

Article

The Effects of Computer-Assisted Learning Based on Dual Coding Theory

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Abstract: This research explored the integration of dual coding theory and modern computer technology with symmetry into a vocabulary class to improve students' learning attitude and effectiveness. Three research questions are addressed in this research on the effects of computer-assisted learning based on dual coding theory (DCT). This experimental research was carried out in a high school in a remote rural area in China. The study was conducted in two parallel classes (the experimental and the control) in Grade 8 with a total of 88 students. Our research methods included pre- and post-test, questionnaires, and an interview with symmetry as the focus to obtain the results as follows: (1) Using the integration of computer assisted language learning (CALL) and DCT to effectively improve students' learning attitude, (2) transforming students' traditional learning methods into the dual coding method, and (3) enhancing students' vocabulary learning effectiveness.

Keywords: dual coding theory; computer assisted language learning; learning attitude; learning effectiveness

1. Introduction

With the rapid development and popularization of network computer technology, how to apply the new technology to education has become a hot topic of general concern to educational scholars. There have been many studies using CALL (Computer Assisted Language Learning) in teaching, and in the process of computer-assisted teaching, many pictures and visual effects are bound to be used to present the language teaching content. As one of the three major elements of language, vocabulary is the material that constitutes the heart of language. Without adequate vocabulary, language loses its meaning [1]. Therefore, vocabulary acquisition is one of the most important parts of language learning. However, teachers often adopt traditional vocabulary teaching methods due to factors such as tight schedules and heavy tasks. Students recite words by themselves, frequently using the rehearsal strategy to memorize words [2]. In order to improve students' vocabulary learning ability, more attention should be paid to exploring correct vocabulary teaching methods. The dual coding theory (DCT), proposed by Paivio in the 1970s, was one of the most important principles at that time [3]. The DCT was first put forward by Paivio [3]. The theory is a description of human cognitive process, including two distinct but interconnected input channels: verbal and non-verbal systems. During the cognitive process, both language generators—logogen—and image generators—imagens— (visual, auditory) were used to activate stimuli. Compared with unitary coding, Paivio strongly believes that using both two systems is more effective than one. The theory attempts to put visual and verbal cognition in equally important positions. By using the visual and verbal system with symmetry in both the left and right hemispheres of the brain, students' learning situations can be improved. This paper

aims to investigate the effect of applying computer-assisted dual coding theory (DCT) (a theory about processing by the human cognitive system) to vocabulary teaching, especially in a high school. This research is conducted on the symmetry subject of vocabulary involved in two parallel classes in Grade 8 in a high school in China. The number of research participants was 88 students around 15 years old who had studied English for at least five years. Class one was the control class (CC), which included 43 students (21 girls and 22 boys), and class two was the experiment class (EC), which included 45 students (22 girls and 23 boys). In this research, we investigated the effectiveness of applying the integration of computer assisted language learning (CALL) and DCT. Moreover, we aimed to explore students' attitudes towards visual assisted vocabulary learning based on dual coding theory. This paper is also devoted to researching the changes in the learning method of high school students using dual coding theory and computer-assisted instruction. Finally, this paper discusses to what extent the computer-assisted dual coding theory improved student's vocabulary learning in a high school.

2. Related Work

2.1. Dual Coding Theory

The dual coding theory (DCT) was first put forward by Allan Urho Paivio, a Canadian psychologist from the University of Western Ontario, in 1970s. The theory is a description of the human cognitive process, including two distinct but interconnected input channels: the imagery system and the verbal system. The verbal system deals with modality-specific verbal codes, which are visual, auditory, etc. (e.g., words and book, teacher and study). Verbal system is specialized for processing verbal information (language); it deals with linguistic input and stores linguistic information. The nonverbal system is specialized for the processing of nonverbal objects and events like mental imagery; it deals with visual images and emotional reactions. It has been found that the left hemisphere of the human brain is good at processing verbal information, while the right hemisphere is good at processing representation information [4], which is in line with the DCT's belief that the human cognitive system is composed of two coding systems. Figure 1 is a schematic diagram of the main elements of dual coding theory; it clearly explains the process of the human cognitive system. The model includes the internal organization and connections of the two systems: verbal and nonverbal, and the three levels of processing: representational processing, referential processing, and associative processing.

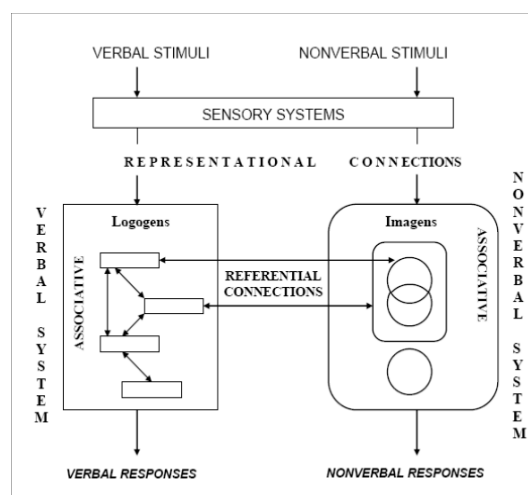


Figure 1. General model of the dual coding theory (DCT) [5].

Figure 1 explains the processing of our cognitive system, which involves the organization of the two coding systems mentioned above: the verbal and nonverbal systems, and the three levels of processing: representational processing, referential processing, and associative processing. The top of

the model shows that the cognitive process begins with the sensory system's initial detection of verbal and nonverbal stimuli from the real environment. As vividly shown in Figure 1, the organization of the verbal system is sequential and hierarchical, which indicates that it is modeled like a network. On the other hand, the imagens in the nonverbal system are constructed in an overlapping and nested way. Representation processing is the direct activation of sensory systems and the activation of logogens in a verbal system and imagens in a nonverbal system. For example, when we see a picture of a monkey, the image stimuli will trigger our visual system, while on seeing or hearing the word panda, the verbal stimuli will also activate our verbal system and form logogens. There are two factors to decide which representations are to be activated: the stimulus situation and the individual differences. When "I" occurs in the context of the word "love", it means the letter "I". However, if "I" is put in a series of numbers, it will more likely to be considered as the number "one" [6]. With the application of multimedia in the field of education, the traditional teaching mode can be updated and reformed. Thus, it enhances students' interest and helps the understanding and memory of language. Computer assisted language learning (CALL) refers to the use of computers as the main media to help foreign language teachers in education activities. More specifically, teachers use computer screen-displayed text, pictures, sound, calculations, control, storage, and other functions to improve the quality of their teaching. Levy defines CALL as finding and studying how to apply computers in language teaching [7].

CALL has a history of more than 40 years. The development of CALL can be divided into three stages: behaviorist CALL, communicative CALL, and integrative CALL. Behaviorist CALL started in the late 1950s, and was based on the behaviorist learning model and consisted of drill-and-practice materials. Based on the increasingly prominent communicative approach, communicative CALL became popular in the 1980s. From the early 1990s to the present, integrative CALL has been very popular.

2.2. Vocabulary Learning and Dual Code

In contrast to dual coding theory, the context-availability method denies that the faster identification of concrete and abstract nouns is determined by different types of information processing systems; this theory explains that specific nouns have greater context support [8]. Compared with abstract words, concrete words have stronger or broader associations with context materials. Similarly, Schwanenflugel and Stowe also agree with this explanation and believe that concrete nouns activate more associative information, thereby hastening the process of recognition [9]. However, if the context of the abstract word is meaningful and there is enough verbal information to support it, the abstract word will be recognized as quickly as the concrete word. The difference between context-availability and dual-coding theory lies in the process and place where the information is stored and processed [10]. Many studies have proven and compared the two rival theories' effectiveness in vocabulary learning. By comparing this two theories, Sadoski, Goetz, and Avila concluded that their results were more consistent with the dual coding theory. The results of previous research [11] also showed that pre-teaching with visual aids has a positive effect on vocabulary acquisition compared with pre-teaching with only written context. They believe that this multi-modal approach improves learners' ability to pay attention to vocabulary items and thus increase their vocabulary learning. However, one study [12] concluded that both dual-coding theory and the situational availability method are effective for vocabulary learning, and no one effective vocabulary teaching method is superior to the other. Therefore, it is thought that the dual-coding theory and the context-availability method can be combined or used independently, depending on the subject-matter; it is suggested that interesting pictures should be carefully chosen and used for word recall, and that various techniques should be used to avoid boredom. Research proves there is a link between rote memory and dual coding theory [13]. The authors studied the effects of rote memorization, background, keywords, and keyword methods on the long-term retention of vocabulary by studying 160 ninth-grade students from two schools in Trujillo, Venezuela [14]. The results show that in both long-term and short-term memory, the effects of other methods are lower than

that of the context method. Rodríguez and Sadoski claim this result can be explained by DCT [5], and that the information processed through both the verbal system and image system will obtain stronger memory traces and more retrieval paths, thus enhancing vocabulary memory. Context method or rote method primarily activates the verbal system, whose effect is lower than the context method, which is activated in both the verbal and the image system. As more elaboration is offered in the context approach, it is also superior to the keyword approach by which both systems are also activated.

2.3. The Application of Dual Coding Theory to Vocabulary Teaching

The application of dual coding theory in vocabulary teaching in a multimedia situation offers many benefits. In the first place, multimodal input like text, graphics, sound, animation, video, etc., can be provided by computer technology. According to dual coding theory, visual, verbal, and sound sensory stimuli carried out at the same time maximally help foreign language learners to understand the learning materials and master the language forms [15]. Effective vocabulary teaching should be a combination of pronunciation, spelling, word meaning, grammar rules, collocation, internal relations, external relations, and pragmatic rules of words. In this way, with the use of multimedia courseware, students are able to imagine images to link the new words with existing knowledge, emotional experience, or real life experience to help them understand and enjoy longer retention of new vocabulary [16]. Mayer explained the concept of cognitive overload in multimedia learning theory [17] and implied that learners should not process too much information which exceeds their available cognitive capacity. Too many pictures can attract students' attention to them but not to the words. The dual coding theory can be used to shape the diversified education samples. The combination of specificity, image, and language has a profound influence in different fields of education: the characterization and understanding of knowledge, the retained memory and learning of school textbooks, effective guidance, individual differences, and the motivation to realize achievements, overcome test anxiety, and master motor skills. Dual coding also has an impact on educational psychology, especially educational research and teacher education [18]. Additionally, one study [19] maintains that the theory of dual coding not only provides a unified interpretation of different topics in education, but its framework can also be applied to other high-level psychological processes. The theory of dual coding provides a concrete model for the behavior and experience of students, teachers, and educational psychologists, and can strengthen the understanding of educational phenomena and teaching practice. Other research [20] investigated the aspect of computer-assisted learning more specifically. The participants were Japanese college science freshmen. The study showed that with online learning, those learning English phrasal verbs with pictures processed information faster and associated non-verbal codes with concepts better. However, the study also found that only relying on picture media is insufficient; other media should also be put into use, reminding us to carefully select pictures, phrasal verbs, and problem formats.

3. Research Method

According to the theory presented in a literature review, compared with the traditional approach, students who accepted dual coding and image creation interventions attained a higher level of vocabulary acquisition. This paper investigates the effectiveness of computer assisted learning based on DCT as the novel teaching method. The proposed research architecture is shown in Figure 2. A framework is used to analyze the influence of computer assisted learning based on DCT teaching effectiveness on the students' studying vocabulary. Furthermore, a questionnaire was designed to investigate the symmetric relationship between variables and statistical methods for analyzing empirical data and verification for answering the research questions. Both quantitative and qualitative research approaches were applied in this study to analyze the data more effectively and reliably. The main research instruments (methods) included: the same pre- and post-questionnaire on students' attitudes, a pretest and a post-test, an interview, and SPSS program version 19.0.

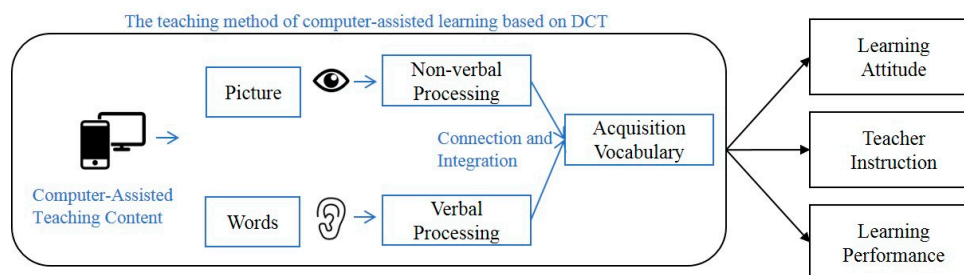


Figure 2. The research architecture.

These research questions are stated below:

1. What are students' attitudes towards visual assisted vocabulary learning based on dual coding theory?
2. What are students' opinions of computer-assisted dual coding theory instruction?
3. To what extent does computer-assisted dual coding theory improve student's vocabulary learning in high school?

3.1. Research Participants

The research participants were 88 students around 15 years old selected randomly from two parallel Grade 8 classes in a high school who had studied English for at least five years. During the four months of vocabulary instruction, the teaching method of dual coding theory was consciously applied to teach vocabulary in the experimental class (EC) with the aid of multimedia. Table 1 shows the background information of the participants.

Table 1. Background information of the participants.

Class	Experimental Class		Control Class	
Student Number	Boys	23	Boys	22
	Girls	22	Girls	21
Total Students	45		43	
Teaching Method	DCT-based Instruction		Traditional Method	

The choice of these students was reasonable because the number of samples was consistent with the results of Gay's research [21]. They claimed that when performing correlation analysis, the scale of the sample should exceed 30 in a group. Additionally, the students were all teenagers whose learning methods were easy to form. They did not previously develop a stable learning habit, even though they had an English learning experience for nearly five years [22]. The specific data analysis is conducted in Section 4. Two tests were given to the participants. One was the pre-test which was completed by all the participants before the experiment to examine their level of vocabulary. The other, a post-test, was administrated after the experiment to verify their achievements. The pre-test was a vocabulary test conducted in the first semester in the second grade of junior school (i.e., Grade 8). All the students, including 45 students in the experimental class (EC) and 43 students in the control class (CC), participated in the pre-test. The vocabulary covered in the test was selected from key words in the word list. The structure of the test included English–Chinese translations and Chinese–English translations, each accounting for 20 points, including both concrete and abstract words [22]. In order to increase the validity of the test, the third type of questions was derived from the city high school entrance examination test from recent years. The aim was to test students' mastery of spelling and meaning of words.

3.2. Questionnaires and Interview

Students were reassured the questionnaires were collected anonymously in order to ensure that the data were true and reliable to garner first-hand information about the effect of vocabulary teaching. The questionnaire was distributed to 88 Grade 8 high school students. After a four-month experiment, two questionnaires (Questionnaires I and II) were designed to answer Research Questions 1 and 2. The questionnaires were designed to elicit: students' basic views on learning vocabulary; their own main use of the word memory method normally used; and their views of the teaching methods used by teachers in the classroom. The questionnaire investigated the main attitudes and means of students when encountering difficulties in memorizing words; the last part investigated the teaching methods that students hope to see in the classroom. In order to understand their changes in terms of vocabulary learning methods after the experiment, the researcher handed out the same questionnaire again to all the students in the EC.

The questionnaires in this study were designed based on the research architecture (see Figure 2). Meanwhile, the design of the questionnaires referred to the references related to this research, whose questionnaires have higher reliability and validity (see Table 3). Additionally, the adaption and revision of these questionnaires matched the aims of this study, mentioned above. Furthermore, all questionnaire items were designed by the use of multiple-choice questions because they can be rapidly coded and speedily accumulated to present frequencies of response (Cohen, Manion, and Morrison, 2007) [23]. Such a kind of questionnaires is very easy and convenient to analyze for researchers. In this study, Likert's five-scale is also adopted in this questionnaire. Regarding five degrees from "strongly disagree" to "strongly agree", "1" stands for "strongly disagree", "2" means "disagree", "3" represents "neutral", "4" refers to "agree", and 5 shows "strongly agree". Because there was only one choice for each question, answers to the questions are easier and more convenient for calculation and statistical analysis so that attitudes and opinions of participants can be tested. Finally, the questionnaires (Questionnaires I and II) were to address Research Questions 1 and 2 respectively, along with some interview questions. The statistical results from both indicated the findings or the conclusion of the two research questions. On the whole, the design of the questionnaires was closely related to the research design so that the objectives of this study could be reached smoothly. In order to collect the attitudes and opinions of students in terms of vocabulary learning methods more directly, the researchers surveyed 10 interviewees in the experimental class. The interview questions were divided into eight questions to investigate respondents' views on the teaching methods. Throughout the interview, the interviewees could express their opinions and share their experiences to ensure that the results of the interview would be meaningful. The interview questions were conducted in Chinese throughout, ensuring that every issue could be accurately communicated. The interviewees' answers underwent a truthful translation and analysis in English.

3.3. Research Procedures

The study was carried out in 2018. Eighty-eight high school students participated in the experiment altogether. One of the authors used computer-assisted dual coding theory to improve students' attitude and memory in the EC, while using traditional vocabulary teaching method in the CC. The research procedures included a pilot study, pre-questionnaire, pre-test, vocabulary teaching, post-questionnaire, post-test, and interview. In brief, tests and questionnaires were used to determine the extent to which the computer-assisted dual coding theory could improve students' vocabulary learning. The detailed research procedures have shown in Table 2.

Cohen [23] pointed out that a pilot study is needed in order to prove the reliability of questionnaires. The questionnaires used in the experiment were administered as a pilot study among 30 students in Grade 8 but not in the EC and CC. Questionnaire I and Questionnaire II were adapted from Zhang [24] and Gu and Johnson [2]. According to the reliability analysis of SPSS shown in Table 3, the reliability coefficients Cronbach's values were 0.80 and 0.76, respectively, which was relatively high, showing that the questionnaires were reliable enough.

Table 2. Detailed research procedures.

Steps	Procedures	Participants
1	Pilot study	30 selected randomly
2	Pre-questionnaire	EC and CC
3	Pre-test	EC and CC
4	Vocabulary teaching	EC and CC
5	Post-questionnaire	EC and CC
6	Post-test	EC and CC
7	Interview	EC

Table 3. Reliability statistics of questionnaires.

Questionnaire	Cronbach's Alpha	N of Items
I	0.80	20
II	0.76	20

4. Results and Discussion

In this research, both qualitative and quantitative analyses were used to address the three research questions. The data from vocabulary tests, questionnaires, and interviews were arranged for analysis and discussion.

4.1. Data Analysis and Discussion of Research Question 1 (RQ1)

Research Question 1 is about students' attitude towards visually assisted vocabulary learning based on dual coding theory (DCT). The first questionnaire included two parts: the students' attitude regarding vocabulary learning and their attitude regarding the teaching method. It was distributed to the EC students before and after the experiment in order to find out if the students' attitude changed with the help of DCT teaching. The first and second questionnaires (Questionnaires I and II) consisted of 20 questions each. There are five scales of choice to reveal the degree of affective responses. Before the experiment, the participants' total average values of attitude on vocabulary learning between EC and CC were similar, indicating similar initial attitude levels regarding vocabulary learning. After the experiment, the total average of EC students reached 3.76, while the total average of CC was 2.99. With the help of dual coding theory, the students' attitude towards vocabulary improved significantly in EC. In addition, the independent sample *t*-test between EC and CC was used to test whether the attitude towards English vocabulary had changed. *T*-test scores of independent samples from pre-questionnaires in EC and CC on vocabulary attitudes showed that students from EC did not significantly differ from the students from CC about vocabulary attitudes ($t(86) = 0.211, p > 0.05$). Inspections of both groups' means indicated that the average vocabulary attitudes of EC were similar to CC. The difference between the means was 0.21395 points. The results are shown in Table 4.

Table 4. Results of Research Question 1.

	Class	N	Mean	Std. Deviation	Std. Error Mean
Pre-questionnaire	EC	45	59.4000	3.99659	0.59578
	CC	43	59.1860	5.43908	0.82945
Post-questionnaire	EC	45	75.2444	3.16340	0.47157
	CC	43	59.7907	4.38373	0.66851

The two groups had the same level before the experiment. With the help of DCT in the experiment, students from EC significantly differed from those in CC in vocabulary learning attitudes ($t(86) = 19.027, p < 0.05$). Inspections of the two groups' means indicate that the average of EC (75.2444) was significantly higher than the score of CC (59.7907). The difference between the means was

15.45375 points. Therefore, the students in EC significantly improved in their vocabulary learning attitude with the help of DCT. To sum up, the analysis of Questionnaire I and the follow-up interview addressed Research Question 1. EC students' attitudes improved after 4 months of teaching based on computer-assisted dual coding theory, which was in line with many other researchers' claims. They held positive attitudes to pictures, which make the learning process more pleasant and memorable.

4.2. Data Analysis and Discussion of Research Question 2 (RQ2)

In order to verify the change of students' learning method after the research, the questionnaire on students' English vocabulary learning and the interview were designed. The mean values of the EC and CC students' use of traditional learning methods were 3.36 and 3.35, respectively, with only 0.01 difference. Nevertheless, change resulted after the use of the DCT. In the post-questionnaire, the total mean value of the students in EC was 2.37, while the total mean value of the CC students on use of traditional method was 3.34. In the post-questionnaire, the mean difference of EC was 0.08 points lower than that of CC. Through these results, we can see that this experiment made the EC students use the traditional vocabulary learning method less compared to the CC students. Students from EC were not significantly different from CC students regarding the use of traditional learning methods ($t(86) = 0.171, p > 0.05$). Inspections of the two groups' means indicated that the average score for students' use of traditional learning method in EC (33.6222) was similar in that in CC (33.4651). It was obvious that the two groups had the same level before the experiment. The difference between the means was 0.15711 points.

The data statistics show that students from EC significantly improved compared to those in CC regarding vocabulary learning attitudes ($t(86) = -11.462, p < 0.05$). Inspections of the two groups' means indicated that the average score on students' use of traditional learning methods in EC (23.6889) was significantly lower than that in CC (4.18628). It was obvious that the two groups had the same level before the experiment. The difference between the means was -9.68320 points. Therefore, the students in EC used traditional methods less after the vocabulary teaching based on DCT. The mean values of the students in EC and CC on the application of traditional learning method only differed by 0.01. It can be deduced that before this experiment, the students in EC and CC were at similar levels in using the DCT method. The total mean value of EC students in the post-questionnaire increased to 3.24 through the experiment, while the total mean value of the CC students in the post-questionnaire was 2.25, nearly the same as in the pre-questionnaire. The mean difference of the EC in the post-questionnaire was 0.09 points higher than that of the CC in post-questionnaire. These results showed that through this experiment, the EC students used the DCT vocabulary learning method more than the CC students did. The data statistics indicate that students from EC did not significantly differ from CC students on the use of the DCT learning method ($t(86) = 0.160, p > 0.05$). Inspections of the two groups' means indicated that the average score of EC students using the DCT learning method was similar to the score of the CC students. The difference between the means was 0.13798 points. The two groups were at the same level before the experiment. This showed that students from EC differed significantly from those in CC regarding vocabulary learning attitudes ($t(86) = 11.076, p < 0.05$). Inspections of the two groups' means indicated that the average score of students' use of DCT learning method in the EC (32.3778) was significantly higher than that in the CC (22.5349). The difference between the means was 9.84289 points. Table 5 shows that the students in EC used the DCT learning method more with the training of DCT.

It can be concluded from the results of Questionnaire II and the follow-up interview that the students were fully aware of the benefits of DCT and that most of them used this strategy to learn vocabulary. After a period, the participants improved their traditional learning methods including transcription and mnemonics. They began to learn words through visual, auditory, tactile, or emotional means, for example, watching English movies and animations. In this way, they were more interested in vocabulary learning and became more confident regarding English study, which had a positive and deep influence on English vocabulary learning.

Table 5. Results of the students' use of the DCT learning method.

	Class	N	Mean	Std. Deviation	Std. Error Mean
Pre-questionnaire	EC	45	22.5333	4.12090	0.61431
	CC	43	22.3953	3.94691	0.60190
Post-questionnaire	EC	45	32.3778	4.63332	0.69069
	CC	43	22.5349	3.61445	0.55120

4.3. Data Analysis and Discussion of Research Question 3 (RQ3)

In the research procedures, a pre-test and a post-test were conducted before and after implementing the DCT-based instruction. The pre-test was designed to find out whether the EC and CC students were at the same English level, while the post-test aimed to verify whether the application of DCT in junior high school was beneficial in improving students' achievement in terms of their English vocabulary level. The pre-test in the EC and CC on vocabulary was designed to find out whether the students were at the same vocabulary learning level. The mean values of the students in the EC and CC were 25.9333 and 25.9302, respectively, with the mean difference of 0.0031 between them from the students' vocabulary achievements in the pre-test result. Furthermore, the standard deviations of the EC and CC were 1.59716 and 1.67563, respectively. Therefore, the students' scores in these two classes were similar. It seems that the students in EC and CC were generally at the same level in terms of vocabulary learning level. From the results of the independent samples *T*-test for scores of the pre-test in EC and CC on vocabulary, the EC and CC students' vocabulary achievements in the pre-test were almost at the same level. The significance value was 0.999, which was higher than 0.05, indicating no significant difference between the EC and CC subjects' vocabulary achievements. The post-test was designed to investigate the difference between the EC and CC students after the research. The data show that the mean value of the students in EC on vocabulary was 31.6667, while the mean value of the students in CC was 25.8837 in the post-test. From the mean value, the EC students got higher scores than the CC students did after this experiment; the difference of scores was 5.78295. Regarding the independent samples *t*-test of students' vocabulary achievements between the students in EC and CC, the significance (2-tailed) value was 0.015, which was lower than 0.05. Thus, we can conclude that through the experiment, the EC and CC students significantly differed in vocabulary achievements. In order to verify that the EC students made significant improvement in vocabulary learning, a paired samples *t*-test was used. The data reveal that the mean value of EC students' vocabulary score increased from 25.9333 in the pre-test to 31.6667 in the post-test. The students' mean score increased by 8.2245, indicating that by applying dual coding theory to vocabulary teaching in a high school, students' vocabulary achievements can be greatly improved. We also compared the EC students' vocabulary achievements in the pre-test and post-test. It showed $t(44) = -5.387, p < 0.05$. The output of the paired sample *t*-test showed that EC students' vocabulary achievement in the post-test significantly differed from that in the pre-test. Therefore, we can say that to some extent, applying computer assisted DCT to vocabulary learning can greatly improve students' vocabulary learning. The CC students' vocabulary scores in the pre-test and post-test were also analyzed in this part to further verify the effectiveness of applying DCT to vocabulary learning. We showed that the CC students' mean value of pre-test on vocabulary was 25.9302. Comparatively, in the post-test, the mean value was 25.8837. The CC students before and after the research were approximately at the same level in terms of vocabulary achievement. The results of the pre- and post-tests for the CC students on vocabulary learning can be seen in Table 6, the $t(42)$ score was 0.61 and $p > 0.05$; they did not make significant progress in vocabulary learning, which was different from the result of students in EC.

To sum up, through qualitative and quantitative analysis, it can be concluded that appropriate visual materials have a positive effect on vocabulary teaching. When students learn vocabulary through text such as sentences and translation, compared with through visual materials, they may forget them more easily. In addition, it should be noted that the pictures are more attractive, and the students

will be more interested in vocabulary learning; therefore, this method improves the learning effect of students, which is consistent with the results of Hashemi and Pourgharib [25].

Table 6. Result of the students' use of the DCT learning method.

	Class	N	Mean	Std. Deviation	Std. Error Mean
Pre-questionnaire	EC	45	25.9333	10.71405	1.59716
	CC	43	25.9302	10.98786	1.67563
Post-questionnaire	EC	45	31.6667	10.83345	1.61496
	CC	43	25.8837	10.91790	1.66496

4.4. Summary

In this paper, quantitative and qualitative data including a questionnaire, interview, and test were collected, analyzed, and discussed based on the three research questions; Table 7 summarizes the research results related to the three research questions.

Table 7. Summary of the results for the three research questions.

Research Question (RQ)	Research Instrument	Major Finding
RQ 1: What are students' attitudes towards visual assisted vocabulary learning based on dual coding theory?	Questionnaire I (Q1–Q20) and interview (Q1–Q3)	After receiving vocabulary teaching based on DCT, the EC students have a more positive attitude towards vocabulary learning, which is conducive to vocabulary learning.
RQ 2: What are students' opinions of computer-assisted dual coding theory instruction?	Questionnaire II (Q1–Q20) and interview (Q4–Q6)	The EC students tend to use traditional rote learning less but more DCT strategies to remember words. They also offered new suggestions on new vocabulary teaching method.
RQ 3: To what extent does the computer-assisted dual coding theory improve students' vocabulary learning in junior high school?	Pre-test and post-test and interview (Q7–Q8)	With the help of DCT training, EC students' performance in the post-test of vocabulary was significantly better than that in the pre-test.

This paper shows that EC students made great progress in this experiment. First of all, the computer assisted DCT vocabulary learning strategy training has a positive effect on constructing positive vocabulary learning attitudes. Secondly, through training, students use the DCT learning method more than the traditional method in vocabulary learning. They offer more new suggestions about vocabulary learning methods. Finally, applying DCT vocabulary learning has greatly enhanced students' vocabulary achievement. By combining both qualitative and quantitative analysis, some findings of the experiment are concluded:

- **Major findings on Research Question 1:** The results of Questionnaire I and the follow-up interview indicate that the computer-assisted dual coding teaching method can improve participants' attitudes towards vocabulary learning. Through the experimental process, students can acquire visual and audio information via pictures, video, audio, and multimedia, so that they experience higher interest in learning. This finding supports the idea of Cohen and Johnson [26] that students were more interested and paid more attention to vocabulary teaching. In addition, through the process of group discussion and image formation, participants were more willing to engage in learning activities, which increased their learning enthusiasm. To recap the findings of Research Question 1, EC students' attitudes were improved after four months of teaching based on computer-assisted dual coding theory. In other words, they held a positive attitude to pictures, which made the learning process more pleasant, meaningful, and memorable. This finding is in

line with Kim and Gilman [20]. Compared with their study, a more detailed analysis process was conducted by the researcher; for example, the study adopted both quantitative and qualitative analysis methods.

- **Major findings on Research Question 2:** In this study, the results of Questionnaire II and the interview show that the interviewees are fully aware of the benefits of DCT and used this strategy more frequently to learn vocabulary, which is consistent with the study of Yanasugondha [18]. After the experiment, the participants improved their traditional learning methods including transcription and mnemonics. Through the training of image formation, students can understand and memorize words with the help of visual, auditory, haptics, feelings, and other aspects, combined with the student's own experience in daily life. The researcher introduced the DCT method at the beginning of the experiment, and then gradually combined this method with technology to present pictures or videos related to new words in each class. After that, some practice instructions were given to help consolidate students' memory. After a period of time, the participants improved the original method of rote learning. They liked to use visual, auditory, tactile, or emotional tools to learn more words, for example, by watching English movies and animations. In this way, they became more interested in vocabulary learning and more confident in English study, which has a positive and deep influence on vocabulary learning. Furthermore, they can think of other new methods for learning vocabulary, which is in line with Cohen and Johnson [26].
- **Major findings on Research Question 3:** From the pre- and post-test results, it can be proven that the computer-assisted dual coding theory is beneficial to vocabulary teaching in school. It improved students' vocabulary scores to a large extent. In the comparison with pre- and post-test results, EC students' scores greatly improved, and it is not difficult to imagine that students will improve their vocabulary level in their future studies by using this method effectively. Compared with traditional teaching, the students can shape their own images in the memory process. Additionally, students can not only improve their memory accuracy, but also reduce the burden of learning as well as avoid bad learning habits such as rote learning. They feel that vocabulary learning has become easier for them. After using the vocabulary teaching method, these students have formed an effective and self-disciplined new vocabulary learning method. Therefore, the vocabulary teaching method based on DCT plays a very vital role in improving students' vocabulary proficiency, which is consistent with the results of Hashemi and Pourgharib [25].

5. Conclusions

Based on the symmetry approach, this research proposed the integration of dual coding theory and modern computer technology into vocabulary classes to improve students' learning attitudes and effectiveness. According to the research results summarized above, the implications are as follows: firstly, visual aids like pictures or videos should be presented to help students learn vocabulary. It is proven that teaching vocabulary with vivid pictures and images and can be more meaningful, while also attracting the attention of students. Through the integration of CALL and DCT, students will be more positive concerning learning words, which will deeply influence their future studies. It was shown herein that the integrated method can effectively improve the learning attitude of students. Moreover, during the DCT vocabulary teaching process, instead of being forced to accept this learning method, the students in the experimental class were guided to develop the habit of forming images gradually and naturally. They found this method more effective and interesting, which makes them prefer using this new method. This study helps prove that dual code theory enhances students' learning methods. Outside of using image formation, teachers should also give feedback and evaluation of a student's or group's answers in a timely manner. In order to help students have a deeper understanding of vocabulary, the teacher's own image examples can also be presented to them when necessary. Finally, students will improve their attitude towards learning, consciously associate

words with images to remember words, and effectively improve their academic performance. The most significant implication in this research is applying modern technology into the field of education with the advanced DCT concepts to maximally improve the quality of education. To conclude, there is no doubt that the innovative vocabulary teaching approach based on DCT plays a very significant part in enhancing EFL (English as a foreign language) students' vocabulary achievements and language teachers' teaching quality. Meanwhile, the present research enlightens educators regarding future language teaching and research.

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References

1. Wilkins, D.A. *Linguistics in Language Teaching*; Edward Arnold: London, UK, 1972.
2. Gu, Y.Q.; Johnson, R.K. Vocabulary Learning Strategies and Language Learning Outcomes. *Lang. Learn.* **1996**, *4*, 643–679. [\[CrossRef\]](#)
3. Paivio, A. *Imagery and Verbal Processes*; Holt, Rinehart and Winston (HRW): New York, NY, USA, 1971.
4. Rizzolatti, G.; Umiltà, C.; Berlucchi, G. Opposite Superiorities of the Right and Left Cerebral Hemispheres in Discriminative Reaction Time to Physiognomical and Alphabetical Material. *Brain A J. Neurol.* **1971**, *94*, 431–442.
5. Paivio, A. *Mental Representations: A Dual Coding Approach*; Oxford Psychology Series: New York, NY, USA, 1986.
6. Nuramah, H. The Effects of Using Dual-Coding Theory in Teaching English Reading Comprehension among Vocational Students at Narathiwat Technical College. *Int. J. Arts Humanit. Soc. Sci. Stud.* **2019**, *4*, 1–6.
7. Levy, M. *CALL: Context and Conceptualization*; Oxford University Press: New York, NY, USA, 1997.
8. Schwanenflugel, P.J.; Shoben, E.J. Differential Context Effects in the Comprehension of Abstract and Concrete Verbal Materials. *J. Exp. Psychol. Learn. Mem. Cogn.* **1983**, *9*, 82–102. [\[CrossRef\]](#)
9. Schwanenflugel, P.; Stowe, R.W. Context Availability and the Processing of Concrete and Abstract Words in Sentences. *Read. Res. Q.* **1989**, *24*, 114–126. [\[CrossRef\]](#)
10. Alam, Y.S.; Oe, Y. E-Learning of English Phrasal Verbs via Pictorial Elucidation and L1 Glosses. In Proceedings of the 12th IEEE International Conference on Advanced Learning Technologies, Rome, Italy, 4–6 July 2012.
11. Alamri, K.; Rogers, V. The Effectiveness of Different Explicit Vocabulary-Teaching Strategies on Learners' Retention of Technical and Academic Words. *Lang. Learn. J.* **2018**, *46*, 622–633. [\[CrossRef\]](#)
12. Soyulu, B.A.; Yelken, T.Y. Dual-coding Versus Context-availability: Quantitative and Qualitative Dimensions of Concreteness Effect. *Procedia Soc. Behav. Sci.* **2014**, *116*, 4814–4818. [\[CrossRef\]](#)
13. Sadoski, M.; Goetz, E.T.; Avila, E. Concreteness Effects in Text Recall: Dual Coding or Context Availability? *Read. Res. Q.* **1995**, *30*, 278–288. [\[CrossRef\]](#)
14. Rodriguez, M.; Sadoski, M. Effects of rote, Context, keyword, and Context/keyword Methods on Retention of Vocabulary in EFL Classrooms. *Lang. Learn.* **2000**, *50*, 385–412. [\[CrossRef\]](#)
15. Kanellopoulou, C.; Kermanidis, K.L.; Giannakouloupoulos, A. The Dual-Coding and Multimedia Learning Theories: Film Subtitles as a Vocabulary Teaching Tool. *Educ. Sci.* **2019**, *9*, 210. [\[CrossRef\]](#)
16. Moody, S.; Hu, X.; Kuo, L.-J.; Jouhar, M.; Xu, Z.; Lee, S. Vocabulary Instruction: A Critical Analysis of Theories, Research, and Practice. *Educ. Sci.* **2018**, *8*, 180. [\[CrossRef\]](#)
17. Mayer, R.E. *Multimedia Learning*; Cambridge University: Cambridge, UK, 2003.
18. Yanasugondha, V. *A Study of English Vocabulary Learning Using the Dual Coding Learning Theory*; Thammasat University: Bangkok, Thailand, 2016.
19. Clark, J.M.; Paivio, A. A Dual Coding Theory and Education. *Educ. Psychol. Rev.* **1991**, *33*, 149–210.

20. Kim, D.; Gilman, D.A. Effects of Text, Audio, and Graphic Aids in Multimedia Instruction for Vocabulary Learning. *Educ. Technol. Soc.* **2008**, *11*, 114–126.
21. Gay, L.R. *Educational Research: Competences for Analysis and Application*; Merrill: New York, NY, USA, 1992.
22. Paivio, A. Dual Coding Theory, Word Abstractness, and Emotion: A Critical Review of Kousta et al. *J. Exp. Psychol. Gen.* **2013**, *142*, 282–287. [[CrossRef](#)]
23. Cohen, L.; Manion, L.; Morrison, K. *Research Methods in Education*; Routledge: London, UK, 2007.
24. Zhang, L. *A Study of the Application of Dual Coding Theory to English Vocabulary Instruction in Junior Middle School*; Shenyang Normal University: Shenyang, China, 2016.
25. Hashemi, M.; Pourgharib, B. The Effect of Visual Instruction on New Vocabularies Learning. *Int. J. Basic Sci. Appl. Res.* **2013**, *2*, 623–627.
26. Cohen, M.T.; Johnson, H.L. Improving the Acquisition and Retention of Science Material by Fifth Grade Students through the Use of Imagery Interventions. *Instr. Sci.* **2012**, *40*, 925–955. [[CrossRef](#)]



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