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Developing Students' Creativity through Computer Simulation Based Learning in Quantum Physics Learning

[a]Muhammad Tawil and [a]Ahmad Dahlan

[a]Universitas Negeri Makassar, INDONESIA

ABSTRACT

This study aims to analyses the effect of Phet computer simulation to the students' creativity increasing in Quantum Physics Learning. There were 120 students as the subject in physics education department at the Faculty of Mathematics and Natural Sciences of State University of Makassar. A pre-test and post-test creativity experimental design was used during which students were randomly assigned into either the experimental or the control group. Interview sheet, observation sheet, and questionnaire were used to obtain quantitative data. The results of the research indicate that there are significant differences between the experimental group and the control group in terms of creativity. Interview result shown that student whose was learned by computer simulation based learning believes that it helped them to improve their creativity in term of quantum subject. The students in the experimental group showed that they prefer to use learning tool namely software and it can help lecturer in teaching quantum physics. These findings support the idea that the students majoring at physics education should be trained in the use of computer simulations to improve their creativity. This puts a responsibility of the educational authorities for the procurement of computer simulation software to be used in teaching physics and other science subjects in University.

KEYWORDS
Students' Creativity, Quantum Physics Learning, Computer Simulation Based Learning

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Introduction

Quantum physics is one of the compulsory courses at Physics Department, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar (State University of Makassar). It is expected that the students achieved the competency meaningfully to the concepts of quantum and the use of it in daily life by applying the basic principles of modern physics. It is indicated that in learning quantum physics, the basic principle of quantum physics is not only known and memorized by the students, but also the concepts must be understood and connected to the concepts of daily life thoroughly.

CORRESPONDENCE M. Tawil ✉ muhammadtawil.unm@gmail.com

To achieve the expected competences, the students should have good previous knowledge before learning quantum physics. In this case, previous knowledge refers to the essential understanding of the material in a modern physics course and having the will to prepare the students themselves in learning quantum physics. However, in learning physics especially in the subject of quantum physics, the understanding is relatively difficult to create because quantum physics has some characteristics. They are difficult to imagine, unobservable, mathematically challenging, and counterintuitive. Those characteristics make students difficult to understand the material and frustrated to build mental models. Thus, quantum physics cannot be related to things in daily life, (McKagan, et. al, 2008).

A research which conducted by Ridong, Yi-Yong & Chich-Jen. (2016) showed four things about creative thinking. The first was creative thinking instruction presents higher sensitivity than traditional instruction. The second was creative thinking instruction reveals higher fluency than traditional instruction. The third was immersion in virtual reality appears the highest sensitivity on creative thinking instruction. The fourth was interaction in virtual reality presents the highest fluency on creative thinking instruction. Based on the preliminary study conducted by the researcher in the year 2012, there were seven things obtained. The first was the readiness of physics lecturers, both in the aspect of learning packages and learning media, in lecturing quantum physics was in a low category. It was conversely to the high need of students to the learning packages. The second was the difficulty of the lecturers in teaching quantum physics was in the high category. The third was the difficulty of students in understanding quantum was in the high category. The fourth was the material in quantum is comprehensively reviewed and based on the curriculum. The fifth was the lecturers, and the students face difficulty in the process of quantum physics learning, since it was very abstract, theoretic, and mathematics. The sixth was the passing rate of students was in low category, which is lower than 60 percent. The seventh is the facilities of the laboratory support the quantum physics learning.

This study suggests that both lecturers of quantum physics course and students faced difficulty in understanding of quantum physics. Some finding supports that students are difficult to comprehend the subject, e.g. (Harrison & Treagust, 2000)

The subject of quantum physics in 2014 curriculum of Physics Education Study Program is a compulsory subject for the seventh-semester students which has three credits. In the syllabus, it covers some chapters, i.e.: 1) basic theory of quantum, 2) particle wave, 3) Schrödinger equation, 4) the application of Schrödinger equation, and 5) hydrogen atom.

Belloni & Cristian (2006) suggests that both lecturers of quantum physics course and students stated that the learning media which is relevant to the course is computer experiment and computer simulation combined with experiment besides media of LCD, OHP, and whiteboard. It is supported by the findings that learning that applied computer simulation could help students to understand the course of basic physics (Finkelstein, et. al. 2005). Furthermore, several lecturers developed and researched about computer simulation to assist students in studying quantum mechanics.

Literature Review

The Computer Simulation in Quantum Physics Learning

The simulation of Physics Education Technology (PhET) has main objective, i.e. improving the ability of students and learning quality. The simulation is designed to assist students in constructing the understanding of concept through physics exploration. PhET is applied in the form of interactive simulation using computer which has about 18 variations of simulation in quantum mechanics subject i.e. quantum Tunneling and wave packets; quantum wave interference; quantum bound states; covalent bonds; band structure; Fourier: making wave. The topics are the basic principles of quantum physics. The simulation of PhET is very effective in learning of basic physics and quantum physics (McKagan, et al, 2008).

Developing Creativity

Clark & Mayer (2011) regarded creativity performance as the interaction among skills in relative fields, skills related to creativity, and work motivation. Flischer, C. (2010) pointed out creativity as the interaction process among individual people, domain, and field. Referring to Huang, Jang, Machtmes, & Deggs (2012), creativity is regarded, in this study, as the transformation of an individual or a group and the performance on cognition, affection, and will, which allow oneself, individual, and created field getting in higher changes. Creativity generally contains several cognitive abilities of divergent thinking, which could be understood through testing tools or evaluators' observation (Hawi, 2012).

1. Fluency. Fluency refers to the number of concepts generated by a person; i.e. the ability to propose several possibilities or solutions for one question. A student's thinking presents fluency when proposing several responses at the stage of concept generation (Hsieh et al., 2011). Two answers are diverse is not necessarily different. Some answers to the problem is said to vary but did not differ when the answers were not the same as one another, but it looks based on a pattern or a specific order. For instance, the answer of problem is based on the relation between acceleration and force a = 2F. When students answer $2ms^{-2}$ (since F = 1N), then $4ms^{-2}$ (since F = 2N), then $6ms^{-2}$ (since F = 3N), then the answers of the students are various but have the same results. When students answer $2ms^{-2}$ (since F = 2,5N), then 1 ms-2 (since F = 1/2N), then the answer of the students are various but not different. The answer are various since the value.
2. Flexibility. Flexibility refers to the ability of an individual changing the thinking direction, i.e. finding out different applications or new concepts with various thinking methods when encountering problems. That is, an individual could adapt to various conditions and treat problems without using inherent habitual and rigid thinking methods. "Flexible changes", "learning by analogy", and "comprehending by analogy" are the specific performance of flexibility.
3. Originality. Originality refers to the ability of an individual being able to come out with unique and novel ideas, i.e. to do unexpected things or presenting abilities different from others. The person could come out with different ideas from others even receive the same stimulus as the others do.

When fewer people are the same, the originality is enhanced, such as the performance of "little green leaves red", "outstanding", and "prominent".

4. Elaboration. Elaboration, as a supplementary idea, refers to individual ability to add new ideas in existing concepts, i.e. increasing novel concepts or composing relevant ideas in inherent ideas or basic concepts. "Making progress" and "searching for excellence" could be used for describing elaboration (Pai & Huang, 2011).

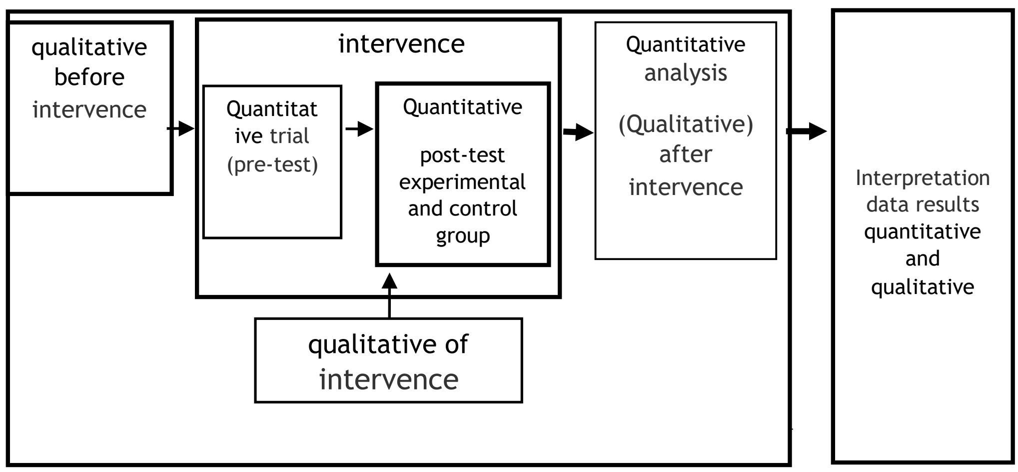
Methodology and Research Design

This study was conducted to the students that programmed the course of quantum physics from the faculty of mathematics and natural sciences in State University of Makassar in the academic year of 2014-2015. The characteristics of all students during the school year of 2014-2015 were are relatively same. The sample was selected randomly namely class A and B.

The aims of this study are:

- to analyze the characteristics of computer simulation based learning in the course of quantum physics
- to analyze the characteristics of the development of the students' creativity through computer simulation based learning.
- to analyze the significant differences in the increase of the students' creativity among the students who attended computer simulation based learning and the students who took conventional quantum lectures in learning physics.
- to analyze the responses of the lecturer and the students to the computer simulation based learning.

This research was embedded experimental study. The preliminary study before doing intervene was carried out by the researcher in 2013. It was found that the creativity of students majoring at physics education at the Faculty of Mathematics and Natural Sciences, State University of Makassar was in the very low category in which the average score was 46.The first thing to do was to analyse the course syllabus of quantum physics to develop indicators of students' creativity. The result of the preliminary study was used as material support simulation of quantum physics. The quantitative and qualitative study was simultaneously performed during the implementation of computer simulation-based learning.



The embedded experimental model (Figure 1) may be the most commonly used variant of the embedded Design (Creswell & Plano Clark, 2007). This model is defined by having qualitative data embedded within an experimental design (such as a true experiment or a quasi-experimental). The priority of this model is established by the quantitative, experimental, methodology. This design can either be used as a two-phase, qualitative data can come before intervention, to shape the intervention, to develop an instrument, select participants, after the intervention (experimental and control group), to explain the results of the intervention or to follow up on the experiences of participants with certain types of outcomes. For the embedded experimental model: 1) the researches must decide at what point in the experimental study to collect the qualitative data (before, during, or after the intervention). This decision should be made based on the intent for the including the qualitative data (e.g., to shape the intervention, to explain the process of participants during treatment, or to follow up on results of the experimental trial), 2) for before-intervention approaches, the researcher needs to decide which qualitative results will be used in the quantitative phase and to consider how to plan the quantitative phase before the qualitative phase has been conducted. Again, the qualitative data collection should be carefully designed to match the intent for including qualitative data, such as to develop an instrument or shape the intervention, 3) for during-intervention approaches, the qualitative data collection may introduce potential treatment bias the affects the outcomes of the experimental, 4) for after-intervention approaches, decisions must be made about which aspect of the trial will be further explored, and the researcher must specify the criteria used to select the participants for the follow-up data collection.

Pre-Intervention Phase

In this phase, the syllabus of quantum physics course was analysed.

1. The analysis of syllabus in the course of quantum physics involved two steps namely lecture and tasks analysis. The lecture analysis was conducted to select and set, and also to summarize and arrange systematically the relevant lectures to implement based on the standard of competency and achieved indicators in the course of quantum physics. While the tasks analysis was to identify the main indicators of the quantum physics lecture and then, the indicators were analyzed into creativity frame that was developed in the form of learning devices and interactive simulation software.
2. The analysis of the students' and teachers' need was conducted by the analysis of the preliminary survey. It was conducted on the implementation of quantum physics lecture at the physics departments, faculty of mathematics and natural science, Universitas Negeri Makassar.
3. The analysis of learning resources and available facilities in the course of physics at Universitas Negeri Makassar. In this phase, the preliminary survey was conducted on the availability of the facilities and infrastructure to support the implementation of the quantum physics lecture. Based on the analysis of learning resources and available facilities, a simulation program was conducted to support the process of the quantum physics lecture.

Competence Formulation Phase

The formulation of competence was intended to convert the competence of lectures and tasks analysis into sub-competencies (basic competencies). The indicators to be achieved included the indicators of creativity (Hawi, 2012). The Phase of the development of computer simulation program. There were three steps in this phase as follows:

1. Developing computer simulation based learning (syntax, social systems, support systems, and the instructional and companion impact) was determined by the characteristics of creative thinking skills.
2. Developing learning device that consisted of the lesson plan, student activity sheet, and guidelines for students and lecturers in making the simulation program.
3. Developing research instruments (tests of creativity, questionnaire), and qualitative process that consisted of observation sheets.

Computer Simulation Program Development Phase

In this phase, storyboard simulation program was developed by determining the indicators of creative thinking skills and the understanding of the concepts. Based on this storyboard, the interactive simulation program was developed by using the program of Physics Education Technology (PheT) (McKagan, et al, 2008). There were some considerations in creating this interactive simulation. Firstly, the student was already familiar with the program, so they did not experience difficulties in operating it. Secondly, the students were very easy to apply for this program, and the license was assured.

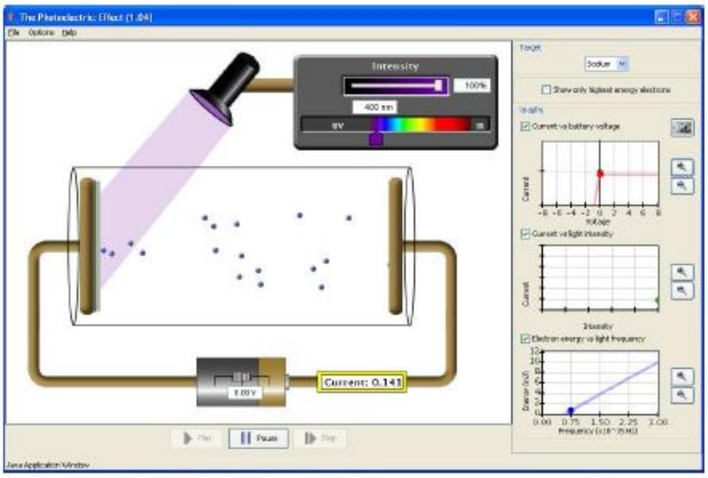


Figure 2. The Photoelectric Effect simulation (Color online)

The Photoelectric Effect simulation, shown in Fig.1, was designed as part of the Physics Education Technologi Project (PhET), and is available for free download, along with many other simulations in quantum physics, from the PhET website http://phet.colorado.edu. This Simuliation has ability ti increase student skill to formulate the equation of photoelectric effect orriginally and to increase student problem skill flexibel

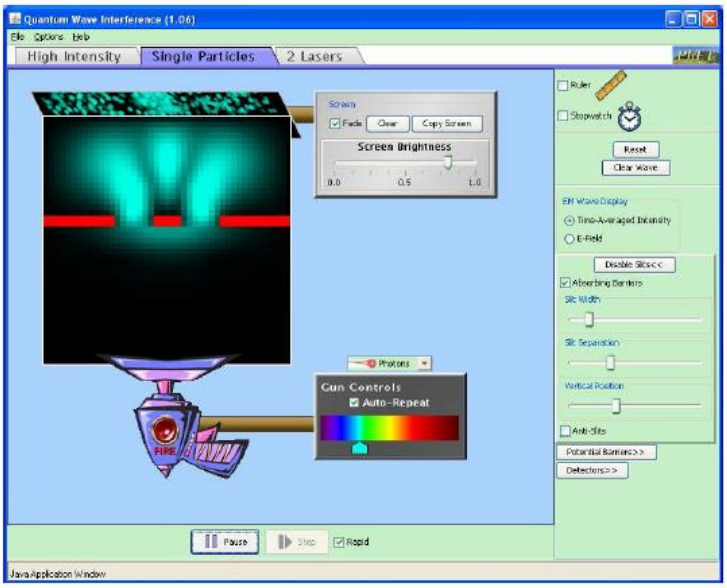


Figure 3. Quantum Wave Interference

Quantum Wave Interference (Figure 3) allows students to follow a light wave from the source and through the slits, observing it interfering with itself and collapsing into a dot on the sreem. Model of the Hydrogen Atom (not shown) allows students to " see" inside atoms.

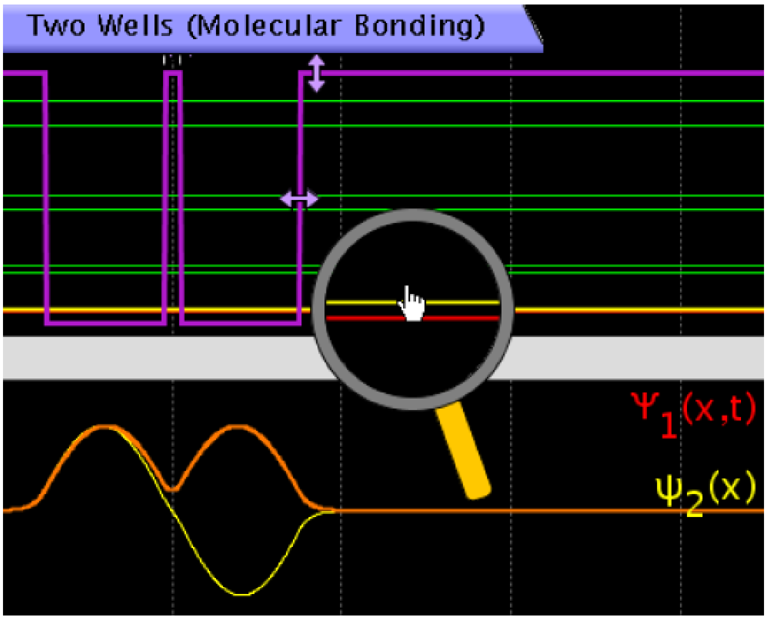


Figure 4. The" Two Well" tab of Quantum Bound States

Figure 4. shows (also Double Wells and Covalent Bonds), the symmetric (ψ_1) and anti-symmetric (ψ_2) states. The "Many Wells" tab (also Band

Structure), not shown, allows users to creat an array of up to 10 wells. This interaction appears to be particularly effective for helping students contruct understanding and intuition for abstract and unfamiliar quantum phenomena. Students can learn about the relationship between potential energy and wave function by clicking and dragging directly on the potential energy diagram to change the offset, height, and witdh of potential wells, and immediately see the effect on the shape of the wave function. Student are able to solve several preblem originally and flexible by their own.

This simulation contains two advanced tabs that allow students to explore double and multiple wells (Figure 4). (These tabs are also available separately as the simulations Double Wells and Covalent Bonds and Band Structure.) Students spent so long playing with single wells that they never got to the advanced tabs. This student, who had previous instruction on single wells but not double wells, was able to explain, based on his exploration of the simulation, the reason for the pairs of symmetric and anti-symmetric states for double wells.

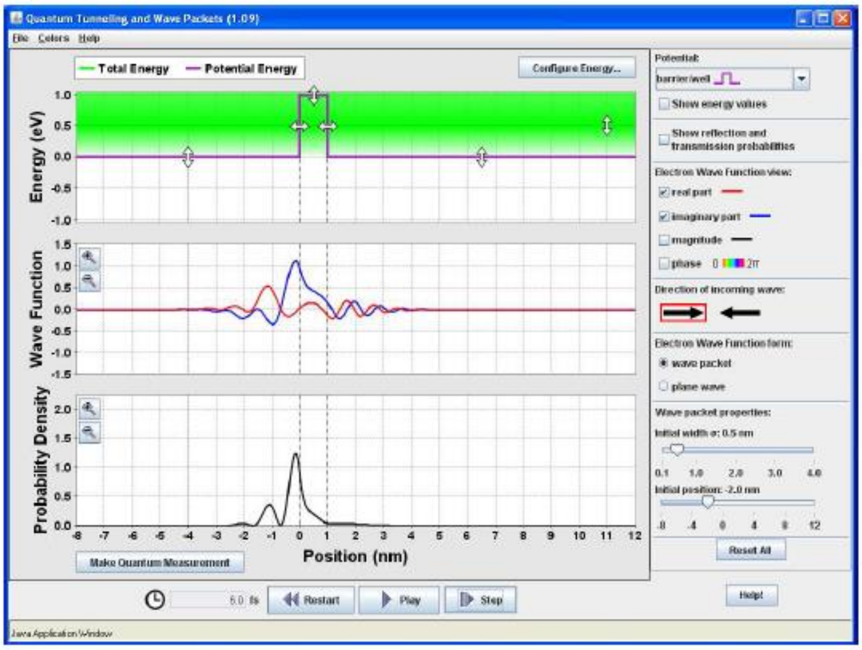


Figure 5. Quantum Tunneling and Wave Packets simulation

Quantum Tunneling and Wave Packets (Figure 5) allows us to bein our instruction on tunneling with packets, so that students can visualize an electron as a slightly-but-not-completely delocalized object that approaches a barrier, interacts with it, and then partially reflects and partially transmits. This is not only much easier to visualize and understand than a wave packet spread over infinite space interacting with a barrier for all time, but also more physically accurate.

Simulations provide a unique tool for exploring time dependence in a way that is impossible in print media, helping student to see how quantum phenomena evolve and change in time. In Model of the Hydrogen Atom, Neon Ligh and other Discharge Lamps, and Lasers, students can observe atoms absorbing and emitting photons. In Quantum Tunneling and Wave Packets and Quantum Bound States, student can observe how wave functions change in time, exploring, for instance, the interchange between real and imaginary parts, the oscillation of superposition states, and the collapse of the wave function when a position measurement is made.

Validation Phase

Learning device, storyboard, interactive simulation software, and research instruments mentioned above were called as the prototype and then were validated by several experts. Limited Trial Test Phase. Before the test was conducted, the lecture model that gave lectures in the class and the observers who observe the process of implementation of lectures in the class were trained at first. The purpose of this training was to avoid the bias of the study. There were some training activities as follows:

1. Assessing the learning device, guidelines to make simulations, and interactive simulation program. Then, explaining the purpose of each component of learning device, guidelines to make simulation and simulation program and technical implementation.
2. Assessing the observation sheet of computer simulation based learning and student activity sheet in following lectures. Reading any components of the observation sheet and explaining the purpose of each point of the components to the two observers.
3. Simulating the material of quantum physics and the observation sheet in the laboratory with three students from physics study program. In this simulation, the students pay attention to the lecture as learning the process in the laboratory, while the observers took a position near the students. After learning process, the simulation activity was discussed to complete the implementation of learning and observation.
4. Stimulating the material of quantum physics trial and the observation sheet in the laboratory with three students from physics study program, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar. The implementation of the simulation was conducted through computer simulation based learning. After the lecture, the result was discussed to complete the implementation of lecture and observation.
5. Stimulating the learning devices by applying computer stimulation base learning with five students from physics study program, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar. After the trials, the results were discussed to complete the implementation of the lecture. In this phase, the data was analysed, and the learning devices were revised by interpreting the data to determine the result of the limited trial.

Implementation Phase

In this phase, the activities were:

1. Implementing computer simulation-based learning in the experimental group with some syntax. The first is explaining the topic of simulation, simulation principles, and practice of creativity, and technical description of the simulation techniques. The sound is giving students the

opportunity to the make the simulation. The third is analyzing the simulation results. The fourth is giving an advanced task and doing evaluation. The fifth is providing exercises and applying the concept. According to Abraham (1986)". *in traditional approach the students are first informed of what they are expected to know. The informing is accomplished via textbook, a motion picture, a teacher or some other type of media. Next, some type of proof is offered to the students in order for them to verify that what they have been told or shown is true. Finally, the students answer question or engage in some other from practice with the new information.*"

2. Collecting and analyzing quantitative and qualitative data.

Interpretation Phase

At this phase, all of the data from quantitative and qualitative analysis interpretations were interpreted to draw conclusions and report the study results. The subjects of this study were 120 students in academic year 2014/2015 in physics education study program at Universitas Negeri Makassar of which during the experiment they took lectures of Quantum Physics. The instruments in this study were interview sheet, observation sheet, questionnaire, and creativity test.

Floropoulos, Spathis, Halvatzis, & Tsipouridou (2010) and Rothes, Lemos, & Gonçalves, (2014) proposed several thinking skills enhance creativity; free association and deferring judgment were effective methods for promoting individual or group creative thinking, in which participants released their opinions under pleasant and intimate atmosphere and acquired large quantity of creativity in short period through group thinking and opinion stimulation. The research results are concluded as following. First, synchronous web-based instruction would affect thinking styles. Second, synchronous web-based instruction would influence creativity. Third, thinking styles reveal notably positive effects on creativity (Kuo, 2016). Ekmekci (2015) presented a case study comparing the effectiveness of computer-based versus hands-on instructional activity on learning electric circuits. The hypotheses of the study showed that there were differences in the creativity increase of the students who followed computer simulations and the students who followed conventional learning.

The data analysis was conducted by referring the study problems. Based on the study problem, the data analysis was conducted in two ways namely quantitative and qualitative. Descriptive statistical analysis by N-gain normalization test was used to see the results of creativity. In addition, to clarify the interpretation of the results of the analysis, the data was also described in the form of diagrams. In this study, the dominant analysis was conducted on the syllabus of the quantum physics course. The students' activity was qualitative, and it has been implied in a whole series of activities that carried out in each stage of the application of computer simulation program in the computer simulation based learning. This analysis was conducted to all components of the application of computer simulation program in the computer simulation based learning that was done by Joice, Weil, and Showers (syntax, social system, the principles of reaction, support systems, and instructional and companion impact). While, quantitative data of the program will be analysed using inferential statistics (Frankel, 2009).

Characteristics of Computer Simulation Based Learning

Computer simulation based learning with learning devices and instrument was based on the learning development. Joyce, Marsha & Showers. (1992) mentioned five things. Firstly, syntax involved orientation, training of students, stabilization, and evaluation. Secondly, the social system involved the cooperation among students and between students and lecturers that were conscientiously in carrying out learning activities. Thirdly, management principles in this study can be shown when the professors act as helper or facilitator. In the whole process of simulation, the instructor was in charge and responsible for maintaining an atmosphere of learning by showing appropriate attitude. Fourthly, support system as the means by which to support the implementation of learning (computer, and learning devices). Finally, instructional and companion impact involved creativity, and the companion impact was the ability to develop a simulation software of quantum physics.

It was important to apply the computer simulation-based learning by following the syntax of learning that has been made. The learning implementation was expected to increase the creativity of the students on the material of quantum physics.

Characteristics of the Increase in Student Creativity

The average score of N-gain of the students' creativity of quantum physics in the experiment class was 0.89 that was categorized as high. While the average score in the control class was -0.10 that was categorized as low. The average score of both classes for each topic was shown in Table 1.

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Table 1. The average score of N-gain of the creativity for each Quantum Physics topics

No	Topic	The average score of N-gain of the creativity on the topic	
		Experiment Class	Control Class
1	Black object radiation	0.94	-0.70
2	The effect of electric photo	0.99	-0.22
3	Atomic model	0.97	-0.40
4	Schrödinger Equation	0.74	0.01

Then, the average score of N-gain for each indicator of students' creativity was shown in the table 2. This table describe that experiment class N-Gain are higher than control class which can be inferred that the software has a positive effect to student's creativity.

Table 2. The average score of N-gain for each indicator of creativity

No.	Creativity Indicators	N-gain average score for creativity indicators					
		Experiment class			Control class		
		H	M	L	H	M	L
1.	Fluency	0.93	-	-	-	-	-0.29
2.	Flexibility	-	0.97	-	-	-	-0.50
3.	Originality	0.95	-	-	-	-	-0.40

H= high; M = middle; and L= low

The result of normality test, homogeneity test, and t-test using $\alpha = 0{,}05$ were shown in Table 3, and Table 4. The t-test of creativity was two way t-test with the same variance with the value of $t_{table} = 2{,}021$.

Tabel 3. The Result of Normality test at Creativity Aspect

Class	N	Mean N-gain	standard deviation	Prob. Value	Conclusion
Control	60	-0.10	0.17	>0.10	Normal
Experiment	60	0.89	0.18	>0.10	Normal

Table 3. shows the distribution of both class have probability value more than 0.10. It is examined by using SPSS 22.0 software at 0.05 of uncertainty standard. By this result, the conclusion of both control and experiment class are in normal distribution.

Table 4. The result of homogeneity test and t-test

Aspect	N	F	Sig.	Conclusion	Sig. (2-tailed)	T_{count}	Conclusion
Creativity	120	0.04	0.84	Homogeny	0.00	24.12	There is a difference

The Response of the Students and the Lecturer

The implementation of computer simulation based learning was given a positive response base on the student response. There were 79% of students gave a positive response on attraction aspect of attraction and 67% of students gave positive response on easy to understand. 75% of students gave positive response to the software which can be conclude that they believe the application help them in the quantum physics learning process. In other side, the Lecturers argued that the software quality and role helped them in the teaching process. They did not find any obstacle to apply the software in learning process refers to the software preparing and organizing time.

In all these observations, we consistently saw that for topics where we used simulations, students developed fluency and originality in high development and flexibility and medium development. For example, when we asked students in problem-solving sessions and interviews about topics related to simulations, they gave animated responses easily and without much time for thought. On exam questions on topics such as the photoelectric effect, discharge lamps, and lasers, students gave fluency, flexibility, and originality, detailed responses, often referring to the simulations explicitly and correctly remembering minute details. On the other hand, when we asked students about other topics not related to simulations, such as models of the atom or infinite square wells (before we developed simulations on these topics), students had to think for a long time, attempting to retrieve memorized facts, and often mixed up important details.

According to the lecturer, the benefit that can be obtained through computer simulation based learning was that students quickly understood the concepts that had been taught and experienced the rapid development of creativity. Evaluation results recorded in the flash disk thus the evaluation system was very practical, effective and efficient.

The lecturer of quantum physics stated that computer simulation based learning was a form of learning that could be applied with innovations. The displayed simulation program was highly interactive.

Discussion

The learning process in this study in experiment group used computer simulation-based. In syntax learning, there were an introduction, the core of learning, consolidation, and closures. In the social system, there was the cooperation among students and the students and the lecturer. In principles of management or reaction, there was a lecturer that acts as a facilitator. In support system, there were computer and learning device. In instructional and companion impact, there was the ability to make decisions and empathy.

This finding was consistent with the development of learning by Joyce, Weil, Marsha & Showers (1992), which emphasized some aspects. The first aspect was syntax or phases of learning. The second was the social system that emphasized the aspects of cooperation among students and students and the lecturer that was conscientiously carried out in the computer simulation based learning. The third was the principles of management / reaction; it emphasized the aspects of the lecturer as helper or facilitator in the learning process in the classroom. The fourth was the impact of instructional and companion that emphasized the achievement of the impact of such instructional creativity.

Learning software in this study was applied using a simulation program Physics Education Technology (PhET). This software contained material for some learning devices of quantum physics, the guidelines to make simulation programs for students and lecturers, 15 types of quantum physics simulation programs, student worksheets, and lesson plan. All of simulation help student to imaging and show the illustration of some quantum particle phenomena. It is very good to improve student understanding to the quantum matter characteristic.

The selection of the simulation program on the basis that this program is already available on many computer machines; very easy to use and already familiar among students; can be used in the learning process in the classroom, especially in developing students' creativity; accessible to students. The interactive simulation program was operated by the lecturer and the students as a simple simulation program and clear instructions for use. The simulation program can be trained to students and lecturer within one to two days and can be made by students and teachers. It was in line with the software implementation by Heinric & Russel (1996) that implementing software as learning media had weaknesses namely cannot reach the aspect of affective, attitude, and psychomotor; cannot solve difficulties in operating without electric sources; cannot solve problem faced individually in learning process; and need expenses for the software.

The results of the implementation of computer simulation-based learning model showed that the lesson plan performed very well in the classroom. Based on the data in the table 1 and table 2, Computer simulation based learning is a student-centred in which the lecturer only acts as a facilitator and help was limited for those who have difficulty understanding the concept and make the simulation program. Such learning was fun for students because they could freely explore their ability both to understand the concept and creativity. This was consistent with the learning theory which was known as conditioning operant. It stated that the students learned through a series of responses and from the response, there was the stimulus that was found by the students themselves. Computer simulation based learning activities were carried by mastery learning (Bruner, 1960) where the teachers or lecturers could train the students continuously until it reached mastery in learning.

The other results of the study was found that there were significant differences in N-gain creativity of the students who attend computer simulation based learning than the students who got conventional teaching on the topic of quantum physics. This was because the experimental class students who attended computer simulation based learning exercised gradually and sustained creativity. It was better than the control class students who did not follow the conventional learning at all to do exercises of creativity.

The next was the average score of N-gain students' creativity in quantum physics was higher than the average score of N-gain towards students' creativity within the conventional learning. This was because the students who attended computer- simulation based learning exercised creativity in every matter of quantum physics was gradually and sustained. Thus, the computer simulation based learning in developing the creativity of students at each quantum physics better than the students who got the conventional learning.

Furthermore, in the experiment class had the average score of N-gain towards creativity on the material of quantum physics was in the high category. Meanwhile, the average score of N-gain in control class included in the low category. Thus it was said that computer simulation based learning could improve student creativity.

The average score of N-gain which was included in the high category namely the indicators of flexibility, originality, fluency. This was because the students often use these creations on other subjects, such as the subject of research and physics experiment.

In the control class, the average score of N-gain to all indicators of creativity was included in the low category. It was because the student did not follow the practice of creativity in conventional learning. However, the students in the control class had the power of creativity on every indicator even though the average score of N-gain towards creativity was still low. This finding was in line with the invention (Huang, Jang, Machtmes,& Deggs, 2012) which concluded that there is creativity in everyone, schools, and teachers need to adopt and apply an approach that supports these skills if you want to teach students to become children of creativity because creativity is crucial for the development of all children. This quality is a vital necessity in life success.

How does the description of the students' creativity when viewed from any material of quantum physics? Based on the results of the study, it was found that the students who attended computer simulation based learning student creativity were in the high category. It was because at the time the students learned the material of black things radiation, photoelectric effect, and atomic model and Schrödinger equation. They practiced to develop fluency ability and to solve the problem in various ways from the graph, the data from each variable (i.e., variable of manipulation, response and control), and various types of alternative models of the atom. Various types of the students' answers from the problems studied were very diverse, and they could find various kinds of new equations. These results were consistent with the analysis of each indicator of the students' creativity like fluency and newness that were included in the high category and flexibility in the medium category. These findings indicated that the computer simulation based learning could develop the creativity of the students in learning quantum physics both regarding fluency creativity, flexibility and also newness. This finding is supported by (Olakanmi, 2015). The results of her research showed that a statistically significant difference was found between the groups and that the web-based computer simulation improved students' development of mental models on rate of reaction in comparison to the students in the experimental group.

How do the students' responses to the implementation of computer simulation-based learning? Based on the results of this study, it was found that the students gave a very positive response in the aspect of interest, delivering clarity of the lecturer, newness, and in the aspect of implementation. The response results indicated that the computer simulation based learning software that has been made was suitable with the level of student ability. The findings were consistent with the constructivist view of learning which stated that learners were given the opportunity to use its own strategy in learning consciously, while the teachers guided students to a higher level of knowledge (Ilham, 2006); (S.B. McKagan et al., 2008).

In general, students were able to develop creativity and analyse the links between the variables (manipulation, response, and control) in function of the mathematical equations that they have created. The relationship between these variables was very attractive to them because it could directly determine whether the equation which has been formulated in agreement with the results of the simulation or not. The calculation and graphic schemes appeared very attractive, fast, and showed precise results. These findings were in line with creative learning model Irina, et all (2016), which emphasized the training aspects of students' creativity in the classroom. Creativity through exercising gradually starting from the easier levels to more difficult on an ongoing basis, their creativity could be expected to develop the indicators that have been separately formulated by Bono (2007) and Northcott, Milliszewska & Dakich (2007).

Based on the responses of the lecturer to computer simulation-based learning software and the implementation of the learning, it showed a positive response. This was caused by the contents of the computer simulation based learning software presentation which was well arranged so that lecturers did not have problems in implementing the learning. These findings was in line with the theory of learning model development by Joyce, Weil, Marsha & Showers, (1992), which stated that the development of a good learning model was a development that emphasized planning aspects or patterns used as a guide in learning in the classroom or learning tutorials and learning tools that were used (books, media, and curriculum). The research conducted by Ekmekci (2015) showed that both computer-based and hands-on activities could be effective when utilized in the right classroom environment.

Conclusion

Quantum physics simulations are designed to address previously-known student difficulties in quantum physics, as well as many new student difficulties uncovered as a result of our research. The result (table 1) show that the lowest N Gain score to grouph who learn quantum with quantum physics simulations are higher then to grouph who learn quantum without quantum physics. The problem of of imaging a very small or quantum particle in the learning procces were solved by the utilization of computer simulation obtained from PhET. It is very good to improve student's understanding to this matter. Our research has shown these summation to be effective in helping students learn, and has revealed new insights into how students thing about quantum physics. That a computer simulation-based learning can improve students' creativity significantly, and the students particularly have a good response toward the simulation program.

Disclosure statement

The Authors reported that no competing financial interest.

Notes on contributors

Dr. Muhammad Tawil MS., M.Pd - Universitas Negeri Makassar, Indonesia.
Ahmad Dahlan S.Pd., M.Pd - Universitas Negeri Makassar, Indonesia.

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