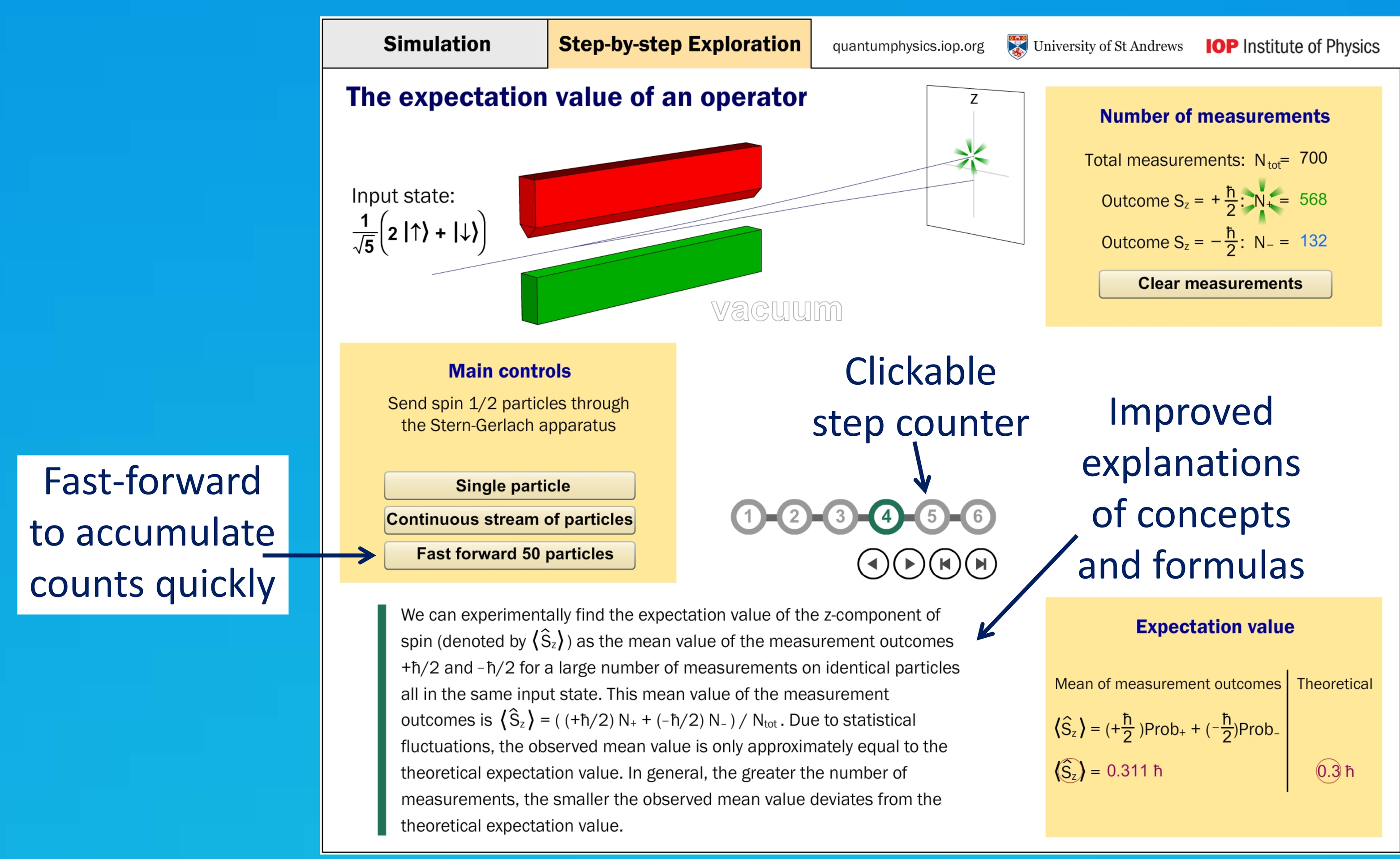
We also used three simulations in the Quantum Physics course, two in computer classroom workshops and one as a homework assignment. We used two simulations as homework assignments in the University of Colorado Boulder Modern Physics course. Analysis of difficulties was used to optimize the simulations, activities and the links between them. Revisions were incorporated into all simulations and activities wherever applicable.

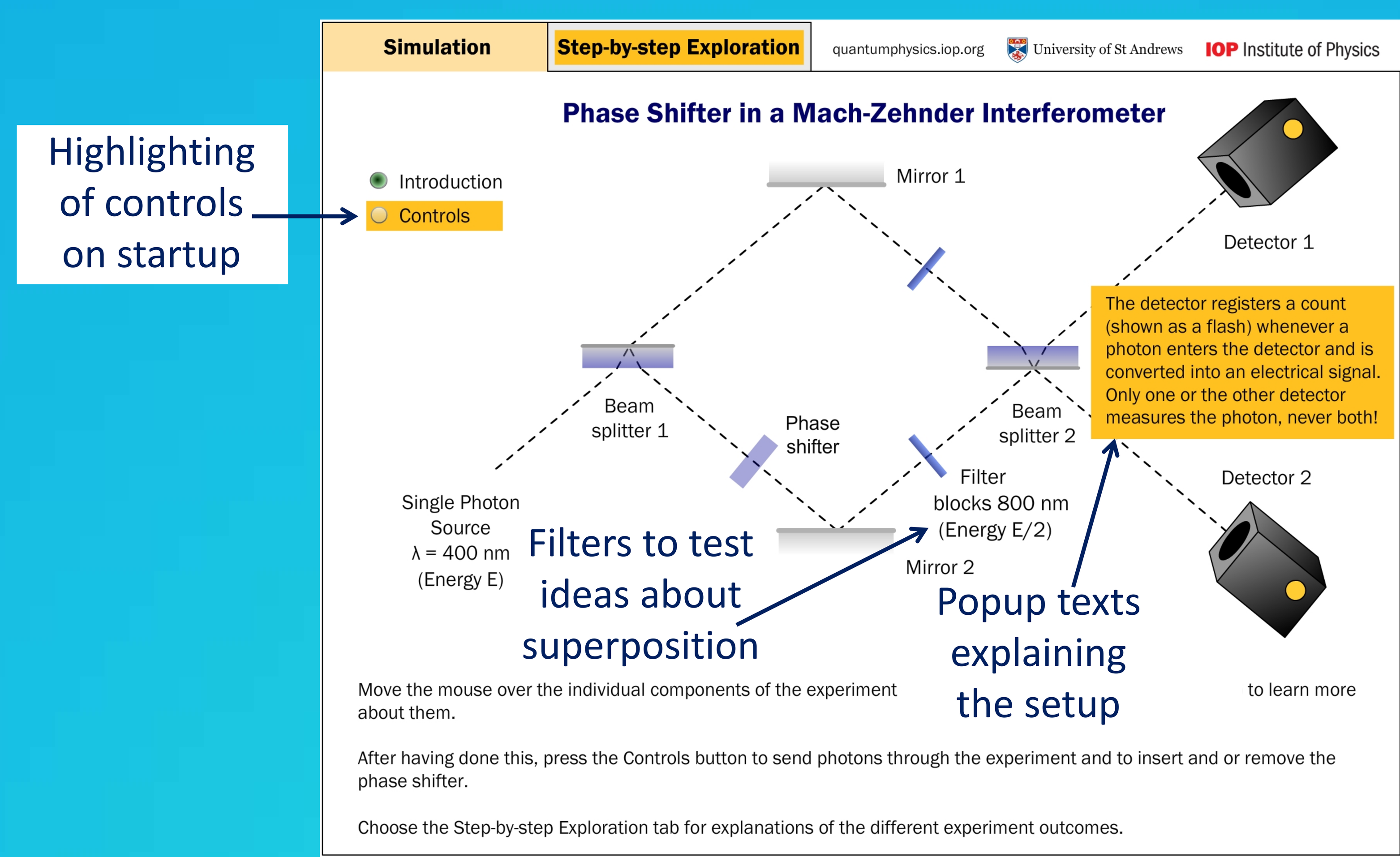
## FUTURE STEPS

We will be conducting further observation studies and evaluation in courses at multiple institutions in the coming year. We plan further refinements to simulations and activities from outcomes of this evaluation. We will also be creating additional activities for the simulations that are more exploratory and promote student discussions and collaboration. For these activities, we wish to carry out observation sessions with students collaboratively working with the simulations.

## EXAMPLES OF OUTCOMES




We revised the activities to help students make better connections between multiple representations and better links with the simulations, using formulations such as

"Using the simulation, come up with a general rule ...",

"Explain how these calculations relate to the experimental observations in the simulation ...",

"Explain how you can see these results graphically in the simulation." etc.

For more complicated simulations such as the hidden variable simulations, we provided additional scaffolding in the activities. For example, we asked students to explain how hidden variable and quantum theory differed in their explanations of the experimental outcomes shown.

## ACKNOWLEDGMENTS

We thank Noah Finkelstein at the University of Colorado Boulder for trialing two simulations in the Spring 2013 Modern Physics course. We thank all students taking part in this study. We thank the Institute of Physics for funding this project and developing and maintaining the New Quantum Curriculum website.

## REFERENCES

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