Quantum Flipped Learning and Students' Cognitive Engagement in Achieving Their Critical and Creative Thinking in Learning

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Abstract—The 21st century as the information age implies that everyone, including students, must be literate in the development and advancement of knowledge-based information and communication technology. That is, students in schools as early as possible must be invited to build 21st century knowledge and skills, namely Communication, Collaboration, Critical thinking and problem solving, and Creativity and innovation or so called 4C skills. To accommodate this, the learning model have to utilize student centered learning approach, one of which is quantum flipped learning (QFL) as a substitute for direct flipped learning (DFL). The aims of this study were 1) to analyze the main and interactive effect between the QFL model vs. the DFL model and students' cognitive involvement on their critical and creative thinking in learning physics. To achieve this goal, experimental research was conducted using a post test only control group design. The population of this research is high school students of class XI SMAN 4 Singaraja, and the sample is 4 classes selected by class random technique. The research data were collected with critical thinking tests, creative thinking tests, and cognitive engagement questionnaires. The research data were analyzed using two-way multivariate analysis of variance. The results showed that 1) critical thinking and creative thinking of students who studied with the QFL model were higher than students who studied with the DFL model, 2) students who had high cognitive engagement showed critical thinking and creative thinking skills that were not different from students who had low cognitive engagement, 3) there is no interactive effect between the learning model and students' cognitive involvement on critical thinking and creative thinking. The implication of this research is that to achieve optimal critical thinking and creative thinking, physics learning will be better if using the QFL model, students who have low cognitive engagement to be guided and motivated in learning to be able to increase their cognitive engagement in learning, both levels of cognitive involvement students are accommodated by both models.

Keywords—quantum flipped learning model, cognitive engagement, critical thinking, creative thinking, physic learning

1 Introduction

The 21st century is a digital era marked by the rapid development of science and technology. In this century, all advances in information and communication have become media that can help every human activity [1]. However, the 21st century is not an easy matter to deal with. This is caused by the development of science and technology that is not limited to starting various changes in the order of human life. These changes resulted in the emergence of global competition that cannot be avoided by everyone, including the people of Indonesia [2][3].

In overcoming this, the Indonesian people need to be directed at improving the quality of human resources [4]. One effective way to improve the quality of human resources is through improving the quality of education [5]. In this case, educational institutions play an important role in preparing human resources, namely increasing the competence of graduates to have the abilities and skills in accordance with the demands of the 21st century [6]. The 21st century skill that is meant is that everyone masters the 4Cs which are the means to achieve success in life in society. The 4C skills in question are communication, collaboration, critical thinking and problem solving, and creativity and innovation.

Unfortunately, until now, efforts to achieve 4C skills for students in learning physics are still experiencing obstacles. One of the potential barriers is that physics learning tends to tolerate direct learning (DL). The DL model that is assisted by flipped learning technology is called direct flipped learning (DFL), where flipped learning is only a way of delivering material content and pedagogical content [7]. Direct Learning as a direct instruction (DI) [8]. In DI, learning material is conveyed through face-to-face interactions between students and instructors, and the material is ordered in such a way and taught explicitly, so that students are not optimal in empowering their thinking potential [9]. Such learning methods have not optimal in it effects, especially in facilitating students to develop critical thinking skills [8]. The DL or DI model has a very low impact on achieving students' critical thinking, creative thinking, and collaborative skills in learning physics [10]. The same fact was also expressed that DL is not effective in learning physics [11]. The DL or DI model as a conventional learning model [12]. This model cannot facilitate developing students' critical and creative thinking skills in learning physics, resulting in low learning achievement [12]. These facts indicate that the DFL model is less accommodating in achieving 4C skills of students in learning physics. Therefore, the DFL model deserves a replacement, namely a learning model that is accommodating in achieving 4C.

One way to achieve these 4C skills, especially for students at school, is for teachers to apply the quantum flipped learning model in high school physics learning [13]. Quantum learning (QL) is one of the clusters of inquiry learning models. QL is a combination of many interactions that exist during learning. This model can be applied to topics that are interesting, contextual, repetitive, and provide opportunities for students to demonstrate their abilities. The QL can improve students' understanding of concepts and learning outcomes [14]. The high understanding of concepts and student learning outcomes in the QL class is in accordance with the statement that learning QL provides several benefits to students, namely 1) being positive, 2) increasing motivation,

3) lifelong learning skills, 4) self-confidence, 5) success in improving learning outcomes. The contextual problem-based QL learning model applied in mathematics learning can improve students' creative thinking skills [15]. The QL learning model can optimize students' brain work, learning based on experience, learning becomes interesting and fun, thus enabling students to be more creative [16]. In addition, the QL model can train students to find their own concepts that must be learned in their own way, so that students' memory becomes better. The QL model can improve student learning outcomes in understanding physics concepts and science concepts in schools [17]. The results of the meta-analysis concluded that the QL model can improve learning outcomes and is effective in helping students to improve creative thinking. The learning outcomes of students who study using the QL model are higher than the average learning outcomes of students who study using conventional methods [14].

The positive impact of the QL model on students' creative thinking skills is shown by the results The QL model was more effective than the DI model in the achievement of students' critical and creative thinking [18]. This is because the QL model provides a comfortable learning process, they are free to express themselves well, so that their critical and creative thinking increases [17]. Students' freedom of expression in learning through the QL model will be further increased if the QL model is combined into e-learning pedagogical content [19]. The QL model which is packaged in the form of an interactive video with physics subject matter as the material content will realize the Quantum Flipped Learning (QFL) model. In addition to more intensive freedom of expression, students can also arrange study times and places to study according to their tastes, so that the QFL model truly becomes a vehicle for independent learning in order to support the development of their critical and creative thinking. In such an independent learning condition, the teacher only needs to provide an authentic assessment, so that in learning students become very understanding of the obligations that must be fulfilled in undergoing the independent learning process [20].

Based on the background, the formulation of the problem raised in this study is as follows. Is there a difference in the main and interactive effect between the quantum flipped learning model vs. the direct flipped learning model and cognitive engagement on students' critical and creative thinking in physics learning?

2 Theoretical framework

2.1 Quantum flipped learning

The quantum learning model was first applied at a learning institution located in Kirkwood Meadows, the state of California, United States. The initial application was carried out in 1982 by Bobby DePorter at the Supercamp school. At Supercamp it combines self-confidence, learning skills, and communication skills in a fun environment [21]. Quantum learning learning model is a way of learning that uses a set of methods or learning philosophies that are proven to be effective for all ages [22]. Quantum learning includes important aspects of the "neuro linguistic program" (NLP) program, namely how the brain organizes the information obtained in learning.

Quantum learning is an orchestration of various interactions in and around a learning moment or a learning which has the main mission to design a fun learning process that is adapted to the level of student development [23]. These interactions include the elements for effective learning that influence student success. Quantum learning learning also makes students learn comfortably and fun because students can relate learning to everyday life, students can practice and listen to music that can stimulate students' thinking skills [16]. In his book "Quantum Learning" DePorter (1992) states: "By providing comfortable and fun learning, quantum learning teaches students how to learn skills in taking notes, memorizing, reading quickly, writing and thinking creatively". Quantum learning is a learning model that allows students to learn comfortably and happily with direct student participation in the learning process [24]. In its implementation, students are motivated to actively participate in learning and be able to conclude the content of learning by applying the *TANDUR* stage. *TANDUR* is an abbreviation in *Indonesian*, namely T = *Temukan* (find out), A = *Alami* (*lakukan*/to conduct), N = *Namai* (*berikan nama*/to give name), D = *Demonstrasikan* (to demonstrate), U = *Ulangi* (repeat), R = *Rayakan* (celebrate). One of the learning models that can enable students, be fun and encourage students to use all their potential is the quantum learning model. The logical reason for this is that the quantum learning model has complex reasons. The quantum learning model reviews the theory of the left brain and the left brain. The quantum learning model also reviews visual, auditory, and kinesthetic learning [19]. There are several characteristics of Quantum Learning that exist in every learning that can be applied, namely 1) creating an exciting atmosphere, 2) dynamic planning, 3) empowering a solid learning foundation, 4) structuring the learning environment, and 5) empowering learning skills. Quantum Learning includes specific instructions for creating an effective learning environment, designing curriculum, delivering content, and facilitating the learning process. The Quantum Learning model is changing the various interactions that exist in and around the learning moment by removing obstacles that hinder the natural learning process by using music, coloring the surrounding environment, compiling appropriate teaching materials, effective ways of learning, and active student involvement [25].

2.2 Direct flipped learning

The Direct Instruction learning model or often referred to as the direct learning (DL) model is one of the teaching approaches specifically designed to support student learning processes related to well-structured declarative knowledge and procedural knowledge that can be taught with a gradual, step-by-step pattern of activities [26]. This traditional teaching, where teachers tend to emphasize factual knowledge and focus on delivering content knowledge. The DL model uses more lectures or demonstration materials to students so that the teacher becomes the main role in classroom management so that students' attention is focused on the teacher [27]. The implementation of the DL model based on E-Learning is the same as the Direct Instruction model but at the implementation stage it is slightly different, where the Direct Flipped Learning (DFL) model is implemented online with the help of the Google Classroom application.

The DFL model in learning physics is applied with the following steps: motivating students, delivering lesson material, forming groups of students, students learning in groups, students reporting the results of the discussion, teachers evaluating student reports [8].

2.3 Cognitive engagement

Cognitive engagement is the extent to which students are able to perform learning tasks. This includes the amount of effort students are willing to invest in doing the assignment. Cognitive engagement involves thinking that students do when they are involved in academic learning tasks [28]. That is, cognitive engagement is involving students in learning tasks related to students' thinking and knowledge in learning [29]. Furthermore, cognitive engagement is related to self-regulated motivation and learning goals [30]. That is, how students in class perform in learning that aims to motivate themselves and how to develop their strategies in learning to get good grades in learning English. In addition, in the teaching and learning process, the teacher has motivated students to participate or be active in the classroom. Cognitive in student engagement is related to strategic learning strategies, and active self-regulation [31]. This type can be seen by investing in learning, flexible problem solving including independent work styles. In this case students and teachers must have their own strategies in learning to create a good atmosphere in learning [32].

The forms of cognitive attachment indicate the level of student activity in learning. Students who are cognitively engaged in the learning process think deeply about the newly presented information and use self-regulated learning strategies that enhance their understanding of the subject matter [33]. Independent students are able to distinguish between facts and the skills they perform. They are able to assess academic assignments and set goals for learning [34]. In addition, independent learners can monitor and regulate their cognition and behavior, and apply adjustments to the learning approach when necessary to ensure academic success [35]. In addition, independent learning is the highest form of cognitive engagement. When tasks make cognitive demands, students can engage in independent learning [36]. They can also shift mental burdens by calling on available external resources such as willing and knowledgeable peers. Independent learning will be proven to have certain cognitive activities, such as planning and monitoring independently that students do when they face academic tasks [37].

Cognitive engagement is also conceptualized as the psychological investment that students make in learning, which ranges from memorization to the use of self-regulatory strategies to facilitate deep understanding [38]. Regardless of the pedagogical strategy, research shows that meaningful learning is based on the quality of cognitive engagement [39]. Cognitive engagement is a hallmark of teaching practice principles. These principles include active learning that emphasizes the importance of cognitive engagement in learning. Deep cognitive engagement has been directly linked to learning achievement [30]. To increase cognitive engagement, students must move from superficial cognitive processes to meaningful cognitive processes. Deep cognitive processing enables the kind of mental connection and elaboration of knowledge that drives higher-order cognitive learning outcomes, while shallow processing perpetuates rote learning which is mostly due to a lack of strong engagement with the learning material [40]. Because of the importance of aspects of students' cognitive involvement in learning, an instrument is needed to measure it. To measure students' cognitive involvement in learning, the Interactive-Constructive-Active-Passive Model which is abbreviated as the ICAP model is used [41].

2.4 Critical thinking ability

Critical thinking is thinking clearly and rationally. The ability to think critically is not an inherent ability of humans from birth, but is something that must be trained so that efforts need to be made to improve this ability [42][43]. Critical thinking has several characteristics [44], namely a) able to analyze arguments, b) able to make a conclusion using inductive/deductive reasoning, c) able to make assessments and evaluations, d) able to make decisions and solve problems.

Basically critical thinking skills consist of 12 sub-indicators [45], namely: 1) focusing on a question including identifying or formulating questions, identifying or formulating criteria for assessing possible answers and considering the situation, 2) analyzing arguments including identifying conclusions, state the reasons, identify reasons that are not stated, see similarities and differences, identify and deal with irrelevant ones, look at the structure of the argument and summarize, 3) ask and answer clarifying and challenging questions such as why, what is meant by, what are examples, what makes it different, 4) assess the credibility of the source, 5) observe and evaluate the observation report, 6) deduction judgment, 7) induction judgment, 8) make value judgments, consequences, application of prime principles, and decide, 9) define terms, 10) identify assumptions, 11) decide a action and lastly 12) interact with other people.

2.5 Creative thinking ability

Creative thinking is the ability to find and solve mathematical problems which include the following components: fluency, flexibility, originality, and elaboration [46]. Creative thinking is a combination of logical thinking with divergent thinking that is based on one's intuition, but remains conscious based on available data or information that can produce many possible answers to a problem [47]. Answers are emphasized on the quantity, usefulness, and diversity of answers, which can be measured by several indicators, including fluency, flexibility, originality, and elaboration. Creative thinking skills are part of higher-order thinking skills that enter the cognitive domain which includes analyzing, evaluating, creating [48]. High order thinking skills (HOTS) are classified in the cognitive domain of questions C-4, C-5 and C-6.

It can be concluded that the ability to think creatively is an ability that arises because of the potential, giving rise to a lot of creativity to create something new and unique with the help of something that already exists [49]. For this reason, learning efforts are needed that can encourage the emergence of creative thinking. Creative learning is a learning process that requires teachers to be able to motivate and bring out students' creativity during learning, using several methods and varied strategies, such as group work, role playing, and problem solving [50]. Creative learning requires teachers to stimulate students' creativity, both in developing thinking skills and in taking action [51]. Students are said to be creative if they are able to do something that produces a new activity obtained from the results of creative thinking by realizing it in the form of a new work [52][53].

3 Research methodology

The research design used is a one-way posttest only non-equivalent control group design, which is a type of research with one main independent variable treatment. The main independent variable is the Quantum Flipped Learning (QFL) model which is juxtaposed with Direct Flipped Learning (DFL). The dependent variable that is measured is students' critical thinking and creative thinking in learning physics in high school. The population of this research is the students of class X and class XI MIPA SMA Negeri 4 Singaraja, totaling 5 classes and 180 students. The sample was selected using a random class technique, obtained from 4 classes or 108 students.

The variables of this study consist of 1) Independent Variables, namely the Quantum Flipped Learning (QFL) model compared with Direct Flipped Learning (DFL). This variable is not measured, but manipulated with the lesson plan and implementation and student worksheets. 2) Moderator variable, namely cognitive engagement, as measured by the ICAP model questionnaire [14]. 3) Critical thinking is measured by a physics critical thinking test [45]. 4) Creative thinking is measured by a physics creative thinking test [45].

In implementing QFL and DFL models, students are guided by flipped learning technology, so that the difference between the two learning models is in the learning activities contained in the student worksheets. The learning steps and student activities in the QFL and DFL models are presented in Table 1.

Table 1. Steps and learning activities for the QFL and DFL models

QFL Model		DFL Model	
Learning Steps	***Learning Activities***	***Learning Steps***	***Learning Activities***
Find out the topics and form study groups	Students find out topics that are relevant to themselves and their groups	motivating students	The teacher motivates students regarding the subject matter discussed
Plan learning tasks	Students develop investigations design according to the roles of each group to achieve group goals	delivering lesson material	The teacher presents the subject matter followed
Carry out an investigation	Students making experience via seek information, analyze data, and draw conclusions, exchange ideas, discuss, clarify, and synthesize ideas	forming groups of students	The teacher instructs students to form groups of 3–5 people and share group assignments
Prepare final report	Students sort and choose important concepts and principles that need to be reported, compile reports, prepare presentations, share presentation assignments	students learning in groups	Students work on assignments given by the teacher in each group and formulate the report on the results of the discussion
Present the final report	Students make presentations alternately according to their	students reporting the results of the discussion	The teacher appoints the group in turn to report the

3.1 Critical thinking

Students' critical thinking skills were collected by means of an essay test using a 4-point scale which includes the subject matter of sound and light waves. First of all, 25 critical thinking items were developed. After being tested, 12 items were determined as research instruments. Based on the test results, these critical thinking skills items have a moving difference power index (DPI) from DPI = 0.25 to DPI = 0.71, with the criteria of 4 low DPI items, 5 medium DPI items, and 3 high DPI items. The item difficulty index (IDI) of the 12 test items moved from IDI = 0.22 to IDI = 0.67 with the criteria of 3 easy items, 4 moderate items, and 5 difficult items. The total-item correlation index of the 12 items is calculated using the moment product correlation, and the results move from r = 0.31 to r = 0.62, with the criteria of 3 items with low correlation index, 8 items with moderate correlation index, and 1 item with high correlation index. The 12 items reliability index of the critical thinking skills test was analyzed using Cronbach's alpha, and the result was Cronbach's alpha = 0.783 with the high category.

3.2 Creative thinking

The physics creative thinking instrument was developed in the form of an essay of 20 items with a measurement scale of 0–5 for each item which includes the subject matter of sound and light waves. After being tested, there were 5 items that did not meet the requirements, so the creative thinking instrument used consisted of 15 items. The difference power index (DPI) of the items is in the range of DPI = 0.29 to DPI = 0.77. The item difficulty index (IDI) is in the range of IDI = 0.48 to IDI = 0.56. The internal consistency of the grains is in the range of r = 0.49 to r = 0.79. The reliability index of the 15 items of the instrument is Cronbach's Alpha = 0.92 which is categorized as very high.

3.3 Cognitive engagement

Students' cognitive engagement can be measured using the Motivated Strategy and Learning Use Questionnaire (MLSQ) instrument, which includes two aspects, namely self-regulation and cognitive strategy [54]. Self-regulation includes three indicators, namely 1) planning cognitive strategies to be used in learning activities, 2) monitoring the understanding obtained from the material being studied, and 3) improving learning behavior that is considered inappropriate. Cognitive strategy includes three indicators, namely 1) practice, 2) elaboration, and 3) organizing knowledge to achieve deep understanding. Based on these aspects of cognitive engagement, 29 items of cognitive engagement questionnaire were developed which have been tested on 185 students. The test results show that the item-total correlation moves from r = 0.318 to r = 0.591. The reliability of 29 cognitive engagement questionnaire items was analyzed with Cronbach's Alpha = 0.864 with a very high category.

Research data were analyzed by descriptive statistics and parametric statistics, with the meaning of each result carried out in a qualitative descriptive manner. Descriptive statistics were used to describe the mean (M) and standard deviation (SD) in each analysis cell. Decision making on the description of the average value and standard deviation uses a five-scale absolute value conversion guideline, namely M > 85 is very high, 70 < M < 85 is high, 55 < M < 70 is moderate, 40 < M < 55 is poor, and M < 40 is very less.Parametric statistical analysis techniques were used to test the null hypothesis (Ho) against the research hypothesis (Ha). Decision-making uses the criteria, that the two-way MANOVA F value shows significant figures less than 0.05, both for testing the main influence and testing for interactive influences, meaning Ho is rejected, in other words Ha is accepted. However, before the two-way MANOVA, the assumptions were first tested, namely 1) the data were normally distributed, 2) the variance of the average value of the dependent variable between treatments was homogeneous, and 3) there was no collinearity effect between the dependent variables. Testing the assumption of normality of data distribution using the criteria, that the F values of Kolmogorov-Smirnov and Shapiro-wilk show significant figures greater than 0.05, meaning the data is normally distributed. Testing the assumption of homogeneity of variance using the criteria, that the variance F values show significant figures greater than 0.05, meaning that the dependent variable variance between treatments is homogeneous. Testing the assumption that there is no collinearity effect between the dependent variables uses the criteria that the product moment correlation coefficient r < 0.80.

4 Results and discussion

4.1 Results

This study uses two-way MANOVA as data analysis. The results of data analysis are used to test hypotheses. As the assumptions of MANOVA are 1) the data distribution is normally distributed, 2) the variance between the dependent variables is homogeneous, and 3) there is no collinearity effect between the dependent variables. To test the normality of the data distribution, the Kolmogorov-Smirnov statistic and the Shapiro-Wilk statistic were used. The results of the analysis are shown in Tables 1 and 2.

Table 2. Normality test of data distribution based on the QFL vs. DFL model

DV	Model	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Critical	1.00	0.069	36	0.200	0.975	36	0.565
	2.00	0.152	36	0.034	0.968	36	0.381
Creative	1.00	0.120	36	0.200	0.970	36	0.419
	2.00	0.135	36	0.093	0.943	36	0.063

Table 2 shows the results of the analysis of the normality of the distribution of the distributed variable (DV) data based on the learning model. The table shows that the Kolmogorov-Smirnov and Shapiro-Wilk statistics, both for DV critical thinking and DV creative thinking students have sig values. > 0.05. Thus, all DV data are normally distributed.

Table 3. Normality test of data distribution based on HCE vs. LCE

DV	CE	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Critical	1.00	0.103	36	0.200*	0.962	36	0.252
	2.00	0.111	36	0.200*	0.964	36	0.277
Creative	1.00	0.110	36	0.200*	0.980	36	0.757
	2.00	0.112	36	0.200*	0.960	36	0.209

Note: *This is a lower bound of the true significance.

Table 3 shows the results of the analysis of the normality of the distribution of the distributed variable (DV) data based on cognitive engagement (CE). The table shows that the Kolmogorov-Smirnov and Shapiro-Wilk statistics, both for DV critical thinking and DV creative thinking students have sig values. > 0.05. Thus, all DV data are normally distributed. To test the assumption that the data variance between DV is used Levene statistics. The results of the analysis are presented in Tables 3 and 4.

Table 4. Variant homogeneity test based on QFL vs. DFL model

DV	Statistic Based On	Levene Statistic	df1	df2	Sig.
Critical	*Based on Mean*	0.893	1	70	0.348
	Based on Median	0.858	1	70	0.358
	Based on Median and with adjusted df	0.858	1	69.878	0.358
	Based on trimmed mean	0.896	1	70	0.347
Creative	*Based on Mean*	4.282	1	70	0.042
	Based on Median	3.156	1	70	0.080
	Based on Median and with adjusted df	3.156	1	59.723	0.081
	Based on trimmed mean	4.343	1	70	0.041

Table 4 shows the results of the analysis of the variance of the derived variable (DV) data based on the learning model. The table shows that Levene's statistics based on mean, median, median with adjusted df, trimmed mean, for both the critical thinking DV variant and the creative thinking DV variant of students between the QFL and DFL learning model groups have sig values. > 0.05. Thus, the variance of the DV data between the two learning models is homogeneous.

Table 5. Variant homogeneity test based on HCE vs. LCE

DV	Statistic Based On	Levene Statistic	df1	df2	Sig.
Critical	*Based on Mean*	0.012	1	70	0.913
	Based on Median	0.006	1	70	0.940
	Based on Median and with adjusted df	0.006	1	69.415	0.940
	Based on trimmed mean	0.014	1	70	0.906
Creative	*Based on Mean*	0.415	1	70	0.522
	Based on Median	0.383	1	70	0.538
	Based on Median and with adjusted df	0.383	1	69.487	0.538
	Based on trimmed mean	0.451	1	70	0.504

Table 5 shows the results of the analysis of variance of the derived variable (DV) data based on differences in CE. The table shows that Levene's statistics are based on mean, median, median with adjusted df, trimmed mean, both for the critical thinking DV variant and the creative thinking DV variant between students who have HCE and DCE have sig values. > 0.05. Thus, the variance of the DV data between students who had HCE and LCE was homogeneous.

The collinearity test between DV is also an assumption of MANOVA. To test the collinearity effect, the Pearson Correlation statistic is used with the criteria r(count) < 0.80. The results of the analysis are shown in Table 6. The table shows that r(count) = 0.375 with sig. = 0.001 < 0.05. The value of r(count) is < 0.80, so that there is no collinearity effect between the two DVs.

Table 6. Collinearity test between DV research QFL vs. DFL

DV	Statistic	Critical	Creative
Critical	*Pearson Correlation*	1	0.375
	Sig. (2-tailed)		0.001
	N	72	72
Creative	*Pearson Correlation*	0.375	1
	Sig. (2-tailed)	0.001	
	N	72	72

The next MANOVA assumption is that there is no difference in Covariance Matrices DV. This assumption is tested with Box's Test, with the criteria that the Box's Test statistic has a sig value. > 0.05. The results of the analysis of these assumptions are presented in Table 7. The results show that the Box's Test statistic is F = 1.242 with sig. = 0.264 > 0.05. Thus, the DV covariance matrices are the same.

Table 7. Box's test of equality of covariance matrices research QFL vs. DFL

Box's M	11.811
F	1.242
df1	9
df2	52990.148
Sig.	0.264

The next analysis is a multivariate test of the effect of the QFL vs. DFL learning model on students' critical and creative thinking in learning physics with the moderator variable being students' cognitive engagement (Cognitive engagement/CE). The CE variable is divided into two categories, namely High CE (HCE) and Low CE (LCE). The results of this multivariate analysis are presented in Table 8.

Table 8. Multivariate test of QFL vs. DFL research

Effect	Statistic	Value	F	Hypothesis df	Error df	Sig.
Intercept	*Pillai's Trace*	0.975	1315.522	2.000	67.000	0.000
	Wilks' Lambda	0.025	1315.522	2.000	67.000	0.000
	Hotelling's Trace	39.269	1315.522	2.000	67.000	0.000
	Roy's Largest Root	39.269	1315.522	2.000	67.000	0.000
Model	*Pillai's Trace*	0.464	29.041	2.000	67.000	0.000
	Wilks' Lambda	0.536	29.041	2.000	67.000	0.000
	Hotelling's Trace	0.867	29.041	2.000	67.000	0.000
	Roy's Largest Root	0.867	29.041	2.000	67.000	0.000
CE	*Pillai's Trace*	0.023	0.773	2.000	67.000	0.466
	Wilks' Lambda	0.977	0.773	2.000	67.000	0.466
	Hotelling's Trace	0.023	0.773	2.000	67.000	0.466
	Roy's Largest Root	0.023	0.773	2.000	67.000	0.466
CE * Model	*Pillai's Trace*	0.035	1.231	2.000	67.000	0.299
	Wilks' Lambda	0.965	1.231	2.000	67.000	0.299
	Hotelling's Trace	0.037	1.231	2.000	67.000	0.299
	Roy's Largest Root	0.037	1.231	2.000	67.000	0.299

Table 8 shows that 1) Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistics based on the effect of the learning model (QFL vs. DFL) have sig values. = 0.001 < 0.05. So, there are differences in students' critical thinking and creative thinking between those who study with the QFL model compared to those who study with DFL. 2) Statistical figures for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root based on CE effect (HCE vs. LCE) have sig values. = 0.466 > 0.05. So, there is no difference in critical thinking and creative thinking between students who have HCE compared to those who have LCE. 3) Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistics figures based on the interactive effect between CE * Models have sig values. = 0.299 > 0.05. So, there is no interactive effect between the learning model and cognitive engagement on students' critical thinking and creative thinking in learning physics.

The follow-up to the multivariate analysis was the Tests of Between-Subjects Effects learning model and cognitive engagement on each student's critical thinking and creative thinking in learning physics. However, the Tests of Between-Subjects Effects assumes that there is no difference in Error Variances between DVs. To test the Equality of Error Variances used Levene's Test. The results of the analysis are presented in Table 9 which shows that the Levene F statistics = 2.355 with a sig. = 0.080 for critical thinking DV, and F = 1529 with sig. = 0.215 for creative thinking DV. sigvalues. each statistic for each DV > 0.05, so the Error Variances between DV are the same.

Table 9. Levene's test of equality of error variances research QFL vs. DFL

DV	F	df1	df2	Sig.
Critical	2.355	3	68	.080
Creative	1.529	3	68	.215

The results of the Tests of Between-Subjects Effects learning model (QFL vs. DFL) and cognitive engagement (HCE vs. LCE) on critical thinking and creative thinking of students in physics learning are presented in Table 10.

Table 10. Tests of between-subjects effects QFL vs. DFL

Source	DV	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Critical	7749.167	3	2583.056	14.293	0.000
	Creative	4684.597	3	1561.532	8.346	0.000
Intercept	Critical	201189.389	1	201189.389	1113.222	0.000
	Creative	330891.125	1	330891.125	1768.459	0.000
Model	Critical	7120.222	1	7120.222	39.398	0.000
	Creative	4528.347	1	4528.347	24.202	0.000
CE	Critical	227.556	1	227.556	1.259	0.266
	Creative	78.125	1	78.125	0.418	0.520
CE * Model	Critical	401.389	1	401.389	2.221	0.141
	Creative	78.125	1	78.125	0.418	0.520
Error	Critical	12289.444	68	180.727		
	Creative	12723.278	68	187.107		
Total	Critical	221228.000	72			
	Creative	348299.000	72			
Corrected Total	Critical	20038.611	71			
	Creative	17407.875	71			

Based on Table 10, the following research findings can be presented. First, based on the source of the influence of the learning model (QFL vs. DFL) on students' critical thinking, it was found that the statistical value of F = 39.398 with sig. = 0.001 < 0.05. These results indicate that there is a difference in the effect between QFL and DFL on students' critical thinking in learning physics. Based on Table 11, it appears that M (QFL) = 62.81; SD = 2.24, while M (DFL) = 42.92 with SD = 2.24. The difference between the two mean values is M = 19.889 with SE = 3.169 and sig. = 0.001 (Table 12). So, the critical thinking of students who study with the QFL model is significantly higher than those who study with the DFL model.

Table 11. The mean (M) and standard deviation (SD) based on the QFL vs. DFL Model

DV	Model	M	SD	95% Confidence Interval	
				Lower Bound	Upper Bound
Critical	1.00	62.806	2.241	58.335	67.277
	2.00	42.917	2.241	38.446	47.388
Creative	1.00	75.722	2.280	71.173	80.271
	2.00	59.861	2.280	55.312	64.410

Table 12. Comparison of the mean (M) and standard error (SE) based on the QFL vs. DFL Model

DV	(I) Model	(J) Model	Mean Difference (I−J)	SE	Sig.	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Critical	1.00	2.00	19.889*	3.169	0.000	13.566	26.212
	2.00	1.00	−19.889*	3.169	0.000	−26.212	−13.566
Creative	1.00	2.00	15.861*	3.224	0.000	9.428	22.295
	2.00	1.00	−15.861*	3.224	0.000	−22.295	−9.428

Note: *This is a lower bound of the true significance.

Second, based on the source of the influence of the learning model (QFL vs. DFL) on students' creative thinking, it was found that the statistical value of F = 24.202 with sig. = 0.001 < 0.05 (Table 13). These results indicate that there are differences in the effect between QFL and DFL on students' creative thinking in learning physics. Based on Table 10, it appears that M (QFL) = 75.72; SD = 2.28, while M (DFL) = 59.86 with SD = 2.28. The difference between the two mean values is M = 15.861 with SE = 3.224 and sig. = 0.001 (Table 12). So, the creative thinking of students who study with the QFL model is significantly higher than those who study with the DFL model.

Third, based on the source of the influence of CE (HCE vs. LCE) on critical thinking, it was found that the statistic number F = 1.259 with sig. = 0.266 > 0.05 (Table 10). These results indicate that there is no difference in the effect between HCE and LCE on students' critical thinking in learning physics. Based on Table 12, it appears that M(HCE) = 54.639; SD = 2.241, while M (LCE) = 51.083 with SD = 2.241. The difference between the two mean values is M = 3556 with SE = 3.169 and sig. = 0.266 > 0.05 (Table 14). So, the critical thinking of students who have HCE is no different compared to those who have LCE.

Table 13. The mean (M) and standard deviation (SD) based on HCE vs. LCE QFL vs. DFL

DV	CE	M	SD	95% Confidence Interval	
				Lower Bound	Upper Bound
Critical	1.00	54.639	2.241	50.168	59.110
	2.00	51.083	2.241	46.612	55.554
Creative	1.00	68.833	2.280	64.284	73.383
	2.00	66.750	2.280	62.201	71.299

Table 14. Comparison of the mean (M) and standard error (SE) based on HCE vs. LCE QFL vs. DFL studies

DV	(I) CE	(J) CE	Mean Difference (I–J)	SE	Sig.	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Critical	1.00	2.00	3.556	3.169	.266	−2.767	9.879
	2.00	1.00	−3.556	3.169	.266	−9.879	2.767
Creative	1.00	2.00	2.083	3.224	.520	−4.350	5.517
	2.00	1.00	−2.083	3.224	.520	−8.517	4.350

Fourth, based on the source of the influence of CE (HCE v.s LCE) on creative thinking, it was found that the statistical number F = .418 with sig. = 0.520 > 0.05 (Table 9). These results indicate that there is no difference in the effect between HCE and LCE on students' creative thinking in learning physics. Based on Table 10, it appears that M(HCE) = 68.833; SD = 2.280, while M (LCE) = 66.750 with SD = 2.280. The difference between the two mean values is M = 2.083 with SE = 3.224 and sig. = 0.520 > 0.05 (Table 12). So, the creative thinking of students who have HCE is no different compared to those who have LCE.

Fifth, based on the source of interactive influence (CE * Model) on critical thinking with F = 2.221; sig. = 0.141; and students' creative thinking with F = 0.418; sig. = 0.520 (Table 9), it appears that there is no interactive effect between the learning model (QFL vs. DFL) and students' cognitive involvement (HCE vs. LCE) on critical thinking and creative thinking of students in learning physics.

This study aims to analyze the main and interactive effects of learning models (quantum flipped learning/QFL vs direct flipped learning/DFL) and cognitive engagement/CE (High CE/HCE vs Low CE/LCE) on students' critical thinking and creative thinking. in learning physics class XI at SMAN 4 Singaraja. The findings obtained are as follows.

4.2 Discussion

First, the QFL model has a greater effect than the DFL model on students' critical thinking and creative thinking. In other words, students who studied with the QFL model showed higher critical thinking and creative thinking compared to students who studied with the DFL model. The QFL model and the DFL model both use flipped learning (FL) as a tool to deliver pedagogical content that integrates with physics content. Quantum learning (QL) model and direct instruction (DI) model are packaged in the form of interactive videos with physics subject matter as the material content, so that the QFL model and DFL model are realized. So, the advantage of the QFL model compared to the DFL model in achieving critical thinking and creative thinking in this study is due to the influence of the QL model which is higher than the DI model. The findings of this study are in accordance with previous findings [16][23][25].

The QL model has a positive impact on students' critical thinking and creative thinking skills in learning. The QL model was more effective than the DI model in achieving students' critical and creative thinking [17]. The QL learning model can optimize students' brain work, experience-based learning activities, so that learning becomes interesting and fun, and allows students to be more creative [16]. The contextual problem-based QL learning model applied in mathematics learning can improve students' creative thinking skills [55]. The QL model can train students to find their own concepts that must be learned in their own way, so that students' memory becomes better. The QL model can improve student learning products in learning Physics [51]. The results of the meta-analysis concluded that the QL model can improve learning products and is effective in helping students to improve creative thinking [46]. The learning products of students who study with the QL model are higher than those who study with the DI model [18].

As a learning model, QL is an orchestration product of various interactions in and around the learning moment, is a learning that has the main mission to design a fun learning process that is adapted to the level of student development [16]. These interactions include the elements for effective learning that influence student success. In his book "Quantum Learning" the QL model gives students freedom of expression in learning. Students' freedom of expression in learning through the QL model is further increased when the QL model is combined into e-learning pedagogical content. The QL model which is packaged in the form of an interactive video with physics subject matter as the material content embodies the Quantum Flipped Learning (QFL) model. In addition to more intensive freedom of expression, students can also arrange study times and places to study according to their tastes, so that the QFL model truly becomes a vehicle for independent learning in order to support the development of their critical and creative thinking [56]. In such an independent learning condition, the teacher only needs to provide an authentic assessment, so that in learning students become very understanding of the obligations that must be fulfilled in undergoing the independent learning process. In other words, QFL is really a comfortable and enjoyable learning facility for students [56].

The QL model facilitates students' learning in a comfortable and fun way, because they can relate learning to everyday life, they can practice and listen to music that can stimulate students' thinking skills [16]. DePorter (1992) states: "By providing comfortable and fun learning, quantum learning facilitates students to build how-to-learn skills in taking notes, memorizing, reading quickly, writing and thinking creatively". This is because the QL model provides a comfortable learning process for students, they are free to express themselves well, so that their critical and creative thinking increases [57][58]. Quantum learning is a learning model that allows students to learn comfortably and happily, because they are the subject of learning directly in the learning process [59].

Second, this study reveals that there is no difference in critical thinking and creative thinking between students who have high cognitive engagement and students who have low cognitive engagement. This result is not in accordance with that found by [31], that high cognitive involvement is superior to low cognitive involvement in the achievement of learning products. This is thought to be caused by the fact that students are not familiar with cognitive engagement strategies in learning. The factors that influence students to be unusual in involving their cognitive engagement in learning are low interest, motivation, and learning attitudes [60]. In addition, learning strategies also have high potential to affect students' cognitive engagement [61]. In conditions of low interest, motivation, and learning attitudes, and learning strategies are also less accommodating to student needs, so they do not fully understand the learning activities that must be carried out when they have high cognitive involvement, so that the activity of empowering their critical thinking and creative thinking skills has no typical difference with students who have low cognitive involvement.

Third, this study also reveals that there is no interactive effect between the learning model (QFL vs. DFL) and cognitive engagement (HCE vs. LCE) on students' critical thinking and creative thinking skills in learning physics. These findings indicate that both high cognitive engagement (HCE) and low cognitive engagement (LCE) are accommodated in both the QFL and DFL models of physics learning. Cognitive involvement of students in learning physics is needed [33]. Therefore, they must be guided and motivated to have adequate cognitive involvement in interacting with the facilitator, with other students, and most importantly interacting with the subject matter and other learning facilities. Intensive motivation and guidance from facilitators to students in terms of cognitive engagement will be a vehicle for students to change their minds from passive to active involvement, and from constructive to interactive engagement [28]. Changes in these thoughts will affect the effectiveness of the learning process and the optimization of learning products.

5 Conclusions and implications

Based on the results of the analysis and discussion presented in the previous chapter, this chapter presents the research conclusions.

For the purpose of analyzing the difference between the main and interactive effects between the quantum flipped learning model vs. the direct flipped learning model and cognitive involvement on students' critical and creative thinking in physics learning in class XI SMA Negeri 4 Singaraja, the following findings were obtained. 1) There is a different between the quantum flipped learning model and the direct flipped learning model on students' critical thinking and creative thinking. 2) The critical thinking and creative thinking of students who study with the quantum flipped learning model are significantly higher than students who study with the direct flipped learning model. 3) There is no different effect between students who have high cognitive involvement and those who have low cognitive involvement in critical thinking and creative thinking. 4) There is no interactive effect between the learning model (quantum flipped learning vs. direct flipped learning model) and cognitive engagement (high cognitive involvement vs. low cognitive engagement) on critical thinking and creative thinking of students in physics learning in class XI in high school. The implication of the findings of this study is that in achieving critical thinking and creative thinking skills in physics learning, the quantum learning model and the direct flipped learning model are both accommodative to students' high cognitive engagement and low cognitive engagement. In studying physics in class XI SMA on wave and optical materials, the learning process and results, especially the results of students' critical thinking and creative thinking, will be more optimally achieved if they are facilitated with the quantum flipped learning model. This study found that students were not influenced by their cognitive involvement in the achievement of critical thinking and creative thinking, but they should be given more intensive guidance to be able to engage in more cognitive activities in order to optimize their learning process in physics learning in class XI SMA.

Based on the research implications described in the conclusion section above, the following research suggestions can be proposed. In achieving critical thinking and creative thinking skills in physics learning in class XI SMA in the subject matter of waves and optics, the quantum learning model and direct flipped learning model are both accommodating to high cognitive engagement and low cognitive engagement of students. Therefore, it is suggested that in learning physics the teacher empowers the potential of students' cognitive involvement optimally in applying the learning model. In studying physics in class XI SMA on wave and optical materials, the learning process and results, especially the results of students' critical thinking and creative thinking, will be more optimally achieved if they are facilitated with the quantum flipped learning model. Suggestions that can be submitted to physics teachers in high school are to be willing and able to change the paradigm from the habit of applying direct instruction to implementing the quantum learning model. In achieving critical thinking and creative thinking, students should be given more intensive guidance so that they are willing and able to engage in more cognitive activities in order to optimize their learning process in physics learning in class XI SMA.

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