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THE EFFECT OF PEER INTERACTIONS ON QUANTUM PHYSICS: A STUDY FROM CHINA

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Abstract. *Many studies in the field of physics have demonstrated that courses which include a component of interaction among peers achieve significantly higher gains in conceptual understanding. However, few of those studies have closely examined the role play in quantum physics. Unlike classical physics, the area of quantum physics has little relation to experiences of students in everyday life. This makes quantum physics very difficult to teach. In this study, Ireson's 29 questions regarding the quantum physics conceptual understandings were developed and validated, then used in the pre- and post-test. It was found that a significant difference in the mean number of correct responses between the experiment class and the control class, through their participation in peer conversations, experiment class students achieved a stronger overall understanding of quantum physics concepts. The result is the same as the previous research in classical physics.*

Key words: *peer interaction, physics education, quantum physics, science education.*

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Introduction

Quantum Physics

"God never plays dice" quoted by Einstein in the early days of modern physics that is now called quantum physics (Ting, 1999). He said those words because he never believed in the concept of the "probability of finding a particle in the space" was the most you could know about a particle. Quantum physics is about the characteristics of the subatomic particles and it says that energy is not continuous except in the form of quanta (French & Taylor, 1978; Robinet, 1997). It means any of the small increments or parcels into which many forms of energy are subdivided and any of the small subdivisions of a quantized physical magnitude (Merriam-Webster, 2006). These ideas were based on non-deterministic worlds and fundamentally opposite of what Newtonian deterministic physics claims. Many famous physicists including Einstein objected to this new physics because of its counterintuitive suggestions, approaches and explanations of atomic physical phenomena. When everything settled about quantum physics in the middle of 20th century, 50 years after its inception, the physicists focused on teaching the quantum theory to science students. In its early years (1950s), quantum physics was mostly taught only to graduate physics (and some chemistry) students (Kroemer, 1994). Because Quantum theory is an essential topic and should be conceptually understood by science or non-science major students (Muller & Wiesner, 2001), at present, it has been introduced to introductory college students and even high school students, but the experiment is mostly historical and phenomenological perspective (Ireson, 1999). Unlike classical (Newtonian) mechanics, the area of quantum physics has little relation to experiences of students in everyday life. This makes quantum physics very difficult to teach (Singh, 2001;

Johnson et al, 1998). Some approaches were proposed to test the students' understanding of quantum physics concept. Cataloglu & Robinett (2001) developed an assessment instrument designed to test conceptual and visualization understanding in quantum theory in order to probe various aspects of student understanding of some of the core ideas of quantum mechanics. Ireson (1999) recommended a questionnaire, it consists of 29 items, using a five-point scale from 'strongly disagree' to 'strongly agree' presented to the participant students. Of the 29 items on the questionnaire, 18 concentrate on quantum phenomena and the remaining items address models in quantum physical concepts. McKagan (2010) also designed a Quantum Mechanics Conceptual Survey (QMCS), it is a 12-question survey of students' conceptual understanding of quantum mechanics. Researches have uncovered many specific incorrect beliefs common among students (Olsen, 2002; Domert et al, 2005).

Peer Interaction Education

Peer interaction methods have shown promise as an easily implemented, efficient and effective pedagogical intervention that can help students to "build knowledge" in physics. Numerous studies provide quantitative data to support the effectiveness of such instructional strategies. In peer-to-peer settings, students explain or defend their beliefs about a given question. Self explanation has been shown to lead to improvements in students' ability to solve physics problems while simultaneously strengthening their general knowledge of the problem's domain (Chi, 1991). Hypothesizing about a question and explaining thinking to peers was shown to deepen students' conceptual understanding of concepts in physical science (Hatano and Inagaki, 1991). In the peer instruction approach described by Crouch & Mazur (2001), students in Peer Instruction classes achieved significant gains over those taught through a more traditional, lecture-based approach. In another, similar intervention Meltzer & Manivannan (2002), the authors reported a normalized gain on the Conceptual Survey of Electricity (CSE) of 0.46 to 0.69 for this new interactive approach (compared to a typical gain of 0.25 from more traditional courses). In an attempt to refine Peer Instruction methodology, Reay et al. (2005) employed a three-question sequence in which all three questions focused on the same idea, but involved different contexts, and different levels of difficulty. The authors found that the three-question sequences appeared to help students assimilate concepts quickly. Attitudinal surveys found that students were overwhelmingly in favor of the use of interactive technology in the physics classroom.

The social structure of peer classes has also been shown to be more conducive to idea generation and elaboration as well as justification of ideas. The synthesis of ideas was attained more highly in those peer classes (Hogan et al, 1999). A close examination of transcripts of productive peer to peer discussions found students re-voicing each other's explanations as well as listening to, reflecting on, clarifying, expanding, translating, evaluating, and integrating those explanations (Forman and Ansell, 2002). Asking open-ended questions and offering even incorrect or inconsistent explanations were found to be useful in constructing a more coherent understanding (Thornton, 2004). These findings strongly support the view that instruction with a substantial component of verbal interaction among peers may help support strong conceptual restructuring or change.

Research Focus

The quantum physics curriculum is mainly based on teacher-oriented classrooms without involving students in the process of learning quantum physics, students passively listening for a majority of instructional time. Peer interaction education in quantum physics is rarely studied. So this study focused on a systematic implementation of peer collaboration in quantum physics courses is much needed. In this study, a pre-test/post-test comparison-class experimental design was adopted to investigate the impact of peer interaction on students' learning outcomes regarding concepts of quantum physics. The researcher wants to see whether there is a significant effect of peer interaction on conceptual understanding of quantum physics.

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Methodology of Research

General Background of the Research

This study evaluated the role of peer interaction in understanding of quantum physics concepts. An instrument which was based on Ireson's 29 questions regarding the concepts of quantum physics was developed and used in the pre- and post-test.

Participants

Introductory quantum physics (QP2) is a course for second-year students who majored in electronics engineering offered by the Department of Physics at the University of Science and Technology Liaoning (USTL). The 40 and 39 second-year students who majored in electronics engineering (two classes) in the introductory quantum physics course were probed during the second semester of the academic years 2011 and 2012, respectively. Each of the students had previously taken college general physics course (classical physics).

Instrument

Students are always adept at solving quantitative problems in physics, but scored poorly when their conceptual understanding was assessed. In order to collect information concerning students' understanding about major quantum mechanics topics and concepts, the researcher utilized and developed a commonly applied questionnaire provided by Ireson (1999). This is because it focuses only on assessing the concept not the calculation, similar to the purpose of this study. The questionnaire was composed of 29 items, Of 29 questions, 18 determine students' conceptual understanding of quantum phenomena and 11 focus on their conceptual understanding of models. Considering the habits of Chinese students, disagree (it is wrong) or agree (it is right) instead of Ireson's five-point, strongly disagree to strongly agree scale.

Since English is not the native language for Chinese people, a translation was needed. The translation was carefully performed by a class of two experienced quantum physics professors and two English professors. Firstly, the test was independently translated by two English professors, then reviewed by two experienced quantum physics professors identify differences between the translations. Furthermore, the test was back translated and was found to match the original items.

The Chinese version of the test used technical terms that were understandable by the students. Each question was translated in a way that all its original meanings were kept and no further explanations were given. The translation into Chinese was validated by 3 academic staff and 37 students in the physics department at the University of Science and Technology Liaoning (USTL). They were asked to do both Chinese and English versions of the test. The Chinese version was given first and then the English one. Therefore, the staff and students had no chance to translate the test on their own. With minor adjustment of the translation, all of the staff and students arrived at the same answers for each question in both the Chinese and English versions.

Procedures

The test was approved by the University of Science and Technology Liaoning Institutional Research Board on September 16, 2011. The researcher contacted the physics instructor who taught the introductory quantum physics offered to two classes' students of electronics engineering department. The purpose of the research was explained to him; he agreed the survey. Class 1 and class 2 were assigned to experiment class and control class randomly.

Pre-testing of quantum physics concepts was conducted during the first one week of the semester (September 19-23, 2011). The instructor introduced the researcher to the students explaining the purpose of research, the benefit to the subjects, their voluntary participation, and the issues of confidentiality. Then the researcher distributed the test package to students. Students in both the experiment and control classes completed the Ireson's 29 questions sets. It took about 15 minutes to complete the tests.

Peer interaction method was used in the experiment class, approximately once or twice per week, for the duration of a one semester long instructional unit in quantum physics. The procedure was as follows: A series of conceptual questions written by the researcher were posed. No Ireson's 29 questions were included. Students were given approximately thirty seconds for the initial response. If nearly all students in the class responded correctly, the question was not discussed in peer class, once there was no clear consensus in the class, students were directed to discuss their initial response with peers. After about two or three minutes of discussion, the same question was posed and students responded again. According to the results, the instructor to make decisions on next instructional steps

The Ireson's 29 questions were also administered as post-testing at the end of the semester (January 10-13, 2012) in both classes. Pre- and post-test scores were collected for students in the experiment and control classes. These scores were analyzed to compare overall achievement on the test (the total number of correct responses).

Data Analysis

Finally both 36 students in two classes completed their respective courses and completed the pre-test and post-test. Descriptive statistical graph and t statistical tests were used to analyze the difference between the experiment class and the control class. All statistical procedures were performed with the Statistical Package for the Social Science (SPSS version 19.0).

Results of Research

There is a significant effect of peer interaction on conceptual understanding of quantum physics. As shown in Figure 1, both experiment and control classes achieved higher scores in the post-test, as compared to the pre-test. However, the increase in the experiment class scores was higher (from a mean of 6.69 correct answers to a mean of 20.11) than the increase for the control class (from 6.86 to 14.19).

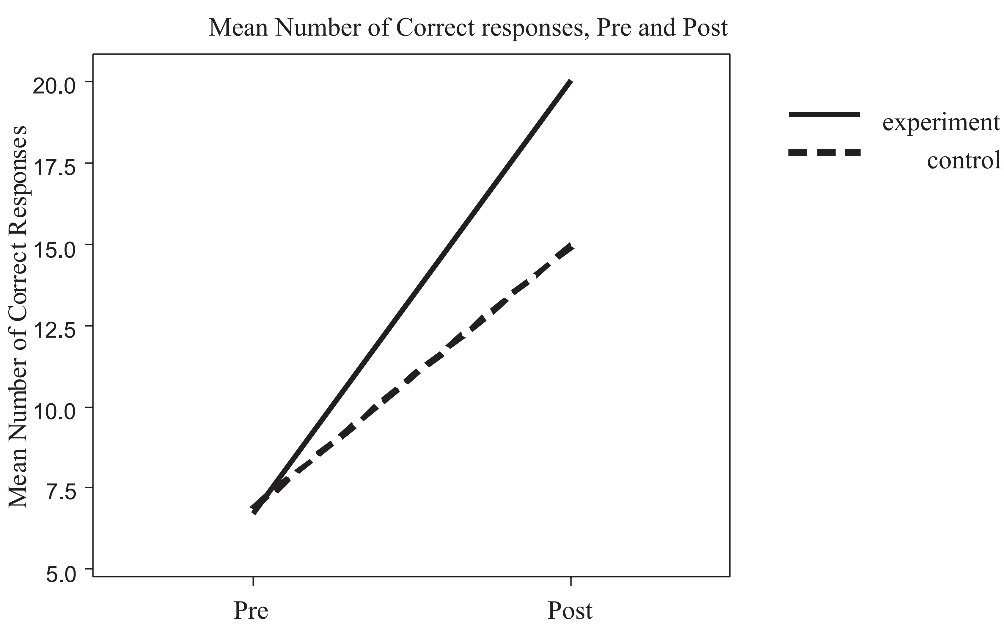

Figure 1: Mean number of correct responses, pre- and post-test.

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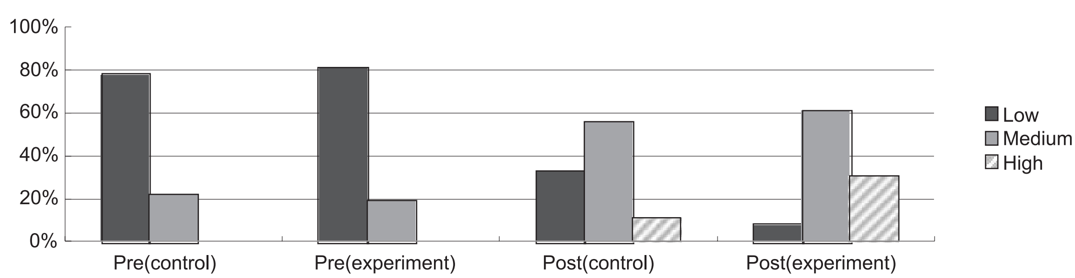
In the Table 1, an independent samples t-test on pre-test scores demonstrated no significant difference in the mean number of correct responses between the experiment class and the control class ($p > 0.05$). On the post-test, the independent samples t-test demonstrated a significant difference in the mean number of correct responses between the experiment class and the control class ($p < 0.01$). These results support the conclusion that participation in peer interactions had a significant effect on conceptual understanding of quantum physics.

Table 1. Mean total number of correct responses, pre- and post-test.

	Experiment	Control	t	df	p
Pre-test	6.69	6.86	-0.63	69	0.530
Post-test	20.11	14.19	4.76	69	0.000

While we categorized achievement as “High”, “Medium” and “Low”(low was defined as scoring below 25%, medium as between 25% and 75% and high as above 75%), it was found movement from the “Low” to the “Medium” or “High” scoring groups happened for a larger percentage of students in the experiment class (73%) as compared to the control class (45%). A z-test for two proportions found a significant difference in the proportion of high scorers in the experiment class (31%) vs. the control class (11%, $z = 2.09$, $p < 0.05$). Fig 2 shows the movement from the “Low” to the “Medium” or “High” scoring groups.

Figure 2: The movement from the “Low” to the “Medium” or “High” scoring groups.



In summary, the study found that participation in peer interactions had a significant effect on quantum physics conceptual understanding.

Discussion

This study provided evidence that through their participation in peer conversations, students in the experiment class achieved higher average total scores on the post-test and more of those students moved from the low to medium or high range in total score. The result is the same as the research in classical physics (Crouch & Mazur, 2001; Meltzer & Manivannan, 2002; Reay et al. 2005).

In order for students to undergo the profound conceptual change, they must first be made aware of their own current beliefs. In this study, one apparent contributor to this awareness may have been a regular opportunity to articulate one’s own ideas. Carey and Spelke (1996) suggested that students may struggle to reason in a new system when their own beliefs are from a different one. Certainly, a clear articulation of one’s current beliefs would necessarily precede any mapping from one system to another. The current study demonstrated that regular peer interactions in the classroom provide ample opportunity for students to take that first step.

Once students are made aware of their current beliefs, they must be dissatisfied with them, in order to be motivated to consider an alterative view. Posner et al (1982) have pointed to the need for dissatisfaction with one's own current belief system as a motivator for conceptual change.

Disagreements among peers may have caused what Hatano & Inagaki (2003) called perplexity and may have motivated reconsideration of the current view.

The process of constructing and providing explanations has been shown to support improved understanding. Chi (1991) noted that, when students construct self-explanations, that construction yielded "new general knowledge that helps complete the students' otherwise incomplete understanding of the domain principles and concepts". In a classroom where peer interactions are not common, this belief may not be expressed.

Recommendations for Further Research

Several recommendations for further research are generated as follows:

1. It is recommended that a study be conducted to investigate whether peer interactions have the same affection on the gender performance.
2. It is recommended that a qualitative study need be conducted to get more information.

Conclusion

As an instructor, we must have a desire to explore efficient and effective ways to support improved conceptual understanding. Peer interaction is a good one. Unlike classical physics, the area of quantum physics has little relation to experiences of students in everyday life. This makes quantum physics very difficult to teach. In this study, it was found that a significant difference in the mean number of correct responses between the experiment class and the control class, through their participation in peer conversations, experiment class students achieved a stronger overall understanding of quantum physics concepts. The result is the same as the previous research in classical physics.

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References

Carey, S., & Spelke, E. (1996). "Science and core knowledge". *Philosophy of Science*, *63* (4), 515-533.

Cataloglu, E., & Robinett, R. W. (2002). Testing the development of student conceptual and visualization understanding in quantum mechanics through the undergraduate career. *American Journal of Physics*, *70* (3), 238-251.

Chi, M., & VanLehn, K. (1991). "The content of physics self-explanations". *The Journal of the Learning Sciences*, *1* (1), 69-105.

Crouch, C., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, *69* (9), 970-977.

Domert, D., Linder, C., & Ingerman, A. (2005). Probability as a conceptual hurdle to understanding one-dimensional quantum scattering and tunneling, *European Journal of Physics*, *26*, 47-61.

Forman, E., & Ansell, E. (2002). Orchestrating the multiple voices and inscriptions of a mathematics classroom. *The Journal of the Learning Sciences*, *11* (2&3), 251-274.

French, A. P., & Taylor, Edwin. F. (1978). *An Introduction to Quantum Physics*. Norton, New York

Hatano, G., & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. In L. Resnick, J. Levine & S. Teasley (Eds.), *Perspectives on socially shared cognition*. Pittsburgh: Learning Research and Development Center, University of Pittsburgh.

Hatano, G., & Inagaki, K. (2003). When is conceptual change intended? A cognitive sociocultural view. In G. Sinatra, & P. Pintrick (Eds.), *Intentional conceptual change*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Hogan, K., Nastasi, B., Pressley, M. (1999). Discourse patterns and collaborative scientific reasoning in peer and teacher-guided discussion. *Cognition and Instruction, 17* (4), 379-432.

Ireson, G. (1999). A multivariate analysis of undergraduate physics students' conceptions of quantum phenomena. *European Journal of Physics*, *20*, 193-199.

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Johnson, I. D., Crawford, K., & Fletcher, P. R. (1998). Student difficulties in learning quantum mechanics. *International Journal of Science Education*, *20* (4), 427-446.

Kroemer, A. (1994). Investigating quantum physics in the high school environments. *Physics Education*, *56* (3), 127-139.

McKagan, S. B., Perkins, K. K., and Wieman, C. E. (2010). Design and validation of the Quantum Mechanics Conceptual Survey. *Physical Review Special Topics-Physics Education Research*, *6*, 020121, 1-17.

Meltzer, D., & Manivannan, K. (2002). Transforming the lecture-hall environment: The fully interactive physics lecture. *American Journal of Physics*, *70* (6), 639-654.

Merriam-Webster (2006). Merriam Webster online dictionary. Available at: http://www.m-w.com/cgi-bin/dictionary

Muller, R., & Wiesner, H. (2001). Teaching quantum mechanics on an introductory level. *American Journal of Physics*, *70* (3), 200-209.

Olsen, R. V. (2002). Introducing quantum mechanics in the upper secondary school: a study in Norway. *International Journal of Science Education*, *24*, 565-585.

Posner, G., Strike, K., Hewson, P., Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66* (2), 211- 227.

Reay, N., Bao, L., Li, P., Warnakulasooriya, R. Baugh, G. (2005). Toward the effective use of voting machines in physics lectures. *American Journal of Physics*, *73* (6), 554-558.

Robinett, Richard. W. (1997). *Quantum Mechanics; Classical Results, Modern Systems, and Visualized Examples*, Oxford University Press, New York.

Singh, C. (2001). Student' understanding of quantum mechanics. *American Journal of Physics*, *69* (8), 885-895.

Thornton, R. (2004). *Uncommon knowledge: Student behavior correlated to conceptual learning.* Proceedings of the International School of Physics "Enrico Fermi," Course CLVI Research on Physics Education, E.F. Redish and M. Vicentini (Eds.), Amsterdam, Oxford: IOS Press.

Ting, S. C. C. (1999). *The bible according to Einstein: a scientific complement to the holy bible for the third millennium* (1st Ed.). Jupiter Scientific Publishing Company.

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