# Qualifier Question: Teaching Quantum Mechanics

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***Abstract*—Quantum Computing is a technological field with an immense possibility of changing the world. In order to prepare the technical workforce for this revolution in computing power, a comprehensive educational curriculum must be standardized. Through further research the teaching methods, study material and assistive technology required to achieve maximum understanding and information retention can be determined.**

## 1 PROMPT

"You have expressed an interest in researching how to teach quantum mechanics. Keep in mind this course requires that you conduct your own research. Identify at least three forms of formal research that will best facilitate the study of this area. Explain how to conduct the research, analyze the results, and draw sound conclusions. Begin your research with the course library and research guide, but your sources should not come exclusively from there. Try to find sources specific to the areas you plan to research." – Stacia Stokes, Teaching Assistant

## 2 INTRODUCTION

Quantum Computing is poised to revolutionize the computing industry. Previously exponential computations which are calculated to take thousands of years to compute can now be computed with a few hundred computing cycles of a quantum computer (Giles, 2020).

Quantum Computing is based on Quantum Mechanics, theoretical physics that seems to contradict everything about classical physics upon which computer technology is based. "Spooky" phenomena, "strange" effects and "unintuitive" interactions are all concepts which make the quantum computer so unique at calculating the answers which classical computer cannot possibly do. Considering the complexity in Quantum Computing, teaching technical leaders and engineers in the craft required an equally unique approach.

In order to determine the best approach to teaching Quantum Computing, there must be an extensive amount of research done to determine study material, teaching technology and content presentation that must be standardized in order to facilitate content retention and understanding. The research can be done using Survey-based research, Qualitative research and Quantitative research.

## 3 SURVEY-BASED RESEARCH

### 3.1 How to Conduct Research

Survey based research is centered on one central article – the survey. Crafting a survey requires meticulous attention so as to extract the maximum amount of information from the participants, with the greatest of accuracy while reducing biases. As described by (McKagan et al, 2010), an example survey of the teaching methods in Quantum Computing consisted of student observation, literature review, faculty and student interviews as well as statistical analysis.

### 3.2 How to Analyze Results

The authors (McKagan et al, 2010) note, the most surprising finding had nothing to do with the student comprehension of quantum mechanics, but instead the fact that the faculty have no consensus on exactly what material is necessary to be taught. Results are drawn by Statistical analysis of any numerical ratings or representations or a verbal summary of any findings.

### 3.3 How to Draw Conclusions

As demonstrated in (McKegan et al, 2010), conclusions can stray out of the original goal of the survey. It is possible that during the survey preparation, certain information from the target cohort can lead researchers down the path to unforeseen conclusions and findings.

## 4 QUALITATIVE RESEARCH

### 4.1 How to Conduct Research

Qualitative research concerns itself with non-numerical data. Qualitative research aims to gain understanding in reasons, opinions and motivations of a target cohort. The same size of the cohort is fairly small to facilitate deep un-

derstanding of each person's individual cognition on the topic. The most prominent features of a qualitative research topic to consider is validity and reliability (Whitetmore, 2001). The most effective way to ensure validity is to remove biases wherever possible to ensure fair evaluation of each respondent's answers. Consequently, the bias of the researchers can carry from design through results as the text of the questions being asked can lead the interviewee to a conclusion they may not necessarily feel themselves, thus invalidating the study (Claydon, 2015).

### 4.2 How to Analyze Results

According to (Ochieng, 2009), Qualitative research is primarily concerned with the process and meaning of a phenomenon, rather than the outcome or the product which results from the process. Qualitative data connects and strings along together to create an overarching theory of how or why a phenomenon exists or behaves in a certain way. Additionally, (Kitchenham & Pfleeger, 2003) maintain that validity of survey also depends on researcher decisiveness about received answers. If some questions are skipped, the researcher must determine fi they should be discarded, or if there is meaning behind a blank answer.

### 4.3 How to Draw Conclusions

(Ochieng, 2009) describes a Qualitative researcher as drawing conclusions by creating abstractions, concepts and hypotheses from the data collected. Drawing conclusion in qualitative data does not discretize data into values, thus no information is lost of the process of analysis. The largest drawback to qualitative data is that it cannot be extended to larger populations. Without statistical meaning put to numerical analysis, qualitative data only explains a phenomenon of the cohort group chosen for evaluation.

## 5 QUANTITATIVE RESEARCH

### 5.1 How to Conduct Research

Quantitative research is often considered more empirical and scientific in nature. The validity of Quantitative research is usually guaranteed by testing, expert review and statistical analysis (Ochieng, 2009). Quantitative research, generally may not be as susceptible to cognitive bias a qualitative research. This is due, primarily, to the numeric nature of a quantitative study (Claydon, 2015).

### 5.2 How to Analyze Results

(Ochieng) summarizes that quantitative research results in confirmatory and deductive results. According to (Kitchenham & Pfleeger, 2003), due to the numerical nature of Quantitative research ordinal and nominal data requires special attention as typical statistical measure may provide no meaning to the obtained data.

### 5.3 How to Draw Conclusions

Quantitative data can be statistically extrapolated to apply to larger populations with some level of certainty. By utilizing statistical techniques, the researcher can determine, with a certain level of certainty, exactly what is causing the explored phenomena. However, quantitative data cannot provide a why or how this phenomena occurred, or is occurring.

## 6 CONCLUSION

(Ostlund et al, 2011) suggest that for complex topics, mixing of Qualitative and Quantitative data may provide the greatest benefit. Especially for a topic such as Quantum Mechanics, Quantitative and Qualitative data can be combined to provide the numbers and the reasons behind the numbers for student understanding on topics. In order to suggest required materials, study curriculum, and teaching methods, a complex survey must be implemented. By understanding what students lack in understanding, what educators desire to teach the student body, and the statistical confidence in the topics being discussed, a proper curriculum can be suggested which will engage students, foster understanding and nurture creativity and content retention. All of these qualities are sorely needed in a complex, advanced field which is foreign to most working with mainstream technology.

## 7 REFERENCES


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