CHAPTER 5

FINDINGS AND DISCUSSION

5.0 Introduction

This chapter presents an overview of the research findings and the discussion of these findings. Findings and analyses are organized in accordance with the sequence of the research questions reported in Chapter 1 which look into the utilization of the brainstorming technique in enhancing creative and critical thinking skills among secondary Iraqi physics students (second grade intermediate) in a selected school as follows, (i) to determine if there is a significant difference for creative thinking skills, critical thinking skills and physics achievement between the control and experimental groups before intervention; (ii) to determine if there is a significant difference for creative and critical thinking skills, between the control and experimental groups after the intervention; (iii) the enhancement of creative and critical thinking skills among students who have utilized the brainstorming technique, (iv) the perceptions of students about learning physics via the brainstorming technique.

The study has attempted to answer the research questions by utilizing data collected by eight different techniques. These techniques include the creative thinking test, the critical thinking test, the survey of student perceptions, students' observation, audio-video recording, students' feedback journals, students' interviews, and teacher comments. The two types of data collected (quantitative and qualitative) in the present study contributed to increasing the confidence in the research findings and to provide a complete picture of the research. The last section of this chapter contains a brief chapter summary.

5.1 Creative Thinking Skills, Critical Thinking Skills and Physics Achievement before the Brainstorming Technique Intervention

The first research question sought to determine if there is a significant difference for creative thinking skills, critical thinking skills and physics achievement among selected secondary Iraqi physics students between the control and experimental groups before the intervention using the brainstorming technique. In order to measure the level of creative and critical thinking skills and physics achievement the creative thinking test, the critical thinking test and the physics achievement test were administrated in the first week before starting the intervention for both the experimental and control groups in the Saba school.

The findings of this research question are important in order to determine how effective is the role of the brainstorming technique in the enhancement of creative and critical thinking skills among Iraqi second-grade intermediate students. Furthermore, the findings of this question allow the researcher to check the homogeneity between the experimental and control groups before the start of the intervention.

Students' answers for the three tests (creative thinking test, critical thinking test, and physics achievement test) were corrected by the researcher of the present study following the score procedures stated in Chapter 4. It is stated in the previous chapter (Methodology) that the quantitative data was analyzed by using the SPSS (Statistical Package for Social Sciences), Version 18 to calculate the normal distribution, homogeneity of variance, means and standard deviation, and Analysis of covariance. The next three sections will display the results of these three tests for both the experimental and control groups.

5.1.1 Pre- Test of Creative Thinking

Before the intervention of the brainstorming technique, verification of the initial status of creative thinking skills of students for both the experimental and control groups needed to be determined. Therefore, the creative thinking test (see APPENDIX A) was administered before the intervention to both the experimental and control groups in the Iraqi Saba School. The data were analyzed by scores obtained in four scales of creative thinking which were fluency, flexibility, originality, and overall.

First, the researcher of the present study investigated the normality of the sample for both the experimental and control groups for the creative thinking test by using numerical and graphical methods. For this purpose, the numerical methods Kolmogorov-Smirnov Test and the Shapiro-Wilk Test were used to compare the scores in the sample to a normally distributed set of scores with the same mean and standard deviation. Table 5.1 shows the result of the normality test for the experimental and control groups for the creative thinking test.

Table 5.1 Kolmogorov-Smirnov and Shapiro-Wilk Tests for normality distribution

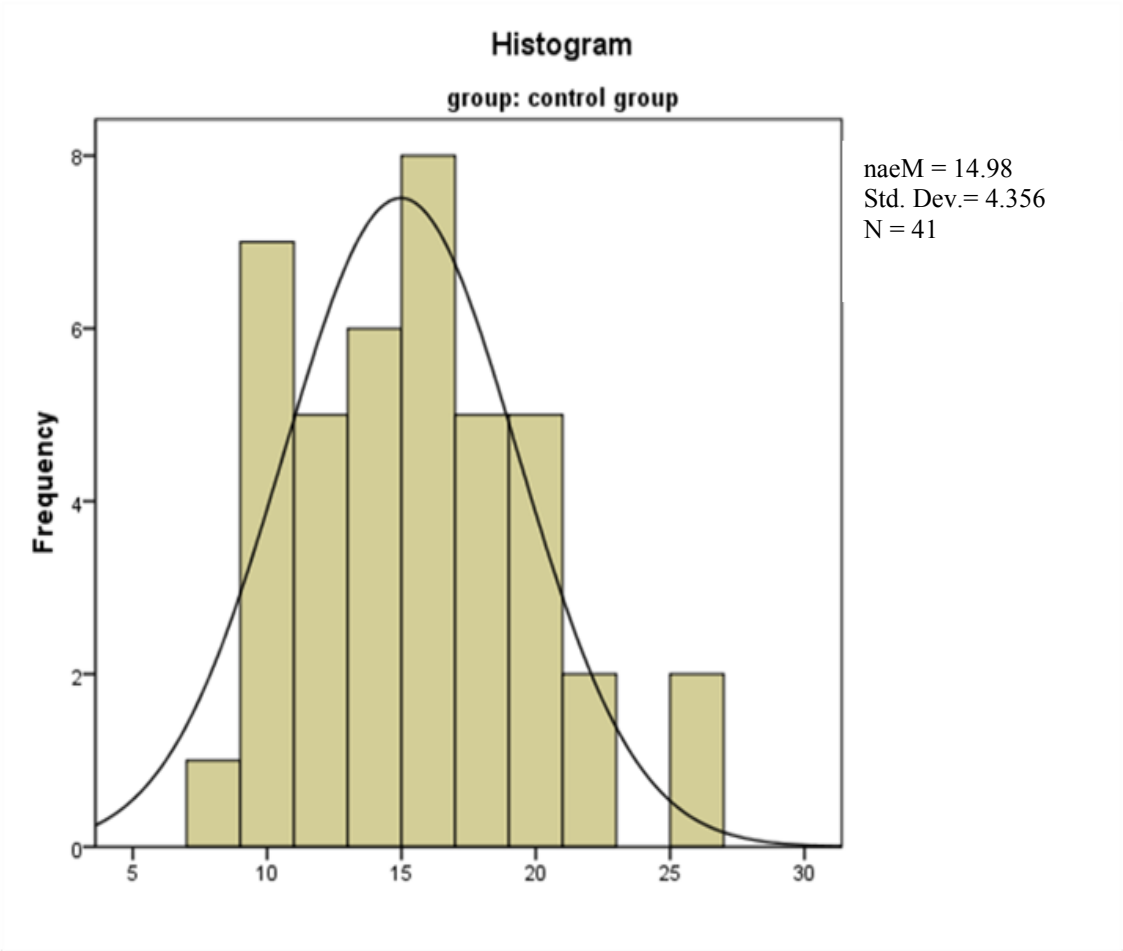
Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	DF	Sig.	Statistic	DF	Sig.
Control group	0.094	41	0.200*	0.957	41	0.121
Experimental group	0.106	39	0.200*	0.97	39	0.55

a. Lilliefors Significance Correction

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

Table 5.1 shows that both tests (the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test) have a p-value greater than 0.05 (P> 0.05), which indicates normal distribution for the control and experimental groups for the creative thinking test.

In addition, to decide upon the normality of the sample graphically, the shape of the histogram is important. Therefore, Figure 5.1 shows the normal curve on the histogram for the creative thinking test for both the control and experimental groups respectively. Figure 5.1 shows the normal distribution for the control and experimental groups in creative thinking test, where the mode is near to the centre of the range. Points are as likely to occur on one side of the average as on the other.



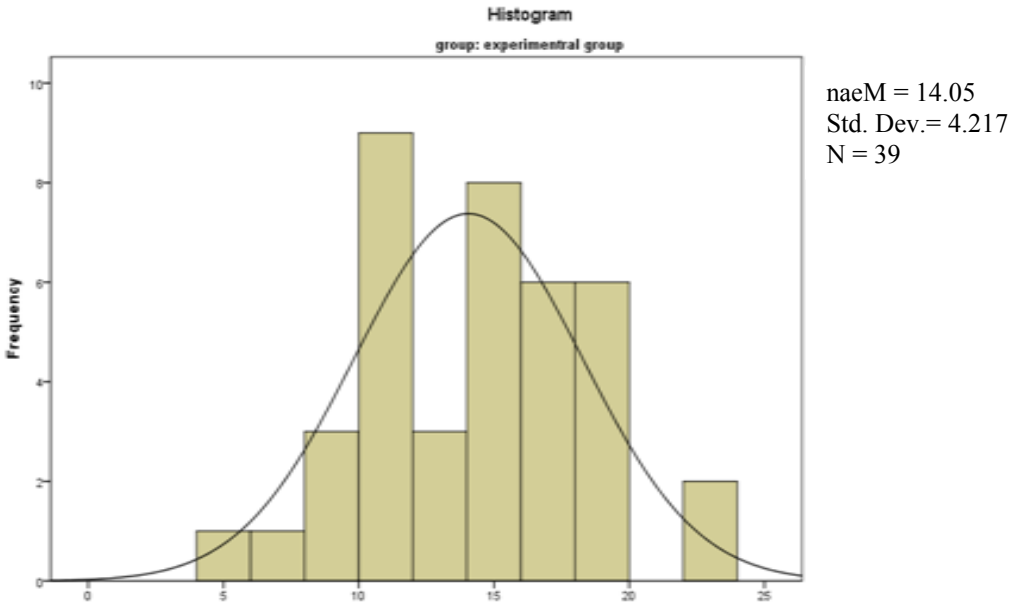


Figure 5.1 Histogram for the control and experimental groups for the creative thinking test

The researcher of the present study checked the verification of the homogeneity of variance between the experimental and control groups for the creative thinking test by using the Levene's Test before applying the ANCOVA test. The results obtained are as shown in Table 5.2.

Table 5.2 Levene's Test of Homogeneity of Variances

	Levene Statistic	DF1	DF2	Sig.
Fluency	0.000	1	78	0.985
Flexibility	2.929	1	78	0.091
Originality	0.029	1	78	0.866
Overall	0.008	1	78	0.930

Table 5.2 shows the value of F (78) = 0.008, p = 0.93 > 0.05, which indicates that there no significant difference exists between the control group and the experimental group for the overall creative thinking test. While the values of F for the sub skills were as follows: fluency skill was F (78) = 0.000, p = 0.98 > 0.05, which indicates that there is no significant difference between the control group and the experimental group for fluency. Flexibility skill was F (78) = 2.92, p = 0.09 > 0.05, which indicates that there is no significant difference between the control group and the experimental group in flexibility skill.

For originality, the result obtained was F (78) = 0.02, p = 0.86 > 0.05, which indicates that there is no significant difference between the control group and the experimental group. The results indicated that there were no statistically significant differences between the control and experimental groups.

Means and standard deviation for the experimental and control groups in the creative thinking test (fluency, flexibility, originality and overall) were calculated followed by a t-test to determine the differences between the mean of the experimental group and the control group in the creative thinking test. The results obtained are shown in Table 5.3.

Table 5.3 t-test for creative thinking test

Creative thinking skills		Control group N(41)	Experimental group N(39)	Independent Sample t-test (DF=78)	Sig.(2-tailed)
Fluency	Mean	6.95	6.62		
	SD	2.17	2.18	0.68	0.49
Flexibility	Mean	5.85	5.31		
	SD	2.39	1.92	1.12	0.26
Originality	Mean	2.17	2.13		

	SD	1.07	1.08	0.17	0.86
Overall	Mean	14.98	14.05		
	SD	4.35	4.21	0.96	0.33

Table 5.3 reveals the means and standard deviation for the experimental and control groups in the creative thinking test (fluency, flexibility, originality and overall) were close. The mean and standard deviation for the control group in the overall of creative thinking were (14.98) and (4.35) respectively, while the mean and SD of the experimental group were (14.05) and (4.21) respectively.

The table also reveals the value of t (78) = 0.96, p = 0.33 > 0.05, which indicates that there is no significant difference between the mean scores of the control group and the mean scores of the experimental group in the overall creative thinking test. The results for the sub creative thinking skills were as follows:

First, the mean and SD for fluency for the control group were (6.95) and (2.17) respectively, while the mean and SD of the experimental group were (6.62) and (2.18) respectively, t (78) = 0.68, p = 0.49 > 0.05. Thus, there was no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for fluency.

Second, the mean and SD for flexibility for the control group was (5.85) and (2.95) respectively, while the mean and SD of the experimental group were (5.31) and (1.92) respectively, t (78) = 1.12, p = 0.26 > 0.05. Thus, there was no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for flexibility.

Third, the mean and SD for originality for the control group were (2.17) and (1.07) respectively, while the mean and SD of the experimental group were (2.13) and (1.08) respectively, t (78) = 0.17, p = 0.86 > 0.05. Thus, there was no statistically

significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for originality.

The results reveal that there was no significant difference in the creative thinking skills between the experimental and the control groups. Therefore, the students in the experimental and control groups showed homogeneity in terms of the total level of creative thinking and sub-skills (fluency, flexibility, and originality) before the start of the intervention.

Therefore, the Null hypothesis $H_o(1)$, that there is no statistically significant difference between the mean scores in the test of creative thinking of the students in the experimental and the control groups before intervention is accepted.

5.1.2 Pre –Test of Critical Thinking

Before applying the brainstorming technique, verification was required for the level of students' critical thinking skills for both experimental and control groups, therefore the critical thinking test (see APPENDIX B) was administered to selected secondary Iraqi students' before intervention for both groups in the Iraqi Saba school. The data were analyzed by scores for the five scales of the critical thinking test (inference, recognizing assumptions, deductions, interpretations, evaluating arguments and overall).

First, the researcher of the present study investigated the normal distribution of the experimental and control groups in the critical thinking test by using numerical and graphical methods. For the numerical method, the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test were used to compare the scores in the sample to a normally distributed set of scores with the same mean and standard deviation. Table 5.4 shows the result of the normality test for the experimental and control groups in critical thinking test.

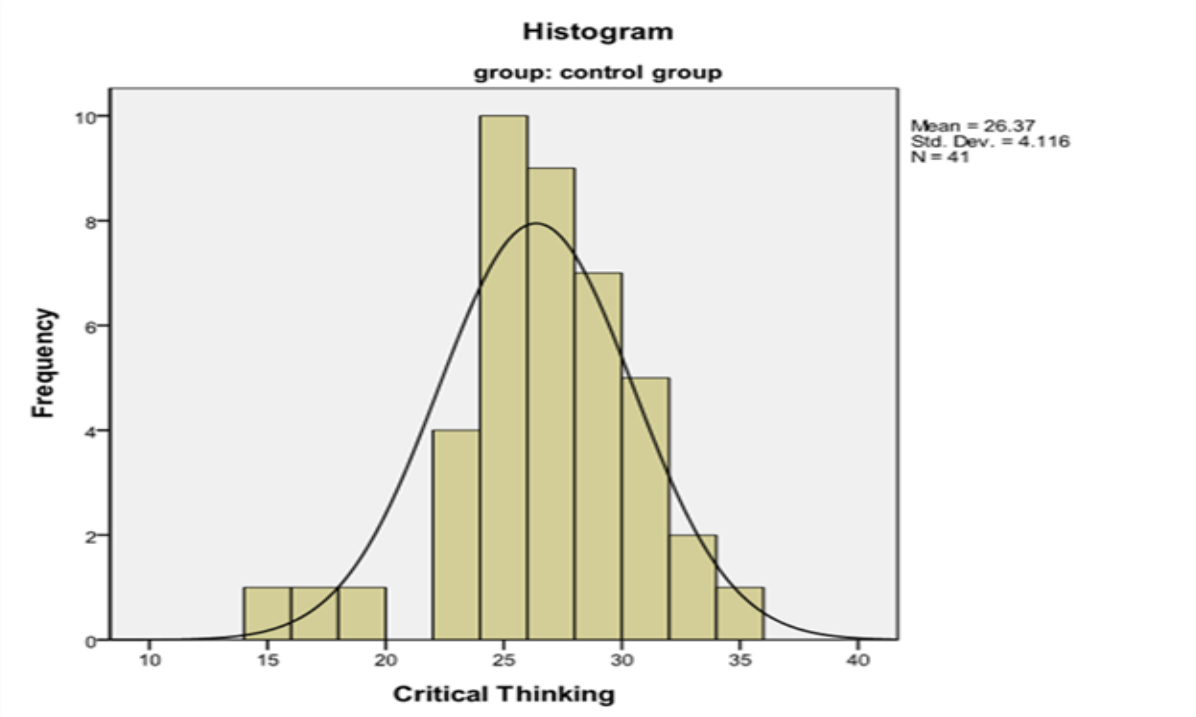
Table 5.4 Kolmogorov-Smirnov and Shapiro-Wilk Tests for normality distribution

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	DF	Sig.	Statistic	DF	Sig.
Control group	0.11	41	0.200*	0.95	41	0.14
Experimental group	0.10	39	0.200*	0.98	39	0.68

a. Lilliefors Significance Correction

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

Table 5.4 indicates that both tests (Kolmogorov-Smirnov Test and the Shapiro-Wilk Test) have a p-value greater than 0.05 (P> 0.05), which indicates the normal distribution for both the control and experimental groups in the critical thinking test. In addition, to decide whether or not the data is of normal distribution, the shape of the histogram is important. Therefore, Figure 5.2 shows the normal curve on the histogram for the critical thinking test for both the control and experimental groups respectively.



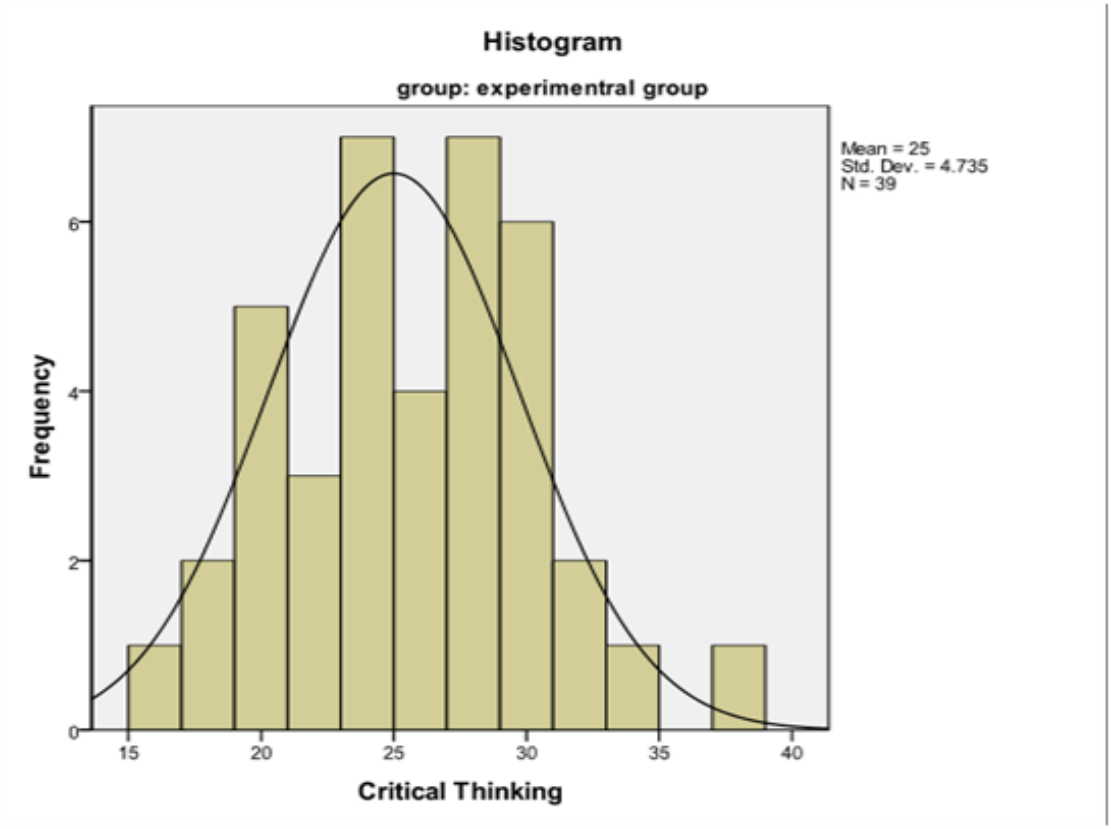


Figure 5.2 Histogram for control and experimental groups for critical thinking test

Figure 5.2 shows the normal distribution for the control and experimental groups in creative thinking, where the mode is near to the centre of the range. Points are as likely to occur on one side of the average as on the other.

The researcher of the present study checked the verification of the homogeneity of variance between the experimental and control groups for critical thinking test by using Levene's Test before applying ANCOVA test. The results were obtained as shown in the Table 5.5.

Table 5.5 Levene Test of Homogeneity of Variances

Critical thinking skills	Levene Statistic	DF1	DF2	Sig.
Inference	0.090	1	78	0.765
Recognizing assumption	0.764	1	78	0.385
Deduction	0.250	1	78	0.618
Interpretation	0.400	1	78	0.529
Evaluating arguments	0.178	1	78	0.674
Overall	1.593	1	78	0.211

Table 5.5 indicates that the value was F (1, 78) = (1.59), p= (0.21) > (0.05), which indicates that no significant difference exists overall between the control group and the experimental group in the critical thinking test. While for the sub skills results for the critical thinking was as follow: inference F (1, 78) = (0.09), p = (0.76) > (0.05), which indicates no significant difference exists between the control group and the experimental group in inference skills. Recognizing assumption was F (1, 78) = (0.76), p = (0.38) > (0.05), which indicates no significant difference exists between the control group and the experimental group for recognizing assumption skills. For deduction the results F (1, 78) = (0.25), p = (0.61) > (0.05) were obtained, which indicates that no significant difference exists between the control group and the experimental group for deduction skills. For interpretation the results F (1, 78) = (0.40), p= (0.52) > (0.05) were obtained, which indicates no significant difference exists between the control group and the experimental group for interpretation skills. For evaluating arguments the results F (1, 78) = (0.17), p= (0.67) > (0.05) were obtained, which indicates no significant difference exists between the control group and the experimental group for evaluating

arguments skills. Thus, there were no significant differences between the experimental and control groups for the critical thinking test in the overall level and the five scales (inference, recognizing assumption, deduction, interpretation, and evaluating arguments). The experimental and control groups were homogeneous for the critical thinking test results before the start of the intervention.

Means and standard deviation values for the experimental and control groups in the critical thinking test (inference, recognizing assumption, deduction, interpretation, evaluating argument and overall) were calculated following this and the t-test was used to find out the differences between the mean of the experimental group and the control group in the critical thinking test. The results obtained are as shown in Table 5.6.

Table 5.6 t-test for critical thinking test

Critical thinking skills		Control group N(41)	Experimental group N(39)	Independent Sample t-test (DF=78)	Sig.(2-tailed)
Inference	Mean	3.59	3.38	0.53	0.59
	SD	1.71	1.63		
Recognizing assumptions	Mean	5.56	5.26	0.52	0.60
	SD	2.70	2.51		
Deduction	Mean	5.78	5.49	0.86	0.38
	SD	1.49	1.53		
Interpretation	Mean	5.61	5.44	0.54	0.58
	SD	1.51	1.33		
Evaluating arguments	Mean	5.83	5.44	1.28	0.20
	SD	1.39	1.33		
Overall	Mean	26.37	25.00	1.37	0.17

Critical thinking skills		Control group N(41)	Experimental group N(39)	Independent Sample t-test (DF=78)	Sig.(2-tailed)
	SD	4.11	4.73		

Table 5.6 reveals that the means and standard deviation for the experimental and control groups for the critical thinking test (inference, recognizing assumption, deduction, interpretation, evaluating arguments, and overall) were close. The arithmetic mean and SD of the control group in the overall aspect of the critical thinking test were (26.37) and (4.11) respectively, while the arithmetic mean and SD of the experimental group in overall aspect of the critical thinking test were (25.00) and (4.73) respectively.

The table also reveals the value of $t(78) = 1.37$, $p = 0.17 > 0.05$, which indicates that there is no significant differences between the mean scores of the control group and the mean scores of the experimental group in the overall aspect of the critical thinking test. The results for the sub critical thinking skills were as follows:

First, the mean and SD for inference for the control group were (3.59) and (1.71) respectively, while the mean and SD for the experimental group were (3.38) and (1.63), and the value of $t(78) = 0.53$, $p = 0.59 > 0.05$. Thus, there is no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for the skill of inference.

Second, the mean and SD for the skill of recognizing assumption for the control group were (5.56) and (2.70) respectively, while the mean and SD for the experimental group were (5.26) and (2.51) respectively, and the value of $t(78) = 0.52$, $p = 0.60 > 0.05$. Thus, there is no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for the skill of recognizing assumption.

Third, the mean and SD for the skill of deduction for the control group were (5.78) and (1.49) respectively, while the mean for the experimental group were (5.49) and (1.53) respectively, and the value of t (78) = 0.86, p = 0.38 > 0.05. Thus, there is no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for the skill of deduction.

Fourth, the mean and SD for the skill of interpretation for the control group were (5.61) and (1.51) respectively, while the mean for the experimental group was (5.44) and (1.33) respectively, and the value of t (78) = 0.54, p = 0.58 > 0.05. Thus, there is no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for the skill of interpretation.

Finally, the mean and SD for the skill of evaluating arguments for the control group were (5.83) and (1.34) respectively, while the mean for the experimental group were (5.44) and (1.33) and the value of t (78) = 1.28, p = 0.20 > 0.05. Thus, there is no statistically significant difference between the mean scores of the control group and the mean scores of the experimental group before applying the brainstorming technique for the skill of evaluating arguments. The results show that the students' level of critical thinking skills in both the experimental and the control groups. Therefore, there is homogeneity between experimental and control groups in terms of the level of overall critical thinking and sub-skills (inference, recognizing assumption, deduction, interpretation, evaluating arguments).

Therefore, the Null hypothesis $H_o(2)$, that there is no statistically significant difference between the mean scores in the test of critical thinking of the students in the experimental and the control groups before intervention is accepted.

5.1.3 Pre- Test of Physics Achievement

To avoid any potential impact to the results of the physics achievement after the application of brainstorming technique, the researcher administered the achievement test before the intervention for both the experimental and control groups.

First, the researcher of the present study investigated the normal distribution of the experimental and control groups for the physics achievement test by using numerical and graphical methods. For the numerical method, the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test were used to compare the scores in the sample to a normally distributed set of scores with the same mean and standard deviation. Table 5.7 shows the result of the normality test for both the experimental and control groups in the physics achievement test.

Table 5.7 Kolmogorov-Smirnov and Shapiro-Wilk Tests for normality distribution

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	DF	Sig.	Statistic	DF	Sig.
Control group	0.114	41	0.200*	0.972	41	0.391
Experimental group	0.093	39	0.200*	0.975	39	0.535

a. Lilliefors Significance Correction

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

Table 5.7 shows that both tests (Kolmogorov-Smirnov Test and the Shapiro-Wilk Test) have a p-value greater than 0.05 (P> 0.05), which indicates normal distribution for both the control and experimental groups in the physics achievement test. In addition, to decide whether or not the data is normally distributed, the shape of the histogram is important. Therefore, Figure 5.3 shows the normal curve on histograms for the physics achievement test for the control and experimental groups respectively.

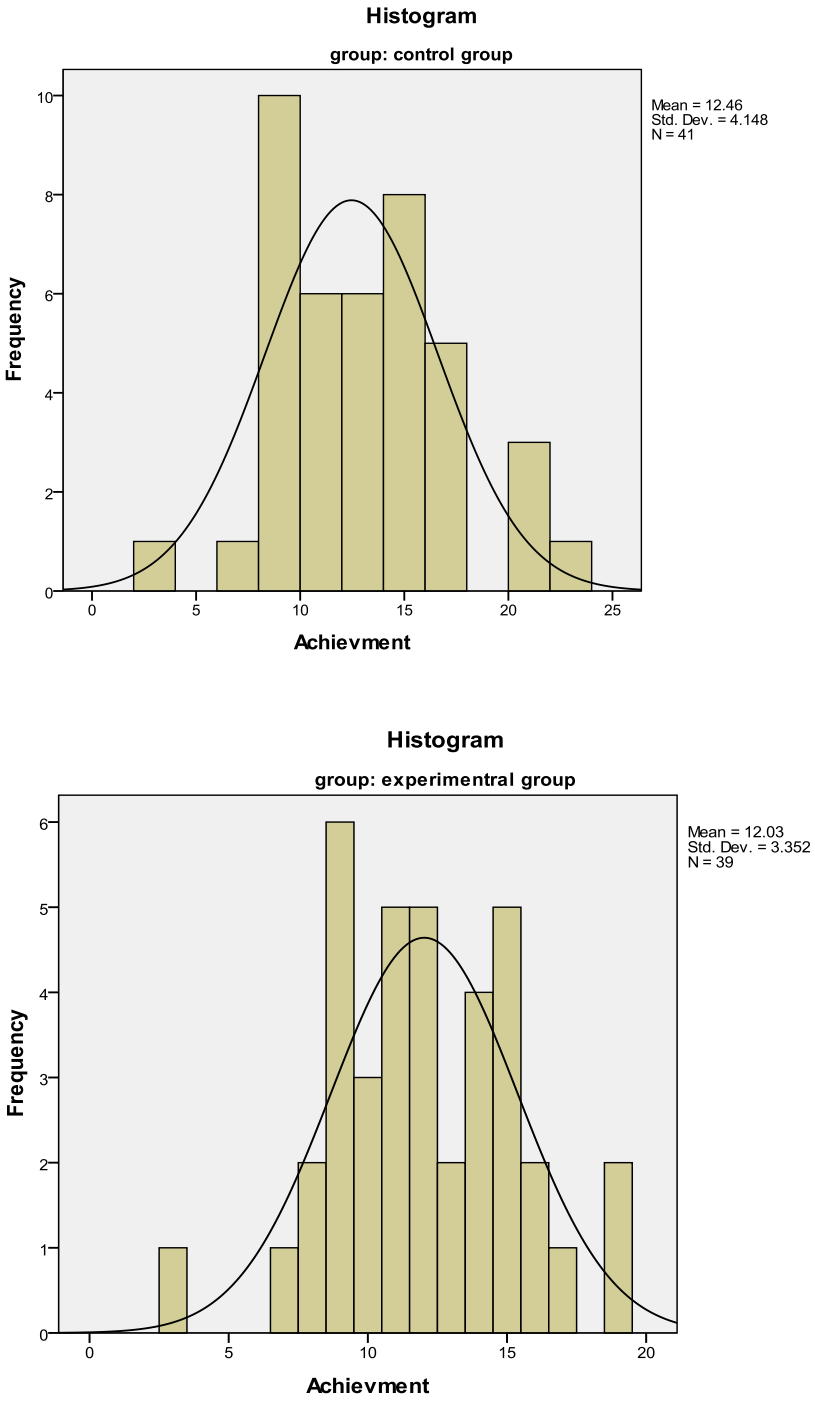


Figure 5.3 Histogram for the control and experimental groups for the physics achievement test.

The researchers of the present study checked the verification of the homogeneity of variance between the experimental and control groups for physics achievement test by using Levene's Test before applying ANCOVA test. The results were obtained as shown in the Table 5.8.

Table 5.8 Levene Test of Homogeneity of Variances

	Levene Statistic	DF1	DF2	Sig.
Physics achievement	2.213	1	78	0.141

Table 5.8 indicates that the value was F (1, 78) = (2.213), p= (0.141) > (0.05), which indicates no significant difference exists between the control group and the experimental group. Thus, the experimental and control groups were homogeneous in physics achievement test.

Means and standard deviation for the experimental and control groups in the physics achievement test were calculated then the t-test was used to find out the differences between the means of the experimental group and the control group for the critical thinking test. The results obtained were as shown in Table 5.9.

Table 5.9 t-test results for the physics achievement test

Group	Mean	SD	Independent Sample t-test (DF=78)	Sig.(2-tailed)
Control group N(41)	12.46	4.14	0.51	0.60
Experimental group N(39)	12.03	3.35		

Table 5.9 indicates that the means and standard deviation for the experimental and control groups in the physics achievement test were close. The arithmetic mean and SD of the control group in the physics achievement test were 12.46 and 4.14 respectively, while the arithmetic mean and SD of the experimental group in the physics achievement test were 12.03 and 3.35 respectively.

The table also reveals the value of $t(78) = 0.51$, $p = 0.60 > 0.05$, which indicates no significant difference exists between the mean scores of the control group and the mean scores of the experimental group for the physics achievement test. The result shows the convergence of students' achievement level in the experimental and the control groups. Therefore, there is homogeneity between the experimental and control groups in terms of the level of physics achievement.

Therefore, the Null hypothesis $H_o(3)$ that there is no statistically significant difference between the mean scores in the physics achievement test of the students in the experimental and the control groups before intervention is accepted.

5.2 Creative and Critical Thinking after Utilizing the Brainstorming Technique

The second and third research questions sought to determine if there is a significant difference of creative and critical thinking skills among selected Secondary Iraqi physics students in the control and experimental group after intervention utilizing the brainstorming technique. Its focus was to discover if the brainstorming technique utilised during the four-month intervention in physics learning for the experimental group led to changes in students' creative and critical thinking skills.

5.2.1 Post test of Creative Thinking

In this section, the researcher found the differences between the brainstorming technique and the traditional method in enhancing creative thinking skills among Iraqi second–grade intermediate students will be discussed. After the completion of the intervention, the creative thinking test was administrated among all research samples (experimental and control group). The data were analyzed by calculating the mean and standard deviation of the students' scores in the three scales of the creative thinking test (originality, fluency, flexibility). Table 5.10 shows the students' performance in the creative thinking test for the experimental group who were taught physics utilising the brainstorming technique compared with the students' performance who were taught physics utilising the traditional method.

Table 5.10 Comparison of pre-test and post – test results for creative thinking

Creative thinking skills	Group	Pre-test		Post-test		Mean Difference in post-test
		Mean	SD	Mean	SD	
Fluency	Control group N (41)	6.27	2.17	8.37	5.49	9.48
	Experimental group N (39)	6.62	2.18	17.85	8.44	
Flexibility	Control group N (41)	5.85	2.39	5.95	3.47	6.56
	Experimental group N (39)	5.31	1.92	12.51	7.46	
Originality	Control group N (41)	2.17	1.07	2.49	1.12	1.12

Creative thinking skills	Group	Pre-test		Post-test		Mean Difference in post-test
		Mean	SD	Mean	SD	
	Experimental group N (39)	2.13	1.08	3.62	1.78	
Overall	Control group N (41)	14.98	4.35	16.80	5.90	17.16
	Experimental group N (39)	14.05	4.21	33.97	15.70	

The results in Table 5.10 reveals the improvement in the results of the post-test for students in the experimental group who were taught physics utilising the brainstorming technique in the enhancement of all three creative thinking skills. The results indicate that the mean and SD of the experimental group were (33.97) and (15.70) respectively, in comparison with the highest mean for the students in the control group which was (16.80) and SD (5.90).

The difference between the mean of the experimental and control groups is (17.16) in favour of the experimental group who were taught physics by utilising the brainstorming technique. These results are confirmed by previous studies which have indicated that creative thinking exists in everyone, but to varying degrees and is subject to the training and enhancement by using interactive teaching methods in a supportive learning environment (see Chapter 1 section Introduction p. 4).

However, with reference to Table 5.10, it can be seen that the influence of the brainstorming technique was disparate from one skill to another. In the skill of fluency there was a clear difference for the experimental group, where the mean and SD for experimental group were (17.85) and (8.44) respectively, while the mean and SD for

control group were (8.37) and (5.49) respectively. The difference between the mean of the experimental and control groups was (9.48) favouring the experimental group who were taught physics by utilizing the brainstorming technique. This difference for the skill of fluency is the highest difference obtained by the experimental group compared with the skills of flexibility and originality.

For the skill of flexibility, the influence of the brainstorming technique was clear for the experimental group, where the mean and SD for were (12.51) and (7.46) respectively, while the mean and SD for the control group were (5.95) and (3.47) respectively. The difference between the mean of the experimental and control group was (6.56) favoring the experimental group who were taught physics by utilizing the brainstorming technique.

For the skill of originality the difference between the experimental and control groups was not as big as for the skills of fluency and flexibility. The mean and SD for the control group were (2.49) and (1.12) respectively, while the mean and SD for the experimental group were (3.62) and (1.78) respectively. The difference between the mean of the experimental and control group was only (1.12) favoring the experimental group who were taught physics by utilising the brainstorming technique. The researcher interpreted this small difference may be due to the fact that it is not easy to generate new and uncommon ideas as explained in Chapter2 (see Section 2.2.1).

Figure 5.4 shows the comparison between the means of experimental and control group in post-test of creative thinking test.

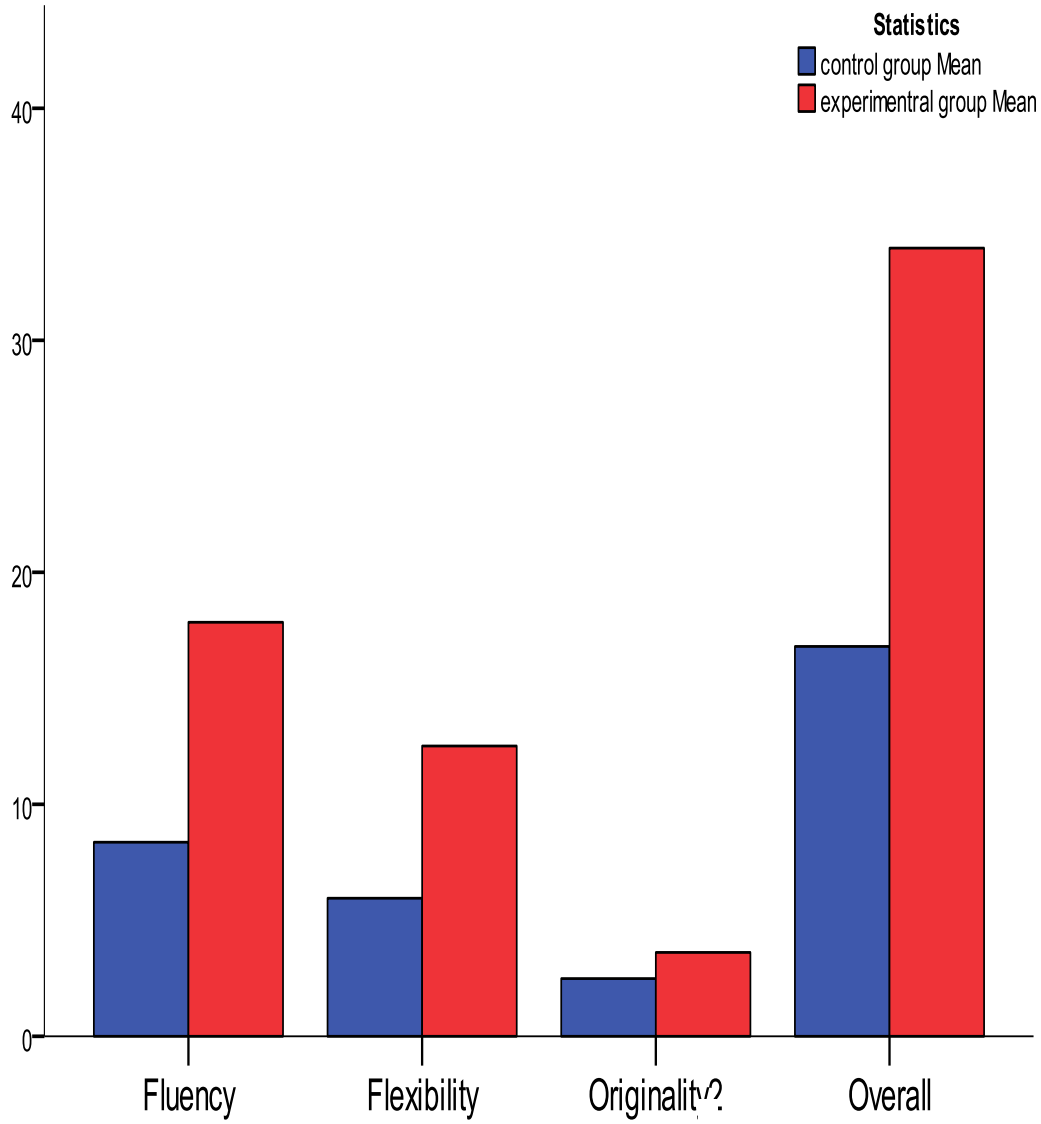


Figure 5.4 Comparison between the means of experimental and control group in creative thinking test

Figure 5.4 shows the comparison of the experimental group in the overall and three criteria of creative thinking (fluency, flexibility, originality, and overall). The researcher could interpret this result to the intervention which had the effect of raising students' creativity in physics.

To test for the effects of the brainstorming technique in enhancing creative thinking skills among Iraqi physics students, the analysis of gain scores provides unbiased results in a much wider array of research designs. This calculation evaluates the effect size between two means (improvements from pretest to posttest for whole groups) (Cohen, 1988). It tells us whether each group has improved, deteriorated, stayed constant, and by precisely how much. The results obtained are as shown in Table 5. 11.

Table 5.11 Analysis of variance of gain scores for creative thinking test

Creative thinking skills	Group	Pre-test		Post-test		M (post-pretest)	SD (Pooled)	d (effect size)
		Mean	SD	Mean	SD			
Fluency	Control N (41)	6.27	2.17	8.37	5.49	2.1	4.174	0.50
	Experimental N (39)	6.62	2.18	17.85	8.44	11.23	6.163	1.82
Flexibility	Control N (41)	5.85	2.39	5.95	3.47	0.1	2.979	0.033
	Experimental N (39)	5.31	1.92	12.51	7.46	7.2	5.446	1.32
Originality	Control N (41)	2.17	1.07	2.49	1.12	0.32	1.095	0.29
	Experimental N (39)	2.13	1.08	3.62	1.78	1.49	1.472	1.01
Overall	Control N (41)	14.98	4.35	16.8	5.9	1.82	5.183	0.35
	Experimental N (39)	14.05	4.21	33.97	15.7	19.92	11.493	1.73

Results in Table 5.11 indicate that the value d (1.73), a positive gain score (a 'large' value of d) revealed that the posttest score was greater than the pretest score for the experimental group who were taught physics via the brainstorming technique. In contrast, results in Table 5.11 shows that the value d for the control group (0.35), a negative gain score (a 'small' value of d) revealed that the traditional method might have had a little effect upon students to improve the creative skills. For the sub skills of creative thinking the results of the gain scores were as follows:

For fluency, the value was d (1.82), a positive gain score (a very large value of d) revealing that the posttest score was greater than the pretest score for the experimental group who were taught physics via the brainstorming technique. In contrast, results in Table 5.11 shows that the value d for the control group (0.50), had a moderate value of d revealing that the traditional method may have had a minor effect to improve the skills of fluency.

For flexibility, the value was d (1.32), a positive gain score (a very large value of d) revealing that the posttest score was greater than the pretest score for the experimental group who were taught physics via the brainstorming technique. In contrast, results in Table 5.11 shows that the value d for the control group (0.033), was too small a value of d revealing that the traditional method may have only had a small effect to improve physics students the skills of flexibility.

For originality. the value was d (1.01), a positive gain score (a very large value of d) revealing that the posttest score was greater than the pretest score for the experimental group who were taught physics via the brainstorming technique. In contrast, results in Table 5.11 shows that the value d for the control group (0.29), was a small value of d revealing that the traditional method may have had a little effect to improve physics students' skills of fluency.

The brainstorming technique appears to have helped students in the experimental group to enhance the students' creative thinking skills. The researcher believes that the brainstorming technique may have eliminated some of the barriers that stand in the way of creativity and train students' minds to make connections between unrelated physics concepts, predict, generate ideas, express their ideas and views freely without fear, make students persevere more, students are willing to double the effort to get satisfactory results in order to recognize and produce solutions that are both novel and suitable.

First, the researcher of the present study found the difference within groups by using within-subject contrast test for both the experimental and control groups for the creative thinking test to find how the brainstorming technique and traditional teaching method were effective in improving the creative thinking skills among Iraqi second-grade intermediate level. The results obtained are as shown in Table 5.12 below.

Table 5.12 Within -subject contrast test for the creative thinking

Creative thinking skills	Group	source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Fluency	Control	Intercept	41.024	1	41.024	2.12	0.15
		Error	770.976	40	19.274		
	Experimental	Intercept	2454.538	1	2454.538	72.48	0.000*
		Error	1289.462	38	33.933		
Flexibility	Control	Intercept	0.195	1	0.195	0.02	0.87
		Error	313.805	40	7.845		
	Experimental	Intercept	1012.321	1	1012.321	47.65	0.000*
		Error	807.179	38	21.242		

Creative thinking skills	Group	source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Originality	Control	Intercept	2.061	1	2.061	2.14	0.15
		Error	38.439	40	0.961		
	Experimental	Intercept	43.128	1	43.128	24.50	0.000*
		Error	66.872	38	1.760		
Overall	Control	Intercept	68.598	1	68.598	2.05	0.15
		Error	1334.902	40	33.373		
	Experimental	Intercept	7740.115	1	77740.115	77.92	0.000*
		Error	3774.385	38	3774.385		

Results in Table 5.12 indicate that the value F (1, 40) = 2.05, P= 0.15> 0.05, indicates no significant difference for the means within the control group in the pre-post test creative thinking test as a result of utilizing the traditional teaching method in physics. For the sub skills of creative thinking the results within the control group were as follows:

For fluency the value was F (1, 40) = 2.12, P= 0.15 > 0.05, thus there is no significant difference for the mean scores within the control group in the pre- post test for fluency.

For flexibility the value was F (1, 40) = 2.02, P= 0.87 > 0.05, thus there is no significant difference for the mean scores within the control group in the pre- post test for flexibility.

For originality the value was F (1, 40) = 2.14, P= 0.15 > 0.05, thus there is no significant difference for the mean scores within the control group in the pre- post test for originality.

In contrast, results in Table 5.12 shows that the value F (1, 38) = 77.92, P= 0.00 < 0.05, indicates a significant different between the mean scores within the experimental group in the pre- post results for creative thinking test as a result of utilizing the brainstorming technique in teaching physics. For the sub skills of creative thinking the results within the experimental group were as follows:

For fluency the value was F (1, 38) = 72.48, P = 0.000 < 0.05, thus there is a significant difference between the mean scores within the experimental group in the pre-post for fluency.

For flexibility the value was F (1, 38) = 47.65, P = 0.000 < 0.05, thus there is a significant difference between the mean scores within the experimental group in the pre-post for flexibility.

For originality the value was F (1, 38) = 24.50, P = 0.000 < 0.05, thus there is a significant difference between the mean scores within the experimental group in the pre-post for originality.

From the results in Table 5.12 the researcher of the present study concluded that the traditional teaching method in teaching physics for the selected secondary Iraqi physics students appears to hinder and may not contribute much in improving and enhancing creative thinking skills in contrast with the brainstorming technique.

To investigate the significant differences between the means of the experimental group and the control group and the effect of the brainstorming technique in enhancing creative thinking skills among the selected Iraqi students in physics, analysis of covariance (ANCOVA) was used at the level of significant (0.05) and the degree of freedom (1,78). The results obtained are as shown in Table 5.13.

Table 5.13 ANCOVA results for the creative thinking test

Creative thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Fluency	Corrected Model	1798.026[a]	2	899.013	18.714	0.000*
	Intercept	1346.221	1	1346.221	28.024	0.000*
	Pre	1.627	1	1.627	0.034	0.854
	Group	1777.186	1	1777.186	36.995	0.000*
	Error	3698.962	77	48.038		
	Total	18991.000	80			
	Corrected Total	5496.987	79			
Flexibility	Corrected Model	908.115[a]	2	454.057	16.728	0.000*
	Intercept	539.897	1	539.897	19.890	0.000*
	Pre	47.561	1	47.561	1.752	0.190
	Group	898.219	1	898.219	33.091	0.000*
	Error	2090.085	77	27.144		
	Total	9696.000	80			
	Corrected Total	2998.200	79			
Originality	Corrected Model	32.629	2	16.315	7.648	0.001*
	Intercept	93.656	1	93.656	43.904	0.000*
	Pre	7.217	1	7.217	3.383	0.070
	Group	25.948	1	25.948	12.164	0.001*
	Error	164.258	77	2.133		
	Total	935.000	80			
	Corrected Total	196.887	79			
Creative thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Overall	Corrected Model	5966.593[a]	2	2983.296	24.534	0.000*
	Intercept	3061.249	1	3061.249	25.175	0.000*

Pre	74.456	1	74.456	0.612	0.436
Group	5966.529	1	5966.529	49.068	0.000*
Error	9362.957	77	121.597		
Total	66032.000	80			
Corrected Total	15329.550	79			

Results in Table 5.13 which shows the value F (1, 78) = 49.06, P= 0.000 < 0.05, indicates significant difference for the mean of the experimental group and the control group in the overall creative thinking test for the experimental group. For the sub-skills of creative thinking the results were as follows:

For fluency the value was F (1, 78) = 36.99, P= 0.000 < 0.05, Thus there is a significant difference between the mean scores of the experimental group and the control group for fluency in favour of the experimental group who were taught physics via the brainstorming technique.

For flexibility the value was F (1, 78) = 33.09, P= 0.000 < 0.05. Thus there is a significant difference between the mean scores of the experimental group and control group for flexibility in favour of the experimental group who were taught physics via the brainstorming technique.

For originality the value was F (1, 78) = 12.16, P= 0.001 < 0.05. Thus, there is a significant difference between the mean scores of the experimental group and control group for originality in favour of the experimental group who were taught physics via the brainstorming technique.

Multivariate Analysis of Variance Analysis (MANOVA) was used next in the study. MANOVA provides a joint test for any significant effects among a set of variables. MANOVA is sensitive not only to mean differences but also to the direction

and size of correlations among the dependent variables. There are two major reasons why MANOVA is used. The first is when there are several correlated dependent variables, and the researcher desires a single, overall statistical test on this set of variables instead of performing multiple individual tests. The second, and in some cases, the more important purpose is to explore how independent variables influence some patterning of response on the dependent variables. Table 5.14 showed the results of MANOVA for creative thinking test.

Table 5.14 MANOVA result for the creative thinking test

Creative thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Fluency	Corrected Model	1796.398	1	1796.398	37.86	0.000*
	Intercept	13732.798	1	13732.798	289.456	0.000*
	Group	1796.398	1	1796.398	37.86	0.000*
	Error	3700.589	78	47.443		
	Total	18991.000	80			
	Corrected Total	5496.987	79			
Flexibility	Corrected Model	7828.021	1	7828.021	70.00	0.000*
	Intercept	11319.221	1	11319.221	280.198	0.000*
	Group	7828.021	1	7828.021	70.00	0.000*
	Error	3150.979	78	40.397		
	Total	17024.000	80			
	Corrected Total	5979.000	79			
Originality	Corrected Model	2008.021	1	2008.021	91.84	0.000*
	Intercept	4497.563	1	4497.563	205.634	0.0000*
	Group	2008.021	1	2008.021	91.84	0.000*
	Error	1705.987	78	21.872		

Creative thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
	Total	8066.00	80			
	Corrected Total	3714.750	79			
Overall	Corrected Model	5892.137	1	5892.137	48.69	0.000*
	Intercept	51528.38	1	51528.38	425.964	0.000*
	Group	3714.750	1	3714.750	48.69	0.000*
	Error	9437.413	78	120.992		
	Total	66032.000	80			
	Corrected Total	15329.550	79			

Results in Table 5.14 show that the value F (1, 78) = 48.69, P= 0.000 < 0.05, indicates significant difference for the mean of the experimental group and the control group in the overall creative thinking test for the experimental group. For the sub-skills of creative thinking the results were as follows:

For fluency the value was F (1, 78) = 37.86, P= 0.000 < 0.05, Thus there is a significant difference between the mean scores of the experimental group and the control group for fluency in favour of the experimental group who were taught physics via the brainstorming technique.

For flexibility the value was F (1, 78) = 70.00, P= 0.000 < 0.05. Thus there is a significant difference between the mean scores of the experimental group and control group for flexibility in favour of the experimental group who were taught physics via the brainstorming technique.

For originality the value was F (1, 78) = 91.84, P= 0.000 < 0.05. Thus, there is a significant difference between the mean scores of the experimental group and control

group for originality in favour of the experimental group who were taught physics via the brainstorming technique.

When compared with previous studies, it was found that these findings are consistent with work reported by Abdul Karim & Amran, (2009), Alaatari, (2006), Cheng, (2004, 2011), DeHaan, (2009), Paulus and Paulus, (1997), and Wang, Rosé, et al., (2006) which indicated the effectiveness of the brainstorming technique in enhancing creative thinking skills in science. The brainstorming technique appears to stimulate students to think creatively in order to produce a high-quality answer and solution to science problems. The researcher of the present study summarized the results of the effectiveness the brainstorming technique in contrast with the traditional teaching method in enhancing the creative thinking skills in physics for the selected Iraqi second-grade intermediate level as shown in table 5.15 below.

Table 5.15 A summary of the results of creative thinking test

Creative thinking skills	**Control group**	**Experimental group**
Fluency	The traditional teaching method does not appear to have supported the selected Iraqi students in improving fluency skills in physics where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique appears to have positive effect on selected Iraqi students in improving fluency skills in physics where the results of within and between groups shows that there is a significant difference within pre-post test and between control and experimental groups.

Creative thinking skills	Control group	Experimental group
Flexibility	The traditional teaching method does not appear to have supported the selected Iraqi students in the skill of flexibility where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique appears to have helped the physics students improve and enhance the skill of flexibility where the results of within and between groups shows that there is a significant difference within pre-post test and between control and experimental groups.
Originality	The traditional teaching method does not appear to have encouraged the physics students for originality where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique could have provoked the minds of physics students to generate new ideas and solutions to the physics problem where the results of within and between groups shows that there is a significant difference within pre-post test and between control and experimental groups.
Overall	The traditional teaching method does not appear to have helped improve the selected Iraqi students in improving their overall creative thinking skills in physics where the results of within and between groups shows that there is no significant difference between pre-post test and between control and experimental groups.	The brainstorming technique seems to have a positive effect among the selected Iraqi students in improving their overall creative thinking skills in physics where the results of within and between groups shows that there is a significant difference between pre-post test and between control and experimental groups.

Therefore, the Null hypotheses $H_o(4)$ and $H_o(5)$ that there is no statistically significant difference in the mean scores and gain scores of the test of creative thinking between the experimental group students who were taught physics via the brainstorming

technique and the control group students who taught physics via the traditional method is rejected.

5.2.2 Post Test of Critical Thinking

This section will discuss if the brainstorming technique utilized during the four months of intervention in physics learning for the experimental group led to changes in students' critical thinking skills as measured by the critical thinking test (see APPENDIX B). In this section, the researcher sought to discover the differences between the brainstorming technique and the traditional method in enhancing critical thinking skills among Iraqi second–grade intermediate students. After the completion of the intervention, the critical thinking test was administrated among all research samples (experimental and control group). The data were analyzed by calculating the mean and standard deviation of the students' scores in the five scales of the critical thinking test (inference, recognizing assumption, deduction, interpretation, and evaluating arguments). Table 5.16 shows the students' performance in the critical thinking test for the experimental group who were taught physics by utilizing the brainstorming technique compared with students' performance who were taught physics by utilizing the traditional method.

Table 5.16 Comparison of pre-test and post – test results for critical thinking

Critical thinking skills	**Group**	**Pre-test**		**Post-test**		**Mean Difference in post-test**
		Mean	**SD**	**Mean**	**SD**	
Inference	Control group N (41)	3.59	1.71	3.49	1.614	0.12
	Experimental group N (39)	3.38	1.63	3.62	1.616	

Critical thinking skills	Group	Pre-test		Post-test		Mean Difference in post-test
		Mean	SD	Mean	SD	
Recognizing assumptions	Control group N (41)	5.56	2.70	5.34	2.105	1.35
	Experimental group N (39)	5.26	2.51	6.69	3.028	
Deduction	Control group N (41)	5.78	1.49	5.73	3.522	0.679
	Experimental group N (39)	5.49	1.53	6.41	1.996	
Interpretation	Control group N (41)	5.61	1.51	5.46	3.083	2.71
	Experimental group N (39)	5.44	1.33	8.18	4.316	
Evaluating argument	Control group N (41)	5.83	1.39	6.59	3.406	2.13
	Experimental group N (39)	5.44	1.33	8.72	4.019	
Overall	Control group N (41)	26.37	4.11	26.61	6.442	7.01
	Experimental group N (39)	25.00	4.73	33.62	8.194	

The results in Table 5.16 indicate an improvement in the results of the post-test for students in the experimental group who were taught physics via the brainstorming technique. The mean and the SD of the experimental group was (33.62) and (8.19) respectively. The mean for students in the control group was (26.61) with a standard deviation of (6.44).

The brainstorming technique appears to have helped students in the experimental group to improve their critical thinking skills compared to the students in the traditional method group. The difference between the mean of the experimental and control group reach (7.01) in favor of the experimental group that taught physics via brainstorming technique.

Therefore, the Null hypothesis $H_o(6)$, that there is no statistically significant difference in the mean scores of the test of critical thinking between the experimental group students who were taught physics via the brainstorming technique and the control group students who taught physics via the traditional method is rejected.

The results in Table 5.16 indicate that the first dimension of critical thinking, inference, showed a (0.12) difference between the experimental and control groups in favour of the experimental group who were taught physics via the brainstorming technique, where the mean and SD for the control group were (3.49) and (1.61) respectively, while the mean and SD for the experimental group were (3.62) and (1.61) respectively.

The results in Table 5.16 indicate that the second dimension of critical thinking, recognizing assumptions, had a difference in mean values of (1.35) in favour of the experimental group who were taught physics via the brainstorming technique, where the mean and SD for the control group were (5.34) and (2.10) respectively, while the mean and SD for the experimental group were (6.69) and (3.02) respectively.

The results for the third dimension of critical thinking, deduction, showed a mean difference of 0.67 in favour of the experimental group who were taught physics via the brainstorming technique. Where the mean and SD for control group were (5.73) and (3.52) respectively, while the mean and SD for experimental group were (6.41) and (1.99) respectively.

The results or the fourth dimension of critical thinking, interpretation, had a difference of (2.71) between the experimental and the control group for the experimental group who were taught physics via the brainstorming technique, where the mean and SD for control group were (5.46) and (3.08) respectively, while the mean and SD for experimental group were (8.18) and (4.31) respectively.

The results for the fifth dimension of critical thinking, evaluating argumentations, showed a difference of (2.13) in favour of the experimental group who were taught physics via the brainstorming technique, where the mean and SD for control group were (6.59) and (3.40) respectively, while the mean and SD for experimental group were (8.72) and (4.01) respectively. Figure 5.5 shows the comparison between the means of the experimental and control groups in the creative thinking test.

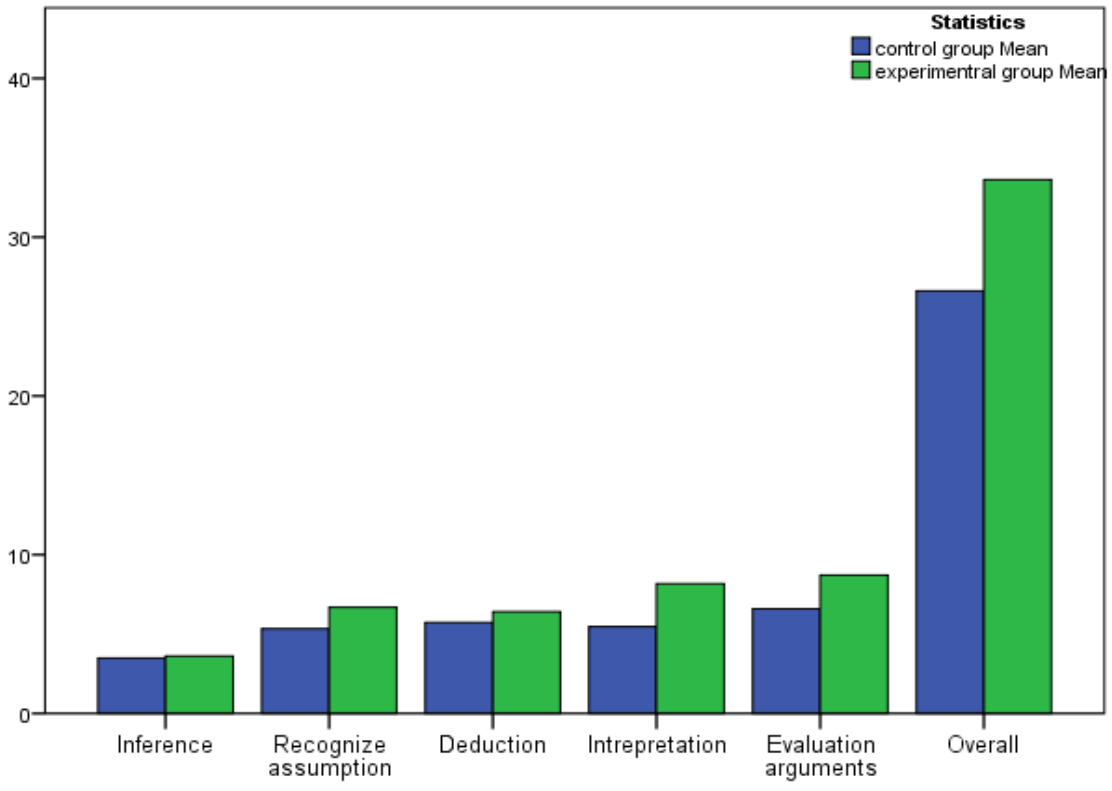


Figure 5.5 Compression between the means of experimental and control group in critical thinking test

Figure 5.5 shows that overall the experimental group scored better for critical thinking in the five sub-skills (inference, recognizing assumptions, deduction, interpretation, and evaluating arguments). The results were further analyzed to ensure accuracy.

To test for the effect of the brainstorming technique for enhancing critical thinking skills among Iraqi physics students, the analysis of gain scores provides unbiased results in a much wider array of research designs. This calculation evaluates the effect size between two means (improvements from pretest to posttest for whole groups) (Cohen, 1988). It tells us whether each group improved, deteriorated, stayed constant, and by precisely how much. The results obtained are as shown in Table 5. 17 below.

Table 5.17 Analysis of variance of gain scores for critical thinking test

Critical thinking skills	Group	Pre-test		Post-test		M(post - pretest)	SD (Pooled)	d (effect size)
		M	SD	M	SD			
Inference	Control N (41)	3.59	1.71	3.49	1.61	0.1	1.66	0.060
	Experimental N (39)	3.38	1.63	3.62	1.61	0.24	1.623	0.147
Recognizing assumptions	Control N (41)	5.56	2.7	5.34	2.10	0.22	2.420	0.090
	Experimental N (39)	5.26	2.51	6.69	3.02	1.43	2.781	0.514
Deduction	Control N (41)	5.78	1.49	5.73	3.52	0.05	2.70	0.018
	Experimental N (39)	5.49	1.53	6.41	1.99	0.92	1.778	0.517
Interpretation	Control	5.61	1.51	5.46	3.08	0.15	2.427	0.061

Critical thinking skills	Group	Pre-test		Post-test		M(post - pretest)	SD (Pooled)	d (effect size)
		M	SD	M	SD			
	N (41)							
	Experimental N (39)	5.44	1.33	8.18	4.31	2.74	3.193	0.857
Evaluating argument	Control N (41)	5.83	1.39	6.59	3.40	0.76	2.60	0.292
	Experimental N (39)	5.44	1.33	8.72	4.01	3.28	2.99	1.095
Overall	Control N (41)	26.37	4.11	26.61	6.44	0.24	5.403	0.044
	Experimental N (39)	25	4.73	33.62	8.19	8.62	6.690	1.28

Results in Table 5.17 indicate that the value d (1.28), a positive gain score (a very large value of d) revealed that the posttest score was greater than the pretest score for experimental group who were taught physics via brainstorming technique. In contrast, results in Table 5.17 shows that the value d for the control group (0.044), a negative gain score (a small value of d) revealed that the traditional method might have had a little effect upon students to improve their critical skills. For the sub skills of critical thinking the results of gain score were as follows:

For inference the value was d (0.14), (a small value of d) revealing that the brainstorming might have had a little effect upon the experimental group for enhancing inference skill in physics. Moreover, results in Table 5.17 shows that the value d for control group (0.06). (a small value of d) revealing that the traditional method may have only had very little effect in enhancing physics students' skills of inference.

For recognizing assumptions the value was d (0.51), (a medium value of d) revealed that the brainstorming technique may have had an effect upon the experimental group for enhancing recognizing assumptions skills in physics. In contrast, results in Table 5.17 shows that the value d for the control group (0.09), a very small value of d revealed that the traditional method might have had little effect in enhancing physics students' skills of recognizing assumptions.

For deduction the value was d (0.51), (a medium value of d) revealed that the brainstorming technique may have had an effect upon the experimental group for enhancing deduction skills in physics. In contrast, results in Table 5.11 shows that the value d for the control group (0.01), a very small value of d revealed that the traditional method might have had little effect in enhancing physics students' skills of deduction.

For interpretation the value was d (0.85) (a large value of d) revealed that brainstorming may have had an effect upon the experimental group for enhancing interpretation skills in physics. In contrast, results in Table 5.11 shows that the value d for the control group (0.06), a very small value of d revealed that the traditional method might have had little effect in enhancing physics students' skills of interpretation.

For the skill of evaluating argument, the value was d (1.09), (a very large value of d) which revealed that brainstorming might have had an effect upon the experimental group for enhancing argument skills in physics. In contrast, results in Table 5.17 shows that the value d for the control group (0.29), a small value of d may indicate that the traditional method may have had very little effect to improve physics students' skills of argument.

Therefore, the Null hypothesis $H_o(7)$, that there is no statistically significant difference in the gain scores of the test of critical thinking between the experimental

group students who were taught physics via the brainstorming technique and the control group students who taught physics via the traditional method is rejected.

First the researcher of the present study found the difference within groups by using within-subject contrast test for both the experimental and control groups for the critical thinking test to determine how the brainstorming technique and the traditional teaching method had influenced the creative thinking skills among the selected Iraqi second-grade intermediate level. The results obtained are as shown in Table 5.18 below.

Table 5.18 Within -subject contrast test for the critical thinking

Critical thinking skills	**Group**	**source**	**Type III Sum of Squares**	**DF**	**Mean Square**	**F**	**Sig.**
Inference	Control	Intercept	0.195	1	0.195	0.08	0.76
		Error	88.805	40	2.220		
	Experimental	Intercept	1.038	1	1.038	0.50	0.48
		Error	78.462	38	2.065		
Recognizing assumptions	Control	Intercept	0.988	1	0.988	0.22	0.64
		Error	179.512	40	4.488		
	Experimental	Intercept	40.205	1	40.205	5.83	0.02*
		Error	261.795	38	6.889		
Deduction	Control	Intercept	0.049	1	0.049	0.006	0.93
		Error	304.951	40	7.624		
	Experimental	Intercept	16.615	1	16.615	6.68	0.01*
		Error	94.385	38	2.484		
Interpretation	Control	Intercept	0.439	1	0.439	0.07	0.78

Critical thinking skills	Group	source	Type III Sum of Squares	DF	Mean Square	F	Sig.
		Error	5.764	40	5.764		
	Experimental	Intercept	146.782	1	146.782	12.98	0.001*
		Error	429.718	38	11.308		
Evaluating arguments	Control	Intercept	11.720	1	11.720	1.74	0.19
		Error	268.780	40	6.720		
	Experimental	Intercept	210.051	1	210.051	23.54	0.000*
		Error	338.949	38	8.920		
Overall	Control	Intercept	1.220	1	1.220	0.042	0.83
		Error	1158.780	40	28.970		
	Experimental	Intercept	1447.1385	1	1447.385	30.31	0.000*
		Error	1814.615	38	47.753		

Results in Table 5.18 indicate that the value F (1, 40) = 0.042, P= 0.83> 0.05, indicates no significant difference for the mean within the control group in the pre- post tests for the overall result of the critical thinking test as a result of the utilizing traditional teaching method in physics. For the sub skills of critical thinking the results within the control group were as follows:

For inference the value was F (1, 40) = 0.008, P= 0.76 > 0.05, thus there was no significant difference for the mean scores within the control group in the pre- post test for inference.

For recognizing assumption the value was F (1, 40) = 0.22, P= 0.64 > 0.05, thus there was no significant difference for the mean scores within the control group in the pre- post test for recognizing assumptions.

For deduction the value was F (1, 40) = 0.006, P= 0.15 > 0.93, thus there was no significant difference for the mean scores within the control group in the pre- post test for deduction.

For interpretation the value was F (1, 40) = 0.07, P= 0.78 > 0.05, thus there was no significant difference for the mean scores within the control group in the pre- post test for interpretation.

For evaluating arguments the value was F (1, 40) = 1.74, P= 0.19 > 0.05, thus there was no significant difference for the mean scores within the control group in the pre- post test for evaluating arguments.

In contrast, results in Table 5.18 shows that the value F (1, 38) = 30.31, P= 0.00 < 0.05, indicates a significant difference between the mean scores within the experimental group in the pre- post results of the overall of the critical thinking test as a result of utilizing the brainstorming technique in teaching physics. The results of the sub skills in the critical thinking within the experimental group were as follows:

For inference the value was F (1, 38) = 0.50, P = 0.48 > 0.05, thus there is no significant difference between the mean scores within the experimental group in the pre- post results for inference.

For recognizing assumption the value was F (1, 38) = 5.83, P = 0.02 < 0.05, thus there is a significant difference between the mean scores within the experimental group in pre- post results for recognizing assumption.

For deduction the value was F (1, 38) = 6.68, P = 0.01 < 0.05, thus there is a significant difference between the mean scores within the experimental group in pre- post results for deduction.

For interpretation the value was F (1, 38) = 12.98, P = 0.001 < 0.05, thus there is a significant difference between the mean scores within the experimental group in pre-post results for interpretation.

For evaluating arguments skill the value was F (1, 38) = 23.54, P = 0.000 < 0.05, thus there is a significant difference between the mean scores within the experimental group in pre- post results for evaluating arguments.

From the results in Table 5.18 the researcher of the present study concluded that the traditional teaching method utilized for teaching physics for selected Iraqi second-grade intermediate level students appear to hinder and does not contribute in improving and enhancing creative thinking skills in contrast to the brainstorming technique.

To investigate the significant differences between the mean of the experimental group and the control group and the effect of the brainstorming technique on enhancing critical thinking skills among the selected second-grade intermediate Iraqi students in physics, analysis of covariance (ANCOVA) was used at the level of significance (0.05) and degrees of freedom (1,78). The results obtained are as shown in the Table 5.19.

Table 5.19 ANCOVA result for critical thinking test

Critical thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig
Inference	Corrected Model	9.183	2	4.592	1.817	0.169
	Intercept	119.676	1	119.676	47.350	0.000*
	Pre	8.858	1	8.858	3.505	0.065
	Group	0.562	1	0.562	0.222	0.639
	Error	194.617	77	2.527		
	Total	1212.000	80			
	Corrected Total	203.800	79			

Critical thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig
Recognizing assumption	Corrected Model	50.786	2	25.393	3.825	0.026*
	Intercept	389.521	1	389.521	58.670	0.000*
	Pre	14.313	1	14.313	2.156	0.146
	Group	39.085	1	39.085	5.887	0.01*
	Error	511.214	77	6.639		
	Total	3442.000	80			
	Corrected Total	562.000	79			
Deduction	Corrected Model	10.267	2	5.133	0.611	0.545
	Intercept	167.154	1	167.154	19.911	0.000
	Pre	1.064	1	1.064	0.127	0.723
	Group	9.733	1	9.733	1.159	0.285
	Error	646.421	77	8.395		
	Total	3597.000	80			
	Corrected Total	656.687	79			
Interpretation	Corrected Model	155.872	2	77.936	5.559	0.006
	Intercept	321.041	1	321.041	22.899	0.000*
	Pre	8.423	1	8.423	0.601	0.441
	Group	142.600	1	142.600	10.171	0.002*
	Error	1079.515	77	14.020		
	Total	4921.000	80			
	Corrected Total	1235.388	79			
Evaluating arguments	Corrected Model	91.006	2	45.503	3.251	0.044*
	Intercept	243.865	1	243.865	17.423	0.000*
	Pre	0.104	1	0.104	0.007	0.931
	Group	89.889	1	89.889	6.422	0.013*

Critical thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig
	Error	1077.744	77	13.997		
	Total	5820.000	80			
	Corrected Total	1168.750	79			
Overall	Corrected Model	987.919	2	493.960	9.047	0.000*
	Intercept	2285.166	1	2285.166	41.855	0.000*
	Pre	6.956	1	6.956	0.127	0.722
	Group	932.602	1	932.602	17.081	0.000*
	Error	4204.031	77	54.598		
	Total	77312.000	80			
	Corrected Total	5191.950	79			

The value F (1, 78) = 17.08, P= 0.000 < 0.05 in Table 5.19 indicates significant difference between the mean of the experimental group and the control group for the overall result of the critical thinking test in favour of the experimental group who were taught physics via the brainstorming technique. For the sub-skills of critical thinking the results were as follows:

For inference the value was F (1, 78) = 0.22, P= 0.63 > 0.05, which indicates that there was no significant difference between the mean of the experimental and the control groups for inference.

For recognizing assumptions the value was F (1, 78) = 5.88, P= 0.01 < 0.05, which indicates that there was a significant difference in the mean of the experimental and the control groups for recognizing assumptions.

For deduction the value was F (1, 78) = 1.15, P= 0.28 > 0.05, which indicates that there was no significant difference between the mean of the experimental and the control groups for deduction.

For the skill of interpretation the value was F (1, 78) = 10.17, P= 0.002 < 0.05, which indicates that there was a significant difference in the mean of the experimental and the control groups interpretation.

For evaluating arguments the value was F (1, 78) = 6.42, P= 0.013 < 0.05, which indicates that there was a significant difference in the mean of the experimental and the control groups for evaluating arguments.

Multivariate Analysis Of Variance Analysis (MANOVA) was used next to further analyse the results of the study. Table 5.20 showed the results of MANOVA for the critical thinking test.

Table 5.20 MANOVA result of critical thinking test

Critical thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig
Inference	Corrected Model	0.325a	1	0.325	0.125	0.725
	Intercept	1008.475	1	1008.475	386.589	0.000
	Group	0.325	1	0.325	0.125	0.725
	Error	203.475	78	2.609		
	Total	1212.000	80			
	Corrected Total	203.800	79			
Recognizing assumption	Corrected Model	3597.000	1	36.473	5.413	0.023
	Intercept	2894.423	1	2894.423	429.597	0.000

Critical thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig
	Group	36.473	1	36.473	5.413	0.023
	Error	525.527	78	6.738		
	Total	3442.000	80			
	Corrected Total	562.000	79			
Deduction	Corrected Model	9.203d	1	9.203	1.109	0.296
	Intercept	2946.703	1	2946.703	354.978	0.000
	Group	9.203	1	9.203	1.109	0.296
	Error	647.485	78	8.301		
	Total	3597.000	80			
	Corrected Total	656.687	79			
Interpretation	Corrected Model	147.449e	1	147.449	10.571	0.002
	Intercept	3720.249	1	3720.249	266.724	0.000
	Group	142.600	1	142.600	10.171	0.002*
	Error	1087.939	78	13.948		
	Total	4921.000	80			
	Corrected Total	1235.388	79			
Evaluating arguments	Corrected Model	90.901f	1	90.901	6.578	0.012
	Intercept	4680.901	1	4680.901	338.740	0.000
	Group	90.901	1	90.901	6.578	0.012
	Error	1077.849	78	13.819		
	Total	5820.000	80			
	Corrected Total	1168.750	79			
Overall	Corrected Model	72496.013	1	72496.013	1342.842	0.000
	Intercept	72496.013	1	72496.013	1342.842	0.000

Critical thinking skills	Source	Type III Sum of Squares	DF	Mean Square	F	Sig
	Group	980.963	1	980.963	18.170	0.000
	Error	4210.987	78	53.987		
	Total	77312.000	80			
	Corrected Total	5191.950	79			

The value F (1, 78) = 18.170, P= 0.000 < 0.05 in Table 5.20 indicates a significant difference between the mean of the experimental group and the control group for the overall result of the critical thinking test in favour of the experimental group who were taught physics via the brainstorming technique. For the sub-skills of critical thinking the results were as follows:

For inference the value was F (1, 78) = 0.12, P= 0.72 > 0.05, which indicates that there was no significant difference between the mean of the experimental and the control groups for inference.

For recognizing assumptions the value was F (1, 78) = 5.41, P= 0.02 < 0.05, which indicates that there was a significant difference in the mean of the experimental and the control groups for recognizing assumptions.

For deduction the value was F (1, 78) = 1.10, P= 0.29 > 0.05, which indicates that there was no significant difference between the mean of the experimental and the control groups for deduction.

For the skill of interpretation the value was F (1, 78) = 10.17, P= 0.002 < 0.05, which indicates that there was a significant difference in the mean of the experimental and the control groups interpretation.

For evaluating arguments the value was F (1, 78) = 6.57, P= 0.012 < 0.05, which indicates that there was a significant difference in the mean of the experimental and the control groups for evaluating arguments.

After a review of previous studies, it was found that the results of the present study are consistent with the findings of each of the following studies (Harbi, 2002; Maitah, et al., 2011) which indicated the effectiveness of the brainstorming technique in enhancing critical thinking skills.

The researcher of present study summarized the results of the influence the brainstorming technique on critical thinking skills in physics for selected Iraqi second-grade intermediate level as shown in table 5.21 below.

Table 5.21 A summary of the results of the critical thinking test

Critical thinking skills	**Control group**	**Experimental group**
Inference	The traditional teaching method does not appear to have supported the selected Iraqi students in improving the inference skill in physics where the results of within and between groups show that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique also does not appear to have supported the selected Iraqi students in improving the inference skill in physics where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.

Critical thinking skills	Control group	Experimental group
Recognizing assumptions	The traditional teaching method does not appear to have supported the selected Iraqi students in improving the recognizing assumption skill in physics where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique appears to have had a positive effect on selected Iraqi students in improving the skill of recognizing assumption where the results of within and between groups shows that there is a significant difference within pre-post test and between control and experimental groups.
Deduction	The traditional teaching method does not appear to have supported the selected Iraqi students in improving deduction skills in physics where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique appears to have had a positive effect on selected Iraqi students in improving deduction skills where the within group result show there is a significant difference within pre-post test. However, the results between groups show that there is no significant difference between control and experimental groups.
Interpretation	The traditional teaching method does not appear to have supported the selected Iraqi students in improving the skill of interpretation in physics where the results of within and between groups shows that there is no significant difference within pre-post test and between control and experimental groups.	The brainstorming technique appears to have had a positive effect on selected Iraqi students in improving interpretative skills in solving physics problems where the results of within and between groups shows that there is a significant difference within pre-post test and between control and experimental groups.
Evaluating arguments	The traditional teaching method does not appear to have supported the selected Iraqi students in improving skills of evaluating arguments in physics where the results of within and between groups shows that there	The brainstorming technique appears to have had a positive effect on selected Iraqi students in improving the skill of evaluating arguments where the results of within and between groups shows that there is a

Critical thinking skills	Control group	Experimental group
	is no significant difference within pre-post test and between control and experimental groups.	significant difference within pre-post test and between control and experimental groups.
Overall	The traditional teaching method does not appear to have supported the selected Iraqi students in improving overall the critical thinking skills in physics where the results of within and between groups shows that there is no significant difference between pre-post test and between control and experimental groups.	The brainstorming technique appears to have had a positive effect on selected Iraqi students in improving overall critical thinking skills in physics where the results of within and between groups shows that there is a significant difference between pre-post test and between control and experimental groups.

5.3 The Enhancement of Creative and Critical Thinking Skills

The fourth research question for the present study was "How is the enhancement of creative and critical thinking skills among selected secondary Iraqi physics students who have experienced brainstorming technique?" This research question focused on describing how the brainstorming technique can possibly lead to the enhancement of creative and critical thinking skills among second-grade intermediate Iraqi students in physics.

To answer this research question, data were collected from different sources, which included students' observations, open-ended survey questions, students' interviews, students' feedback journals and teachers' comments. The observations were recorded in the form of audio, and video of the whole class as well as photographs.

Observational data were integrated with other data such as interview data and student's feedback journals to build a deeper understanding of how the learners learn

through the brainstorming technique. The researcher noted down all the teacher's comments during the informal discussions. The researcher then read the data very carefully, summarized, and developed the coding categories and the coding themes.

As mentioned in Chapter 1 and Chapter 3, the brainstorming technique can be utilized to place the learner's brain in a state of high concentration in order to generate the largest possible number of ideas about a particular problem, so that problems are converted to creative ideas. Furthermore, the brainstorming technique can be a tool to challenge students and move the mind of the learner to a state of excitement and readiness as the students reflect on the generation of solutions to a problem.

The analysis of data identified two important aspects in the enhancement of creative and critical thinking skills among the selected sample. First, the data collected helped explain the key elements which could possibly have helped students to enhance the skills of higher-order thinking where in the context of this study are creative and critical thinking. Second, it allowed the researcher of the present study to understand the possible mental processes used by the Iraqi students in the enhancement of creative and critical thinking. The following sections will explain both these aspects.

5.3.1 Key Elements in the Enhancement of Creative and Critical Thinking Skills

The key elements identified in the study that could have assisted in the enhancement of creative and critical thinking skills among the sample of physics students in the study are,

(a) Scaffolding provided by the brainstorming technique, and

(b) Motivation which came about because of the utilization of the brainstorming technique.

Figure 5.6 below, illustrate the elements (the given physics problem; lesson rules - collective learning and classroom climate) that could have motivated the mental process in the enhancement of creative and critical thinking skills through the processes of associating new and old knowledge, by giving rise to cognitive conflict and encouraging social construction of knowledge.

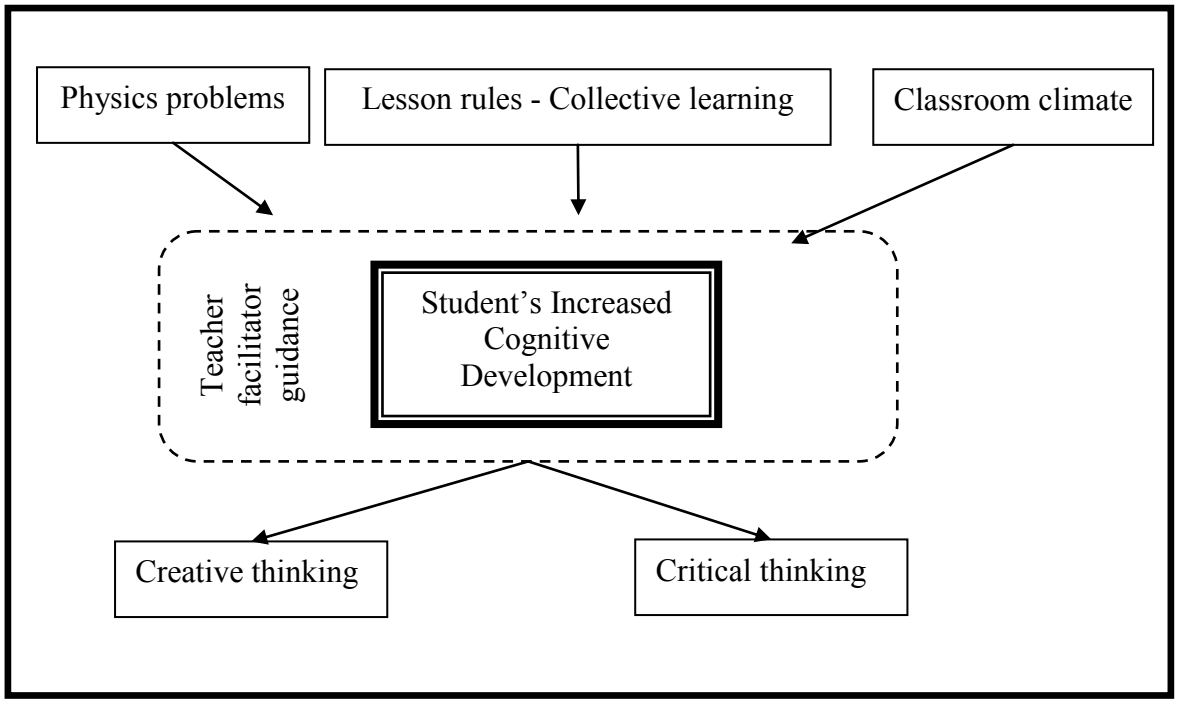


Figure 5.6 Elements that have an effect on enhancing creative and critical thinking

5.3.1.1 Scaffolding through the Brainstorming Technique

The support on scaffold for the enhancement of creative and critical thinking skills involved:

(i) The carefully planned physics problems presented via the brainstorming technique,

(ii) The rules set down for the lessons using the brainstorming technique, and

(iii) The classroom climate created utilizing the brainstorming technique.

(i) Physics Problems Presented in the Brain Storming Technique

Thinking does not occur from nothing. Hence, the physics problems presented to the students through the brainstorming technique seemed to catch the attention and interest of the students. Most students expressed that the physics problem provoked their interest and attention to stimulate and activate their minds to retrieve and recall different information related to the problem to participate in discussions with group members.

> *"The physics problem was interesting stimulus for me to think and search for information for that I tried to take advantage from my previous information about the problem in addition to the involvement with members of the group in the discussion to obtain information and ideas which helped me in merging the information and ideas together to generate a large number of ideas".* (Cardana, interview, 5/3/2013).

> *"The problems presented helped me to recall information, laws, concepts and physics theories I had learned in previous academic levels which exist in the physics textbook and some information I gained from different sources such as reading scientific books and watching scientific programmes".* (Isal, student journal feedback, 12/3.2013).

> *"Most problems presented helped me to activate my mind to recall ideas and information I learned in the previous lessons".* (Noor, interview, 26/3.2013).

> *"After the problem was presented I remember different information relating to the problem that I have gained from the physics book and my daily life and watching science programmes to try to understand the problem and reach for solutions"*. (Hassan, interview, 2/4/2013).

> *"The problem raised and provoked my curiosity in the search, verification and predictability so I tried to recall all my personal information about the problem to try and solve it".* (Nassm, open ended question, 21/5/2013).

Physics has a sufficient range to promote creativity in its own domain which indicates the possibility of bringing up creativity in the context of learning physics. The physics problems presented during the brainstorming technique appeared to stimulate recall and retrieve previous concepts and perceptions of the students from

their Long Term Memory (LTM) which lead the student to research, discuss and investigate to arrive at a solution to the problem. Physics teacher (Miss Zainab) commented that "I observed that the physics problem has attracted the interest of students to solve it, the motivation of my students to learn physics increased after I submitted the physics problem the confusion and anxiety and tension of the student have been provoke. Students' starts discuss, ask questions related to the problem, and recall some physics laws and previous information to reach solutions to the problem" (Miss Zainab, Teacher's comment, 2/4/2013).

The researcher of the present study found that the physics problems challenged the learners' minds and created cognitive conflict and stimulated them to recall and retrieve different information related to the problems from LTM to help them in discussing with group members and generating many ideas.

(ii) Brainstorming Technique Lesson Rules

In the context of this study, the lesson rules emphasised as the brainstorming technique utilized were (i) generate as many initial ideas as possible, (ii) criticism and evaluation was not allowed until all ideas were in, (iii) all ideas no matter how farfetched were allowed, and (iv) ideas put forward can be built upon the ideas of others.

The rules of brainstorming appears to have released the student from being passive and an introvert, removed the fear of participating in the brainstorming sessions and helped them to integrate and cooperate with other members of the group and gave them more freedom to express their ideas, and to unleash thinking. Most of the students in the experimental group expressed that the plans and rules of the brainstorming based physics lessons activated their minds and made them think more freely.

> *"The rules that teacher always remind us for example no criticism of any ideas, focus on numbers of ideas regardless of their quality, launched your*

mind and gave the freedom to think whatever kind of ideas and building on others ideas encourage me to generate a large numbers of ideas". (Isal, student feedback journal, 9/4/2013).

"The rules of the lesson motivated me to participate in the lesson and work with my group members to solve problems". (Abdel Aziz, student feedback journal, 9/4/2013).

"Accept all the ideas and opinions raised by my group members because the process to postpone criticism and non-evaluation ideas the moment it appears for a temporary period encouraged me to increase the production of ideas to the problem". (Amer interview, 23/4/2013).

The teacher, who taught the experimental group, Miss Zainab, commented that the changed rules and plans for the physics lessons based upon the brainstorming technique impacted the students as they become more active and willing to do the activities compared with the traditional lessons.

The researcher found that the brainstorming technique stimulated students to participate and cooperate and encouraged them to find new ideas for intellectual competition without fear of the teacher. Giving greater freedom for students in thinking and to generate solutions to a presented problem, whatever the quality of these solutions or any level, will exclude any kind of judgment or criticism or evaluation of ideas generated, provoke the enthusiasm of the students in brainstorming sessions and to generate the largest possible number of ideas. This will increase the likelihood of achieving a greater of the original ideas to the problem.

The researcher of the present study found that the deferred judgment for the ideas generated, and not to criticize makes students' flow with ideas in full freedom, which creates an atmosphere free for the brain and thought in general, in addition to being an interesting process for students to participate in exchanging opinion and mix exotic ridiculous and unusual ideas with each others. This psychological safety helped

the participant feel safe enough to open up and offer the more creative ideas (Paulus, Nakui, & Putman, 2005).

(iii) Classroom Climate

The nature of the environment created by the brainstorming technique played an important role in that it provided students a space for dialogue and expression of opinion and discussion and allowed students to go beyond the role of the listener or receiver of information alone. The brainstorming appeared to bring about satisfaction and happiness among the students. Observations indicated the continued willingness of students to perform activities. The cooperation between the students and encourage each other to integrate thinking with the group and encourage the teacher and give humor and fun and playing on the educational situation is a good tool to stir up ideas of students and facilitate the process of thinking and creativity. Students appear to have fun where learning physics in a non-traditional method and solving physics problem does not make them feel bored. A student commented as follows,

> *"This method is very useful because it does not focus only on the physics topics, but planted the love between students through cooperation and harmony with each other; it is transformed studied physics from cumbersome, boring and routine into the wonderful lesson characterized by joy and pleasure*". (Dania, open-ended question, 21/5/2013).
>
> *"All students in classroom were happy during the sessions and they were conducting experiments with each other and sharing laughs unlike previous physics lessons we sat silently without movement or laughed just attention to the teacher and the blackboard"*. (Mayssam, interview, 30/4/2013)

Observations also indicated the integration of students in brainstorming sessions and the accept any of idea posed lead to respect of other students' ideas and not ridicule. This encouraged students to cooperate and participate and to give different opinions and

ideas. It was observed that students' moved from being negative to participate with others in debates and to offer the best solutions and seek to analyze all the aspects related to the problem.

> *"I was shy of putting my thoughts in front of members of my group at the beginning of the sessions then I found some of my friends are pose ideas were weak, illogical or unworkable to solve physics problems (focus and focal length topic), then I decided any idea come to my mind I pose it to my group without hesitation".* (Warda, student feedback journal, 16/4/2013).

In addition to the interesting presentation of educational materials and method of implementation through the steps of the brainstorming process in the classroom, it seems that the approach removes the psychological pressures of the subject teacher. It was observed that removing the fear of the participants and being freed from the control of the teacher in the brainstorming sessions helps the students' to integrate with the rest of the members of the group and gave them more freedom to express their ideas which unleashed their thinking.

> *"I was liberated from the control of the teacher during the physics lesson I can speak with my friends and asked some questions that I was afraid that the asked teacher".* (Abdel Rahman, interview, 23/4/2013).

> *Physics teacher (Miss Zainab) was very nice, she guide the groups in class to cooperate, research and discussion. She was only watching us how we are solving physic problems without interference or pressure.* (Iaa, students' journal feedback, 2/4/2013).

Brainstorming eliminates the barriers between the teacher and students and between students with each other which increases the participation of students in generating ideas without fear or embarrassment of making mistakes in front of others.

Thus an appropriate climate which promotes democracy in discussions and creates a relaxed environment makes room for the students to voice out various ideas. Some comments were,

> *"I was relaxed and relived during activities"*. (Yasser, student feedback journal, 16/4/2013).

> *"I feel my mind is opening (unrestricted), giving freedom to experiment and try until a solution is reached"*. (Khalil, student feedback journal, 16/4/2013).

It was observed that the brainstorming sessions made available to the student an atmosphere of freedom and relaxation in discussions and allows the emergence of all views and ideas. The physics teacher (Miss Zainab) commented that the brainstorming technique expels students' boredom and pushes them to challenge and stimulate their own minds to participate actively and to solve the physics problem.

> *"No longer physics lessons boring and difficult, because the physics questions become interesting and also I found a lot of my friends help me to understand the physics problem as well as I did experimentation and discovery by myself and this makes the lesson fun and enjoyable for me because I rejoice too much when I get to the solution of the problem"*. (Noor, interview, 23/4/2013).

> *"I was very happy and I wait physics lessons for the coming of the eagerly because it was fun and not unlike the rest lessons like mathematic lesson"*. (Nizar, open ended questions, 21/5/2013).

The brainstorming technique creates a challenging intellectual environment in which debate is honest and ideas are critiqued. It is the teacher's role to create an atmosphere of support and nurture in which students feel accepted as young intellectuals. A nurturing environment enables students to develop the confidence to experiment with ideas and overcome the fear of being wrong, thus fostering creativity and imagination (Chang, 2011).

Observations indicated the lesson climate in brainstorming sessions was one of freedom and security which helped in the expression of ideas, as there was no evaluation or criticism. Tolerance towards ideas of students was evident. No idea was made fun of which could impede creative thinking.

The scaffolding provided by the brainstorming technique discussed above provided the platform to motivate the students which will now be discussed.

5.3.1.2 Motivation through the Utilization of the Brainstorming Technique

Motivation appears to be a primary factor influencing the activation of thinking abilities among students. A key feature of the brainstorming technique is student - centered learning. The learner has full responsibility for her/his learning. Brainstorming works to increase the dynamism and active learning of students in the organization and planning of learning while trying to solve the problem at hand. To get students actively engaged in thinking about what they are trying to learn during the learning process motivation is important.

Students' feedback and interview data described that this learning experience utilizing the brainstorming technique makes the students more active in acquiring knowledge and skills as well as motivate them to discover, share information, discuss, communicate, and experiment. This appears to move students from a passive role to an active one. Thus, it seems that the time invested in the physics lessons was efficient and effective for student learning. One student commented that:

> *"I no longer sit down to listen to the teacher's lecture, which is a transfer of existing information in the physics book to the lesson and remember the information without understanding and thinking; but I participated in a physics experience and discovered the causes and generated ideas to find solutions for a physics problem".* (Nassm, interview, 23/4/2013).

Some students commented that the students' roles in the activities during physics lessons have changed from being marginalized and negative (sitting quietly and only listening) to taking on a more positive role (being a leader or secretary) which motivated students to search, discover, discuss, and conduct experiments.

> *"The biggest motivation for me to learn physics is that I have a positive role, being involved in the search and collection of information, discussion and discovery and implementation of ideas that I have not ever participated in the regular lessons"*. (Manar Mohamed, students' journal feedback, 2/4/2013).

> *"I have never taken part in a physics lesson before because I do not have the ability to remember information in the book and repeat to the teacher, while in this new learning experience I am encouraged to solve the physics problem without the need to remember the information in the book and I practiced my ability to think and I generated creative ideas"*. (Maryam, open-ended question, 21/5/2013).

> *"I feel stimulated to participate in the search for information, discussion with peers; generate ideas and experiment to reach a solution to the physics problem. In contrast, in the normal lesson I was only listening to remember the concepts of physics without understanding or focus because the teacher explains and generates ideas and conclude and give the answer to us, the answer ready which does not allow us to think or debate, and also the time does not allow for discussion and thinking"*. (Mohammed, interview, 19/3/2013).

> *"I participated in all the lessons of physics and I had a role in solving the questions provided by the teacher"*. (Rafal, student journal feedback, 2/4/2013).

The researcher of the present study asked the physics teacher (Miss Zainab) about the brainstorming technique based on the students' descriptions of the learning activities via the brainstorming technique given above. The teacher commented that a student became more active and attentive to the lesson when the teacher gave her/him full responsibility for learning physics.

> *"My responsibilities changed from remember the information in the textbook as it without change to the research and discussion with peers and thinking for finding solutions to the physics problem. The teacher (Miss Zainab) is no longer giving me ready- solutions or examples of the physics topic, but I must find it by myself"*. (Mohammad, open-ended questions, 21/5/2013).

> *"I have been involved in the discussion, research and physics experiment, all of these were the responsibility of the physics teacher (Miss Zainab) and I was just sit down to watch without the participation in the new*

teaching method I have responsibility to learn so that I can understand the physics problem". (Sarah, interview, 19/3/2013).

In contrast, in the normal physics class the full responsibility was upon the teacher for teaching, discussions, and answering questions. At the end of the brainstorming technique integrated lessons, the teacher stated that she increased her experiences in the teaching and learning process and the students gained understating through much thinking. She said, through the application of brainstorming technique,

"I realized that the students have mental capabilities and high ideas to solve the physics problem which it better ideas from the teacher and I found that use of teaching methods that focus on the student and where the student is a researcher and thinker contribute to the development of mental skills and cognitive and increase their achievement which is one of the important elements that sought by the teacher". (Miss Zainab, teacher comment, 27/3/2013).

Now that the key elements have been put forward in the enhancement of creative and critical thinking skills, the discussion will turn to the mental processes that the students go through as they enhance creative and critical skills in the classroom utilizing the brainstorming technique.

5.3.1.3 Mental Processes in the Enhancement of Creative and Critical Thinking

The mental processes that the students in the experimental group indicated as they participated in the brainstorming technique based lessons include:

(a) Associating new knowledge with the old,

(b) Cognitive conflict, and

(c) Social construction of ideas.

The following three sections will describe in detail the mental processes that Iraqi second grade intermediate level indicated during brainstorming sessions.

(a) Associating New and Old Knowledge

The fragmentation and analysis of the given problem to its primary elements appears to have helped the students in a brainstorming session to start to recall, which leads to links between the new concept or concepts embedded within the problem with many past daily experiences and natural phenomena. One student stated,

> *"I built a bridge between associated and non-associated ideas with the problem until I get a large number of ideas".* (Iaa, interview, 2/4/2013).

The researcher is of the opinion that the student will start to enhance the sub skill of creativity that is fluency to recall and remember the greatest possible number of ideas, information and alternatives that have already been learned from previous academic stages and that its relationship with the problem at hand in a meaningful way from long-term memory, which represents the permanent inventory of ideas and information.

> *"I used strange and ridiculous ideas raised by group members during the discussion and I convert it to valuable ideas contribute for solving the problem".* (Abraham, interview, 30/4/2013).

> *"I collected information and ideas from my group then I used my mind to turn it into many new ideas".* (Yasser, open-ended, 21/5/2013).

> *"I integrated the ideas of the group and I took the correct ones then I developed in a formula of new ideas".* (Shaima, student feedback journal, 16/4//2013).

> *"I linked between my ideas and my friends ideas to generate largest possible of physics ideas".* (Ahmed, interview, 30/4/2013).

The qualitative data complements the quantitative data discussed earlier, for fluency where the ANCOVA results show the value was $F(1, 78) = 36.99$, $P = 0.000 <$

0.05, Thus there is a statistically significant difference between the mean scores of the experimental group and control group for fluency in favour of the experimental group.

The researcher argues that the brainstorming technique contributed actively to the enhancement of the skill of fluency due to brainstorming aims to get the largest possible quantity of ideas on the problem at hand, and this in turn allowed them enough opportunities the potential to generate ideas. The student tries to associate the new with the old meaningfully in various ways (fluency) (DeHaan, 2009) the quantitative aspect of creativity, where the brainstorming technique encourages the flow of ideas (while delaying evaluation to a later stage) can be accentuated. This would enable the student to generate a large number of ideas and this leads to increased fluency. That fluency is measured by the number of ideas is also stated in the literature (Benedek, et al., 2012; Rather, 2004) and the brainstorming technique encourages the generation of this quantity due to students being able to focus more on generating the greatest possible number of ideas, regardless of their quality. This is because no criticism is allowed, no matter how silly the ideas are, which leads the students to generate a big list of ideas for physics problems. As a result, the secondary second-grade intermediate Iraqi students were improving their skill of fluency as measured in the creative thinking test.

> *"My sense that my thoughts may not be placement to criticism or censorship and blame by teacher or the students each other when it arises was enough factor to issue any other ideas. On the other hand the fear of criticism weakens or stops the ability to generate ideas".* (Cardana, student feedback journal, 16/4//2013).
>
> *"Confirmation teacher to generate the largest possible number of ideas (an unspecified number of ideas) whatever the quality of these ideas and so welcoming exotic and unfamiliar ideas gave me greater freedom in thinking*".(Noor, interview, 30/4/2013).

The student, while trying to associate the new and the old knowledge and in trying to generate initial ideas will also probably begin the enhancement of another sub

skill of creativity, originality. The quantitative results have shown that the difference between the experimental group and the control group was the low although significant as shown by the ANCOVA results. For originality the value was F (1, 78) = 12.16, P= 0.001 < 0.05, and there is a significant difference between the mean scores of the experimental group and control group for originality in favour of the experimental group. There could be several factors that may affect the enhancement of originality. For instance, a lack of information possessed by the student (previous experiences and knowledge), and a weakness in the capabilities of the student in the construction of new relationships between old and new physics concepts or did not have enough confidence or inability to diagnose the problem (Cheng, 2010; Shaheen, 2010).

> *"Making indirect links (think in new ways or unusual or extraordinary) between knowledge and information that I already have it and information gained by the members of my groups and think alone to find unique and new solutions to the physics problem and violation of others were very few"*. (Manar, student journal feedback, 16/4//2013).

> *"I have found it difficult to generate new ideas or solutions to the physics problem where most of my thoughts were familiar and unusual and duplicate with majority of the members of my group". (Dania, interview, 30/4/2013).*

> *"I'm afraid the generation of a new or strange idea may be the ideas failed so often I was thinking in a way similar to the members of my group so as not to be in the position of irony in if found that ideas is wrong and cannot be applied because there are in my group who have capabilities to analyze the solution and finding evidence that this idea or solution is not logical that in most cases I prefer thinking in the familiar solutions"*. (Obeida, interview, 30/4/2013).

Thus, in brainstorming, the association of old knowledge with the new is an important aspect that can contribute to the initial enhancement of creative thinking skills.

(b) Cognitive Conflict

As described above, initially the students will begin to generate ideas on their own when faced with the physics problem. As the new concepts they are trying to process connect with existing concepts previously learnt, the students may face cognitive conflict within

their own minds first and experience disequilibrium. This will probably lead to existing schema being modified to achieve equilibrium individually.

The sub creative skills of originality will probably continue to enhance as each individual student after putting forward their initial ideas, begin to think about ideas put forward by peers in their group. The researcher believes that the originality skills can be enhanced because in the brainstorming technique especially after all students have finished generating initial ideas, all the ideas that were generated will be collected and be discussed together. In discussing together the students could experience cognitive disequilibrium repeatedly as they are faced with opposing and alternative ideas compared to their own. Their initial mental structures and schema could change before equilibrium is restored. This is reflected in one of the student's statements,

> *"I discussed with members of the group, there were conflicting ideas pushed me to rethink the problem and benefited from the ideas and opinions during the discussion to reach a suitable solution to the problem".* (Obedia, interview, 19/3/2013).

> *"I took a long time to decide and choose the right idea although I benefited greatly from my friends ideas and opinions during the discussion as well as my group benefited from my thoughts by reminding us of information and examples related to the physics problem given in the previous chapters supported the ideas selected*". (Muammil, interview, 30/4/2013).

This will further increase the ideas and could probably lead to the acquisition of new information and experiences and help to increase the likelihood of achieving even greater original ideas that will help the students to collectively reach a creative solution to the problem presented. The exchange of ideas between group members most probably provokes thinking and draws attention to aspects not thought of before. Some of the students' statements below support this,

> *"After discussion and exchange of views with members of the group and the analysis and classification of presented ideas helped me to know the correct solution, especially that Manar my colleague presented strong evidence I take*

advantage from it to support my selected one idea". (Isra, interview, 30/4/2013).

"I carefully thinking and I seriously tried and I discuss with the members of the group unable me to choose the closer idea related to the problem at hand". (Ali, open-ended question, 21/5/2013).

"Differing views among the group members prompted me to think deep in the selection of appropriate idea about the conclusion and decision-making to help the group to reach a solution to the problem". (Zahraa, student feedback journal, 20/3/2013).

"After reviewing my group's ideas, the problem is brewing in my mind and I understood it's from all dimensions. Where I left non practical solutions because there are alternative solutions are achievable and have a value to solve proposed question". (Iaa, interview, 23/4/2013).

"The differences between my idea and my group ideas pushed me to more checking and thinking again to reach the correct conclusion". (Suhad, student feedback journal, 7/5/2013).

"I stimulated more to solve the problem after I read and listen to the ideas of the group members. The exclusion of ideas that is not linked to the problem and retention of the most useful ideas make me concentrate in the selection of appropriate idea to solve the problem". (Mohammed, interview, 5/3/2013).

"I focused more on the problem to determine the reasons and analysis the ideas to find out the similarity and differences between them". (Noor, open-ended questions, 21/5/2013).

The sub creative skill of flexibility will also probably begin to be enhanced. The divergence of views and opinions among the members of the group could lead to cognitive conflict in the minds of the students, but at the same time provide a broad base of information and various ideas to help students to assimilate and accommodate as they examined the given physics problem from all aspects and generate a variety of kinds of ideas (Flexibility).

"Analysis of ideas into its basic elements and linking between similar ideas during the discussion with my members of the group helped me to understand the problem in all its aspects and to reach the right solution". (Mustafa, student feedback journal, 26/3/2013).

The learner requires the flexibility skill to convert or routing paths of thinking and creates the biggest network of linkages between new concepts of the physics problem and concepts existing in the prior cognitive structure to generate a variety of ideas and solutions to the problem.

> *"My discussion with my group members helped me in the detected of new relationships between physics concepts, so I used the information which I acquired in the synthesis of ideas and modify and change ideas to generate the largest possible number of various ideas".* (Daha, interview, 30/4/2013).

It appears that in the discussion students try to weigh multiple answers and think in multiple directions in order to rearrange, organize and connect ideas. One of the students said that,

> *"My group submitted many of the ideas and during the discussion excluded wrong ideas and found more than one member of my members focused on one idea and clarified reason for their choice of the idea so guessed it appropriate idea to solve the problem".* (Reem, student feedback journal, 6/4/2013).

The researcher is of the opinion that in the brainstorming sessions the exchange of ideas and discussion among students could lead to the emergence of ideas and production of advanced 'new' ways (flexibility). The Physics teacher always encouraged the students to build ideas upon the ideas put forward by others in order to generate multiple answers to a physics problem, and not adhering to any one solution or idea to the problem. During group discussions, students listen to the opinions and ideas of their peers for the problem at hand, experience disequilibrium, help in the reconstruction of ideas by directing or diverting thinking of their peers through an understanding of the problem from different aspects and then re-formulate the ideas and opinions in an alternate way (DeHaan, 2009; Hogan & Tudge, 1999; Thurston, et al., 2007). As a result, second-grade intermediate Iraqi students were improving their skill of flexibility as measured by the creative thinking test.

The quantitative data for flexibility also explains the ANCOVA results for flexibility where the value obtained was F (1, 78) = 33.09, P= 0.000 < 0.05. Thus there is a statistically significant difference between the mean scores of the experimental group and control group for flexibility in favour of the experimental group. In other words, it appears that brainstorming stimulates the imagination of the students to reach the largest possible number of creative ideas to resolve problems and help enhance flexibility.

(c) Social Construction of Ideas

The brainstorming technique requires two parties, one challenging the other, which can happen in the discussions while using the brainstorming technique. Brainstorming is designed to employ the power of collective thinking of the group to reach ideas that the individual alone cannot achieve. Each student's mind works concertedly with the others in the group in a systematic way. Ideas generated by each individual member can stimulate the emergence of new ideas with the other members of the group. This will probably help to enhance the sub skills of fluency, flexibility and originality. Some students commented that:

> *"Ideas and opinions of my group made my mind in a situation of excitement and readiness to think in all directions to generate ideas for the problem at hand".* (Reem, interview, 23/4/2013).

> *"I greatly benefited from the information and experiences raised by each member of the group during discussion time to mix it with my knowledge about the problem to generate a large number of ideas in order to contribute in solving the problem physics with my group members".* (Mariam, student feedback journal, 16/4/2013).

> *"I obtained lot information and various ideas from my group members helped me to increase my speed of thinking to generate a large number of ideas".* (Sarah, open-ended question, 21/5/2013).

> *"I used the information which obtained from peers to generate ideas. Get around the problem and viewed from more than one side, and trying to encircle and storm".* (Mustafa, interview, 23/4/2013).

> *"Exchange ideas with my group members and with my information about the problem helped me to generate one idea. This one idea leads me to think another idea and then to another and then to another and then to another".* (Maryam, interview, 30/4/2013).

Others students commented that the competition between the group members encouraged them to generate ideas during brainstorming sessions.

> *"Competition between my group members was the biggest incentive for me to generate the maximum amount of ideas" (*Reem, student feedback jounal, 16/4/2013).

> *"There was a competition between me and the rest of the my group members encouraged me to think about the physics problem and finding variety, unique and new solutions to the problem in order to be my thoughts distinct from others".* (Ahmed, interview, 30/4/2013).

The physics teacher described the experimental group class like a beehive, that is, all students work together in order to reach the desired goals to solve the problem at hand. The researcher found that the mutual stimulation by listening to other students' ideas provokes thinking and draws attention to different aspects did not come to mind before. This stimulation is as a result to listening to the ideas of others and viewing their ideas from angles as seen by the proposer of their ideas. Exchange of ideas with others provokes thinking and draws attention to aspects not thinking before. Providing an opportunity for students to exchange ideas and to modify and adding to the information also allowed social construction of students' knowledge activity influenced each other. Any participant within the group has a wider range of experience and knowledge due to the others participants who come from a variety of backgrounds. Thus, the learner rebuilds the cognitive structures through social interaction with others (Stroebe, et al., 2010).

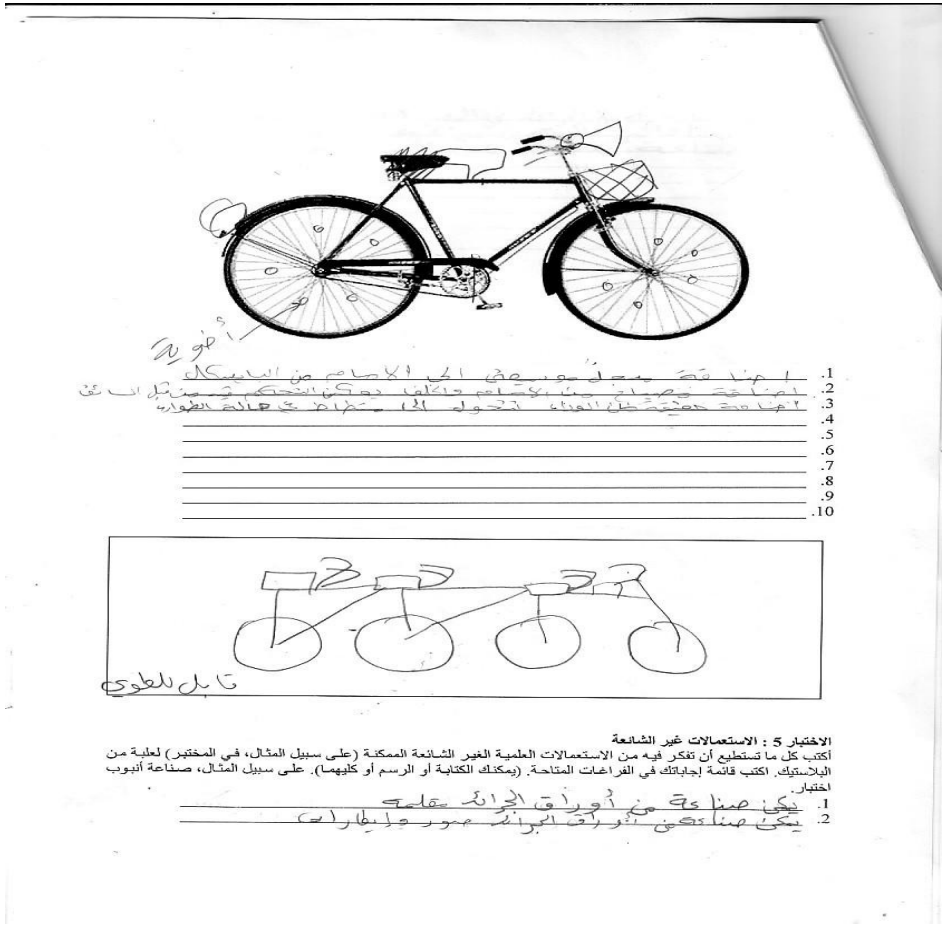
The researcher believes that creative abilities exist in all students in different ratios; it needs to be woken up and trained. Therefore, the researcher of the present study found

that some of students answers were quite interesting and creative such as for the task 4 (improving products). Before intervention a student only suggested adding only three things to improve the ordinary bicycle in the pre-test of creative thinking. However, after intervention the same student suggested adding more than ten interesting and creative things to improve the ordinary bicycle.

These suggested improvements included a first aid kit, a button to turn the bike into a balloon during an emergency, add GPS, speedometer, stand to install the bike to use at home for exercise, make the bike rollaway, seat for child, illuminated wheels, portfolio of mobile and other of water, add multiple seats, add umbrella - fan - lamp - screen - recorded to hear music, basket for development purposes, helmet to protect the rider from accidents. As shown in Figure 5.7 below.

For the task 5 (extraordinary uses) before intervention a student only suggested only two ideas extraordinary uses to the plastic bottle in the pre-test of creative thinking. However, after intervention the same student suggested more than ten interesting and creative ideas for extraordinary uses to the plastic bottle. These suggested included: listed cylinder to measure liquids in the physics laboratory, convert plastic bottle into pens portfolio, box to save money, pots for planting flowers in physics lab, a framework for pictures, making paintings, making plastic fan rotates by wind, making plastic bags to save the laboratory tools, making blackboard can write on with a ink pen, making different kinds of plastic shoes resist rain, assembling plastic containers to make Robert, making games for children of different sizes and shapes powered optical, food box for pets like cat, making physics devices used in experiments.

Pre-test of creative



Post-test of creative

Figure 5.7 Compare the student's answers in pre-post test of creative thinking

As indicated in the Chapter 4 (see Figure 4.1) and the theoretical framework for this study Chapter 2 (see Section 3.3), the brainstorming technique procedures encourage students to be more active in terms of critical thinking processes as well. Evaluation sessions stimulate students to criticism of ideas and discussion with each other and the expression of different views. Therefore, besides creative skills, critical thinking skills will also begin to be enhanced, especially when the group finally begins to evaluate the generated ideas in front of them to select a solution to the given problem. The brainstorming technique therefore stimulates students to analyze, criticize, and discover relationships, similarities, and differences. All participants subsequently were asked to select their top ideas in a group evaluation phase (Putman & Paulus, 2009). Each generated idea will be discussed and considered, some ideas will be eliminated, and a final list will be ranked for possible use as a solution toward solving the problem. The group members combine and splice ideas together. This is the basis of Vygotskyian co-construction. For example, the sub critical thinking skill inference is the mental ability requires the students to use all the knowledge and information put forward together in order to reach a conclusion. Using the various information the students will be able to analyze the relationships between concepts and discuss relations between the laws of physics.

Inference

In the brainstorming sessions the learner obtained a lot of information about the physics problems from the group members during discussion and evaluation of ideas. However, this is not enough to unable students' to acquire the inference skill. It requires a learner to have the ability to review the presented ideas in the evaluation session during the group discussion, interpret the information properly, analyze information, link between

different information, determine the ideas required to reach the acceptable logical conclusions, search for evidence, associate ideas with the problem so as to reach the conclusion and findings which supports his/her selected ideas.

The researcher found that some of the students were characterized by a lack of patience, rushing to discuss alternatives and assumptions before analyzing and discussing all generated ideas. As a result the learners have difficulty in reaching the correct conclusion during a specific period of time in brainstorming sessions due to student inaction, dependency on others and lack of effort in the search for the right solution, lack of student's experience in the process of linking the question with answer required, lack of the cognitive base of the student in the level of result extraction among facts. Some excerpts below indicate this finding.

> *"During the discussion each student presents his ideas and opinions so I found that most of my members of the group agree on some of the ideas, therefore, I chose one of them based on the thoughts and opinions of the group members".* (Warda, interview, 5/3/2013).
>
> *"The large number of ideas generated by members of my group and contradictions in the ideas and opinions prevented me an organized facts or information in manner so that lead to the conclusion of the decision, or solve a problem".* (Noor, open ended questions, 21/5/2013).
>
> *"I found it difficult to retrieve all the facts relating to the problem quickly and compare them and connect them with all the information and ideas presented by my members of the group during a short period of time on the other some members of my group have capabilities better than me in the analysis and comparison ideas".* (Hassan, student feedback journal, 6/4/2013).
>
> *"It is difficult to analyses and interprets all generated ideas of my group members which involved a lot of physics laws and therefore I depended on my group member in selected idea".* (Dania, interview, 19/2/2013).
>
> *"During the discussion I found one idea my group member were agreement it so I follow the choice of my group".* (Ali, open-ended question, 21/5/2013).
>
> *"My members of the group did not discuss or analyzes all generated ideas because of Ali stressed that the idea is correct and the group's views were consistent with him. Therefore, I have not been able to identify essential*

elements of the physics problem to draw reasonable conclusions". (Zahraa, interview, 5/3/2013).

From the qualitative data the researcher synthesized Figure 5.8 to explain the four main skills which are interpret, deduct, analyze and link skills required to help students reach the inference skill.

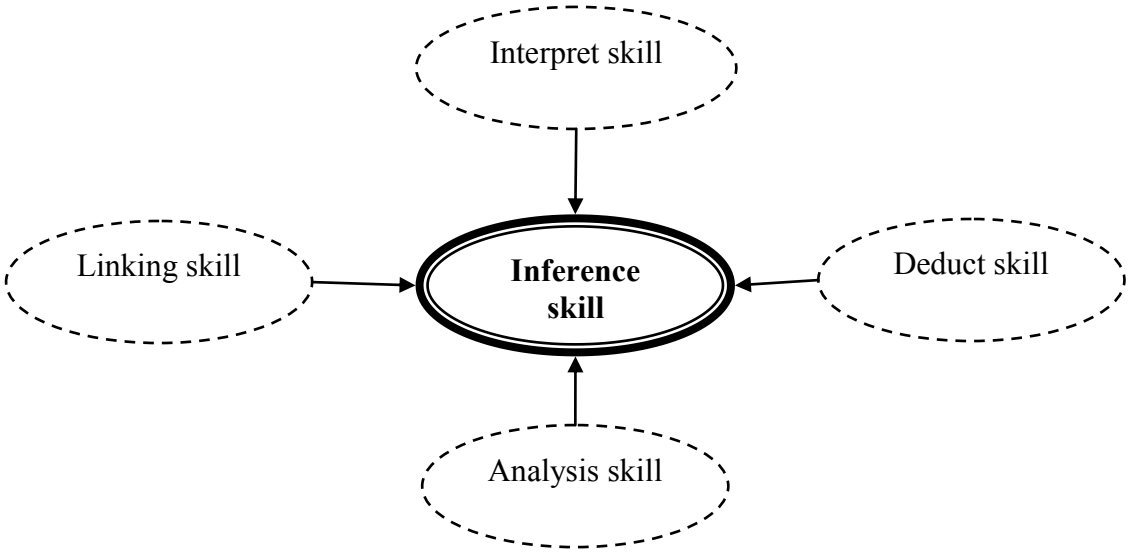


Figure 5.8 Components of the inference skill

The researcher thought that this skill of critical thinking requires the student to organize her/his previous experiences and ideas from general to the specific to reach conclusions. However, as described above the students faced some challenges with regards to this skill. The qualitative data complements the quantitative data discussed earlier, for inference where the ANCOVA results show the value was $F(1, 78) = 0.22$, $P = 0.63 > 0.05$, which indicates that there is no statistically significant difference between the mean of the experimental and the control groups for the skill of inference.

Recognizing assumption

During the evaluation sessions students participate in the classification and tabulation of ideas into categories according to the criteria of evaluation to identify suitable and powerful ideas to solve the problem.

Therefore, the students practiced the skill of recognizing assumption to recognize the sincerity and authenticity of the information, ideas, and facts generated by the members of the group and the distinction between ideas that can be proved and the self allegations or allegations as well as distinction between information and causes related of the problem and those that are not linked it. For example some stated below,

> *"Distinguish between good and non good generated ideas during my group discussion, determined the necessary information; compare ideas and identify similarities and differences then be classified according to the criteria facilitate reach to the solution".* (Rafal, interview, 2/4/2013).
>
> *"Filtering ideas during evaluation sessions helped me to recognize the good ideas and related information to the physics problem as well as I found some of my ideas were very weak and cannot be applied". (*Zafar, open ended question, 21/5/2013*).*
>
> *"Test the proposed ideas by the practical experience to make sure it is correct or fault helped us to reach the right solution to the problem of physics, it is found that there are hypotheses that cannot be achieved and wrong".* (Abdul Rahman, student journal feedback, 5/3/2013).

Thus the brainstorming technique appeared to have influenced the students in recognizing assumptions. The qualitative data complements the quantitative data discussed earlier, for recognizing assumption where the ANCOVA results show the value was $F(1, 78) = 5.88$, $P = 0.01 < 0.05$, which indicate that there is a statistically significant difference in the mean of the experimental and the control group for the skill of recognizing assumption in favor of the experimental group who taught physics via brainstorming technique.

Deduction

After the students have classified the generated ideas according to the criteria they need to decide upon a conclusion (deduction) based on the assumptions or ideas and information available based on the general physics principle or law. Evidence of this can be seen in the excerpts below.

> *"Implementation of the proposed ideas by members of my group practically through the experiment was able me to reach conclude a general rule for concave and convex lenses".* (Mustafa, interview, 2/4/2013).

> *"I experimented practically different types of mirrors in the physics laboratory and discovered by myself through vision in mirrors how the composition of the image behind and in front of the mirror and I reach to the conclude that flat mirror reflect the full picture of the person while convex mirror reflecting a smaller picture of the person and concave mirror reflects the fact image (estimated)".* (Isal, student feedback journal, 6/4/2013).

> *"Experiment conducted and practical application help me to come to conclusion to a general rule, and new knowledge based on assumptions or placed ideas and information available that the concave lens smaller person eye who wearing while a convex lens bigger up person eye who wearing".* (Mayssam, interview, 2/4/2013).

However, students in the experimental group did not make an effort to devise examples from a general rule to reach a different result by moving from whole to part and from general to particular. The physics teacher (Miss Zainab) asked students in the experimental group during the brainstorming sessions to give examples and explanations to the general physics law or rules (deduction) from natural phenomena in their daily life to gain full understanding of the physics problem. Some students commented that,

> *"Jump from the general rule or law to the physics example or new knowledge requires great thinking and discussion with my members of the group to reach examples or phenomena related to applicable physics*

> *law or principle and this needs to conduct other tests to make sure of the validity of the examples".* (Mariam, student journal feedback, 6/4/2013).

> *"I spending so much energy and attention just trying to reach solution to the physics problem did not come to my mind that deduced from the general law examples or explain natural phenomena return back to the general law".* (Ahmed, open ended question, 21/5/2013).

The observations indicate that the students were rushing to reach the solution to the physics problem. The discussions between students were devoid of the expansion of the problem to include natural phenomena in daily life connecting the physics law with the natural phenomenon. The teacher found the students lacked in accuracy of observations and the ability to generate examples based on general physics law or principle (draw conclusions using facts and rules of logic). Moreover, some students preferred a physics teacher who gives ready (examples) deductions related to the problem instead of reach having these examples through analysis, criticism and hard thinking by themselves.

> *"To find examples linked to the problem requires a lot of observation and comparison processes, interpretation and test hypotheses and research, while the teacher gives ready and accurate physics examples".* (Khalil, interview, 2/4/2013).

> *"I expect teacher will refuses my examples because may be false or inaccurate, so I prefer that the teacher who provide me the physics examples".* (Zafar, student feedback journal, 6/4/2013).

Thus, this could have slowed down the enhancement of the skill of deduction. The qualitative data complements the quantitative data discussed earlier, for deduction skill where the ANCOVA results show the value was $F(1, 78) = 1.15$, $P = 0.28 > 0.05$, which indicate that there are no statistically significant differences between the mean of the experimental and the control groups in the skill of deduction.

Interpretation

After the students conduct the practical experiment and have obtained the results for the physics problems the students started using the skill of interpretation to interpret the results and explain the reasons for the physics problem. In the brainstorming sessions, the interpretation skills are employed when the physics teacher asks students interpretation or explanation of physics phenomena or problems in order to reach a deeper understanding of the problem. Therefore, in the discussion session each student provides the interpretation, reasons and explanation of the results that have been obtained through experience. Some students commented that,

> *"After I conduct the experiment I reached to the interpretation of that why the pen put in the cup of water seems broken to the phenomenon of refraction where the light is transmitted from the air (homogeneous medium) to the water (non homogeneous medium) thereby water work to obstruct the passage of optical package which seems the pen broken in water with size larger than normal".* (Abraham, interview, 23/4/2013).

> *"me and my group members reach to the interpretations to the result that the plane mirror reflect light is reflection regularly so the full image size equal to the real body size while the convex mirror reflect light through the outer surface so the picture is formed as behind the convex mirror finally, concave mirror reflect light from the internal surface so the picture looks as in front of the concave mirror".* (Cardana, student feedback journal, 16/4/2013).

> *"from the experiment I found that the person who wears glasses and his eyes behind the glasses seem smaller size suffer from farsightedness because the convex lens helps a person to see nearby objects while the lenses that seem the person's eyes enlarge is concave lenses to help a person to see distant objects".* (Abdel Rahman, open ended question, 21/5/2013).

> *"The reason for exists two prism in the telescope is to reduce the length of the telescope and make a image moderate for the viewer".* (Mohammad, open ended question, 21/9/2013).

> *"mirage phenomenon consists as a result of differing optical density of air layers different temperatures where at the time of the afternoon air layers are in contact with the road surface hottest from the air in the upper layers of the atmosphere which leads to a overall reflection so*

> *person seen something like water"*. (Nizar, student journal feedback, 16/4/2013).
>
> *"I interpreted the reason the configure of the rainbow is the analyze of white light of the sun to the seven components of colors (colors of the solar spectrum) (red, yellow, green, blue, indigo, violet)"*. (Dania, interview, 30/4/2013).

The qualitative data complements the quantitative data discussed earlier, for interpretation skill where the ANCOVA results show the value was F (1, 78) = 10.17, P= 0.002 < 0.05, which indicates that there is a statistically significant difference between the mean of the experimental and the control groups in the skill of interpretation in favour of the experimental group who taught physics via brainstorming technique.

Evaluating Arguments

The brainstorming technique appears to have trained students to distinguish between strong and weak arguments, by discussing many alternatives to solve the physics problem (Harbi, 2002; Mohammed, 2010). In the brainstorming sessions, especially in the selection ideas phase it required student to distinguish between strength and weakness evidence to provide reasons for choosing specific idea where all students submit evidence to the choice at this stage student listens to several reasons to choose the right ideas and the justification and estimate the allegations and arguments. Thus the student gets feedback from peers and benefited from the strengths and weaknesses ideas of the members of the group's.

> *"In the physics problem "which one is faster light or sound", Doha who are one of my group provided conclusive evidence that light is faster than sound, and she gave us example we see lightning (light) before thunder (sound) and the speed of light is 300 times greater than the speed of sound that strong evidence help me to chose right idea and also help me to understanding the physics problem"*. (Rafal, interview, 30/4/2013).
>
> *"During the evaluation phase of generated ideas by each student in groups members presented evidence and information to support his idea*

and proof that his idea of a logical and correct. Ahmed gave proof that women on both sides of the car are convex because its reflective surface is the outer surface of which are image (and fictitious miniature moderate), which helps the driver to get a broad vision. I benefited from all the information of the members of my group to reach a decision and choose strong idea supported by evidence". (Ahmed, student feedback journal, 12/3.2013).

"A principle of evaluation session is to provide evidence to prove the validity of the proposed idea. Some evidence of my group members was weak and unsupportive so I excluded and focused on strong ideas during the debate in order to support my selected idea. For example Isal provide my group a strong argument about the rainbow emerged from the occurrence of the sun on the small water droplets in the air when rainfall, and then suffer internal reflection radiation when the sun beam enters the raindrop, it refract or bend and then reflected from the point of water so that the light appear rainbow colors. The colors can be seen when the angle between the sun and reflection drop water line to vision who watches these colors are 40° and 42."". (Obeida, open ended questions, 21/5/2013).

"I distinction between strong and weak evidence during the discussion where that strong evidence was supported by physics laws and examples which I previously learned unlike to the weak evidence that was not logical and not possible provable". (Sarah, interview, 5/3/2013).

The physics teacher commented that the students in the experimental group were excellent in the discussion and evaluation of the generated ideas. The discussion was interesting and made sure there was an evidence, to support the ideas and they were not convinced with non supported solutions by the law or the principle of physics.

The qualitative data complements the quantitative data discussed earlier, for evaluation arguments where the ANCOVA results show the value was $F(1, 78) = 6.42$, $P = 0.013 < 0.05$, which indicates that there are there are statistically significant differences between the mean of the experimental and the control groups in the skill of evaluation arguments in favour of the experimental group who taught physics via brainstorming technique.

Table 5.22 shows the pre- post answers for one student in the experimental group in the evaluation arguments task.

Table 5.22 Compare the student's answers in pre-post test of critical thinking

Pre-test of critical thinking	Post-test of critical thinking
Do you think that the electric current amount, one ampere or more cause serious burns if it passed through the body tissue? 61. The current is less than this amount causes more damage from burns. 62. That the current more than this amount leads to death immediately. 63. That the passage of electric current, even if the value is less than ten times this value will lead to serious burns in the body tissue.	Do you think that the electric current amount, one ampere or more cause serious burns if it passed through the body tissue? 61. The current is less than this amount causes more damage from burns. 62. That the current more than this amount leads to death immediately. 63. That the passage of electric current, even if the value is less than ten times this value will lead to serious burns in the body tissue.
It is that water vapor hotter than boiling water or vice versa and both at a temperature of 100C°? 64. Boiling water hotter than the water vapor / because of water vapor loses a large amount of heat during condensing and turning into a liquid. 65. Water vapor the most hotly of boiling water / because when sprayed water vapor on the body is fewer hot cause burns stronger than boiling water. 66. Boiling water hotter than the water vapor / because of the temperature water vapor is always less than the temperature of boiling water. 67. Water vapor the most hotly of boiling water / because internal energy stored in the water vapor is greater than the energy stored in the boiling water.	It is that water vapor hotter than boiling water or vice versa and both at a temperature of 100C°? 64. Boiling water hotter than the water vapor / because of water vapor loses a large amount of heat during condensing and turning into a liquid. 65. Water vapor the most hotly of boiling water / because when sprayed water vapor on the body is fewer hot cause burns stronger than boiling water. 66. Boiling water hotter than the water vapor / because of the temperature water vapor is always less than the temperature of boiling water. 67. Water vapor the most hotly of boiling water / because internal energy stored in the water vapor is greater than the energy stored in the boiling water.

	Strong	Weak
61	√	
62		√
63		√

	Strong	Weak
61	√	
62	√	
63		√

Pre-test of critical thinking

	Strong	Weak
64	√	
65		√
66		√
67		√

When the gas leakage in the kitchen, are you started to open the windows?

68. Yes, to reduce the speed of its spread within the kitchen and let him out through the windows.
69. No, because it is supposed to close the valve before start to open the windows so as not to allow leakage large amount in the kitchen.
70. Yes, because the gas occupies a size larger than the size of the kitchen.

	Strong	Weak
68	√	
69		
70		

Source: (Alwani, 1999)

Post-test of critical thinking

	Strong	Weak
64	√	
65		√
66	√	
67		√

When the gas leakage in the kitchen, are you started to open the windows?

68. Yes, to reduce the speed of its spread within the kitchen and let him out through the windows.
69. No, because it is supposed to close the valve before start to open the windows so as not to allow leakage large amount in the kitchen.
70. Yes, because the gas occupies a size larger than the size of the kitchen.

	Strong	Weak
68		√
69	√	
70		√

Source: (Alwani, 1999)

From the qualitative data the researcher of the present study has summarized the key elements that contributed in the enhancement of creative and critical thinking skills among Iraqi second grade intermediate level. First, the physics students were motivated to learn physics during the brainstorming technique sessions through three elements: classroom climate, rules of brainstorming technique (no criticism, focus on quantity, freewheeling is welcome, building on others ides), and physics problems. After the physics problems were given and the students began to try and solve them, the students seem to experience disequilibrium and therefore they tried to activate related knowledge to the physics problem from their Long-Term Memory (LTM) to find a solution to the problem. The students appear to use the cognitive structures in his\her mind which involve a network of connections (physics laws, concepts, phenomenon, theory, principles). The students probably used the network of connections to associate old knowledge with new knowledge. After students generated list of ideas (solutions) to the physics problems the group discussion sessions started to evaluate each generated ideas. In this stage the students' faced cognitive conflict as a result of social interaction, which probably led to the loss of their equilibrium again, and the students probably tried again to activate related knowledge from LTM to generate new ideas. From the group discussion the student probably gained the feedback and reinforcement about the physics problems. Therefore, more suitable ideas became highlighted during group discussions. Finally the students were asked to select the best ideas, which needed to be supported by evidence in order to convince members of the group. The best ideas were tested via practical experimentation to be sure of the validity and suitability of the idea to solve the physics problem at hand. All the above elements are thought to have overlapped with each other to enhance the creative and critical thinking skills among the selected second grade intermediate Iraqi students in physics. As illustrated in Figure 5.9.

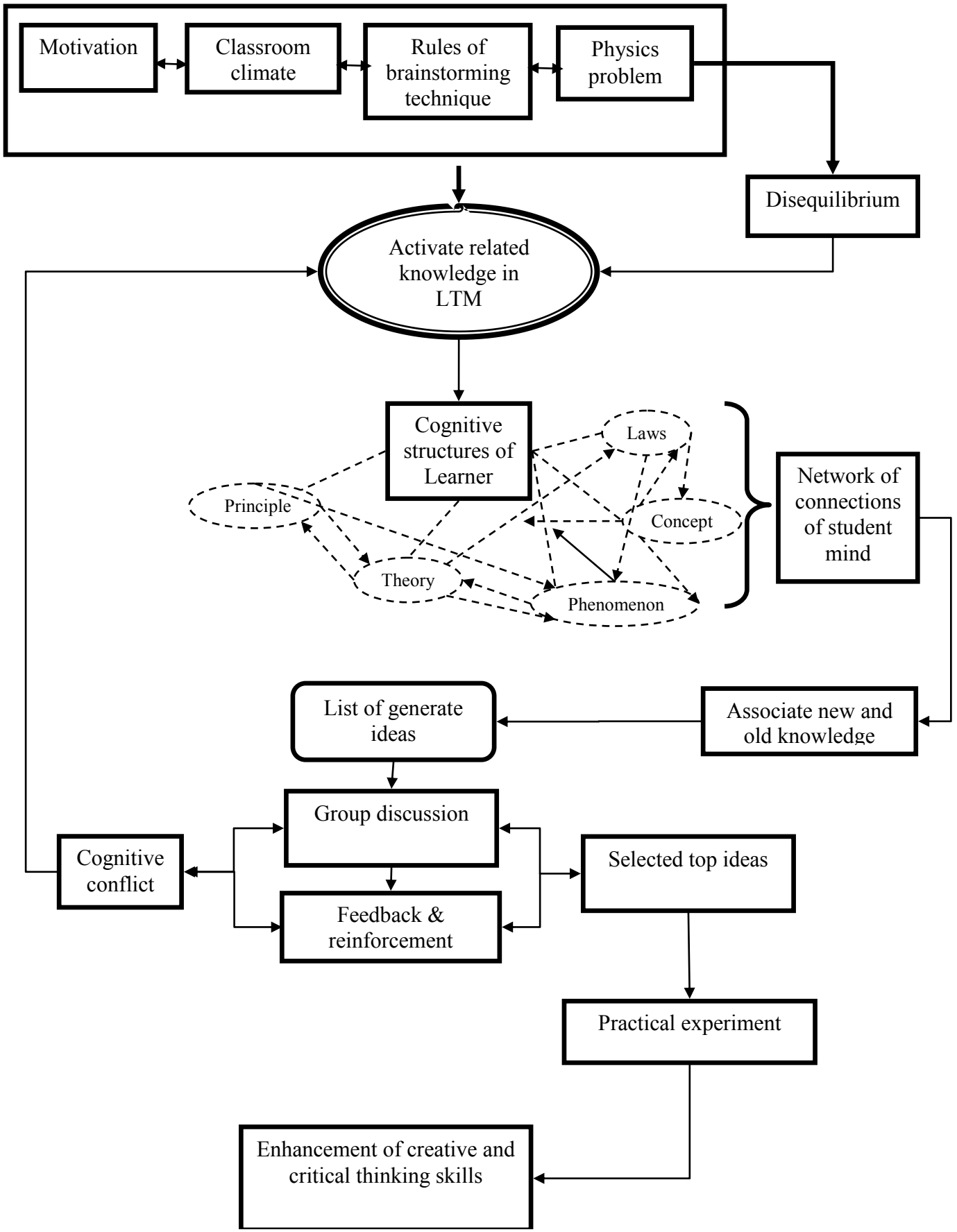


Figure 5.9 Summary of key elements that enhancement of creative and critical thinking skills

5.4 Students Perceptions of Learning via The Brainstorming Technique

Research question five of the present study was "What are physics students' perceptions about learning via the brainstorming technique?" It sought to discover Iraqi second-grade intermediate students' views and perceptions of the brainstorming technique in terms of learning outcomes and features of the brainstorming technique. The questionnaires provided subjective information according to the participants' perceptions about the brainstorming technique used for teaching physics. Therefore, the survey of students' perceptions was administered in the 15 week of intervention to students in the experimental group after the completion of all the activities of teaching via the brainstorming technique (see APPENDIX D).

In this section, the researcher sought to understand if students held positive or negative perceptions toward the intervention described in Chapter 4 (see section 4.6 Research Intervention). There were two parts which comprised the survey: part A consists of 30 items related to learning outcomes of the brainstorming technique and part B consists of 10 items related to features of the brainstorming technique. In the following two sections the results of students' perceptions of the brainstorming technique in part A and part B will be discussed.

5.4.1 Learning outcomes Part A

In this part, the researcher sought to understand students' views regarding the brainstorming technique in terms of their experiences in learning Physics in the duration of the study. There were 30 questions prepared based on a five - point Likert scale which comprised (15) questions for application knowledge and skills, (9) questions for communication, and (6) for independent learning.

Participants' answers were analyzed using the frequency, percentage, mean and standard deviation for each statement. The results are shown in Table 5.23.

Table 5.23 Physics students' perceptions of brainstorming technique- part A

Statements	**Mean**	**SD**
Application of knowledge and skills	3.55	0.30
Communications skill	3.70	0.21
Independent learning	3.51	0.26

Table 5.23 show large mean values ranging from (3.70- 3.51) and SD (0.30-0.21) in perceived learning outcomes for students who participated in the brainstorming technique. Iraqi students in the second-grade intermediate level were very positive about learning through the brainstorming technique. The majority of students agreed that learning outcomes have been achieved through their participation in the brainstorming technique in terms of application of knowledge, communication skills and independent learning; the next three sections will illustrate this in detail.

5.4.1.1 Application of knowledge and skills

The majority of the Iraqi students felt that their ability to think broader and analyse physics problem were developed, and understanding to the physics content were improved as a result of learning via brainstorming technique. Students felt satisfied and interested in the brainstorming process that makes physics lessons have more activities and not rote learning, more practices, more student participation, more chances to interact with classmates and more self-initiated. Gaining more knowledge, better understanding and opportunities to explore science in daily-life and discover newer ideas.

The overall mean value for application of knowledge and skills is (3.55) and SD (0.30). Application of knowledge and skills part involved 15 items for which the researcher of the present study computed the frequency, percentage, mean and standard deviation for each statement as illustrated in APPENDIX K.

The researcher of the present study found that the mean values of all statements of application of knowledge and skills were high where ranging from 3.92 to 2.85. This indicates that the brainstorming technique has a positive impact on Iraqi students' perceptions for application of knowledge and skills. The researcher of the present study interpreted these results due to the features of brainstorming technique (see Chapter 1 Figure 1.3) which helped Iraqi students to promote and improve creativity, critical thinking skills, achievement, efficiency, and problem solving skills. Moreover, the procedural steps of brainstorming technique (see Chapter 3 Section 3.3) were based on the three cognitive theories (Search of Ideas in Associative Memory (SIAM) theory (2003), Piaget's cognitive development theory (1929) and Vygotsky's social-cultural theory (1978) and thinking models. The brainstorming procedure involves scientific methods such as identify and organize any existing knowledge about the problem, analysis of the problem to clarify the different facets of the problem, construction of hypotheses to explore the possible solutions, evaluate the optimal solution for the problem (Chang, 2011, DaHaan, 2009). Thus, these procedures provide opportunities for learners to apply their knowledge and develop the science process skills, problem solving skill, creative thinking skills, and critical thinking skills.

The researcher of present study summarized the results of the experimental group (Iraqi second-grade intermediate level students) perceptions of learning physics via the brainstorming technique for application of knowledge and skills as shown in Table 5.24 below.

Table 5.24 A summary of the results of the students' perceptions of application of knowledge and skills

Statement	Students perceptions
Application of knowledge and skills	The brainstorming technique has a positive impact on students' perceptions for application of knowledge and skills. The Iraqi students asserted that the brainstorming technique enabled them to think broader and more from multiple perspectives (over the physics content) (3.79); develop the solution for physics problem (3.79); analyze physics problem (3.62); generate creative ideas(3.21); think critically (2.85); built new links between different facts (3.59); evaluate ideas and finding (3.10); retain what they had learned more (3.87); apply what they have learned (3.44); recognize the related of what they learned to their daily life (3.41); apply synthesis skills more deeply (3.51); predicate of new ideas (3.87). Moreover, the results show that the students asserted that they acquired better memory of the physics subject content (3.72); and understanding of the physics content have been improved as a result of learning physics via brainstorming technique (3.92).

5.4.1.2 Communications skill

Iraqi students felt that the communications skills have been developed as a result of participating in the collective and cooperative learning style. Students felt that they were able to share and exchange knowledge and information with the group members, as well as benefit from the ideas of others during brainstorming sessions. The overall mean value for communications skills is (3.70) and SD (0.21). The communication skills part involved 9 items for which the researcher of the present study computed the frequency, percentage, mean and standard deviation for each statement as illustrated in APPENDIX K.

The researcher of the present study found that the mean values of all statements of application of knowledge and skills were higher than the part of application of knowledge and skills and the part of independent learning where it ranged from 4.05 to 3.90. This indicates that the brainstorming technique has a positive impact on Iraqi students' perceptions for communication skills during learning physics. The researcher of the present study interpreted these results due to the learning through brainstorming technique based on collaborative and cooperative process of students' building on other's ideas (Vygotsky's ideas to promote social interaction and instructional conversations (scaffolding and collaborative process) (Wang et al., 2011). Moreover, the rules (such as no criticism, building on others ideas) and process of brainstorming technique (such as group discussion during generate and evaluate ideas) encouraged learners to input positive participation and interaction with others to help each other expand their minds and create an enthusiastic atmosphere (Maheshwai, Singh, & Agarwal, 2003). Students took the initiative to discuss with classmates and ask questions as well as learn new things from peers that they did not know before and gain different perspectives that they would never have thought of; and others appreciated their ideas (Finney, 2008).

The researcher of the present study summarized the results of the experimental group perceptions' of learning physics via the brainstorming technique for communication skills as shown in Table 5.25 below.

Table 5.25 A summary of the results of the students' perceptions of communication skills

Statement	Students perceptions
Communication skills	The brainstorming technique appears to have had a positive impact on students' perceptions for communication skills. The Iraqi students asserted that the brainstorming technique gave them opportunities to

Statement	Students perceptions
	participate in diversified classroom learning activities (3.67); participate in novel learning activities (3.31); exchange ideas with classmates (3.85); discuss with classmate (3.72); express many ideas without being criticized (3.72); respect and appreciation of views and ideas of others, even thought did not fully agree with them (3.90); opportunity to listen to perspectives and points of view of classmates and keep an open mind about their views (3.54); play an important role as one of the main resource contributor during brainstorming session (3.62); and benefit from the ideas of others, through the development and build on it (4.05).

5.4.1.3 Independent Learning

The majority of Iraqi students felt that the brainstorming technique gave the opportunity to the students to think in different and useful ways to solve the problems and make them to work independently to generate multiple solutions and evaluate and select more appropriate solution to the problem independently as illustrated in brainstorming procedures (see Chapter 3). The overall mean value for independent learning is (3.51) and SD (0.26). The independent learning part involved 6 items for which the researcher of the present study computed the frequency, percentage, mean and standard deviation for each statement as illustrated in APPENDIX K. The researcher of the present study found that the mean values of all statements of application of knowledge and skills were high ranging from 3.85 to 3.21. This indicates that the brainstorming technique has had a positive impact on Iraqi students' perceptions for independent learning. The researcher of the present study interpreted these results due to the brainstorming technique process based on Piaget's theory (promote disequilibrium and self-discovery) which provides an opportunity for a learner to impose assumptions, observe, experiment, measure, analysis, retrieval of knowledge,

reflect, make decision, generate and evaluate ideas (Mohammed, 2010). Brainstorming sessions appeared to have trained the selected Iraqi learners to construct new ideas by associating new knowledge with old, build new links, rearrange or reverse knowledge, connection between various concepts, forming new associations, or applying knowledge to a new domain (Brown & Paulus, 2002; Nijstad, et al., 2003).

The researcher of present study summarized the results of the experimental group's perceptions of learning physics via the brainstorming technique for independent learning as shown in Table below 5.26.

Table 5.26 A summary of the results of the students' perceptions of independent learning

Statement	Students perceptions
Independent learning	The brainstorming technique appears to have had a positive impact on students' perceptions of independent learning. The Iraqi students asserted that the brainstorming technique gave them opportunities to do experiments on physics content (3.56); choose and apply their strategy as when learning (3.38); solve interesting and relevant physics problems (3.21); learn new knowledge during problem-solving (3.85); work independently (3.31); and think in different and useful way to solve problems (3.79).

The findings of student perceptions toward learning physics via the brainstorming technique are supported by the study of Chang (2004, 2011) who stated that the brainstorming technique has a positive impact on students' perceptions and attitudes in physics learning. Students felt that the brainstorming made them think wider, realized that physics is related to daily life and contribute to knowledge acquisition and understanding in physics. In relation to the students' perceptions toward teaching physics via the brainstorming technique Cheng (2004) also found that physics teachers

agreed that the brainstorming technique enhances students in learning and improving students understanding and memory in physics. Nevertheless, Holubova (2010) disagreed, saying that the physics teachers have negative perceptions about teaching via brainstorming technique. The researcher of the present study is of the opinion that not all teachers have sufficient capability and expertise to apply the brainstorming technique in their physics lessons and if applied ineffectively, learning outcomes may not be achieved. In this study the researcher had given specific training to the participating teacher.

5.4.2 Features of Brainstorming Technique Part B

In this part, the researcher sought to discover what the students' awareness is regarding the brainstorming technique in terms of students' reflections on the brainstorming technique. There were 10 questions prepared by the researcher of the present study based on a five point Likert scale, related to the features of the brainstorming as a technique for teaching physics in terms of as a student- centered approaches, whether the learning activities were enjoyable, interesting and did the activities enhance the learning and understanding of physics. Additionally, students' abilities in fluency of expression and abilities to grasp the relationships between physics laws, concepts and facts were questioned. Participants' answers were analyzed using the frequency, percentage, mean and standard deviation for each statement. The results are shown in Table 5.27.

Table 5.27 Part B: Students' reflections on brainstorming specific features

	The statements	Analysis	Strongly disagree	Disagree	Natural	Agree	Strongly agree	Mean	SD
1	Brainstorming is one of the effective students-centered approaches.	Frequencies	2	5	8	22	2	3.44	0.96
		Percent	5.1	12.8	20.5	56.4	5.1		
2	The learning activities in the brainstorming group were enjoyable.	Frequencies	-	2	7	25	5	3.85	0.70
		Percent	-	5.1	17.9	69.1	12.8		
3	My interest in learning physics increased as result of using this technique to learning.	Frequencies	-	3	6	21	9	3.92	0.83
		Percent	-	7.7	15.4	53.8	23.1		
4	I was more actively enhanced in learning physics.	Frequencies	3	3	12	16	5	3.44	1.07
		Percent	7.7	7.7	30.8	41.0	12.8		
5	My confidence was enhanced as result of using this technique to learning.	Frequencies	1	2	9	20	7	3.77	0.90
		Percent	2.6	5.1	23.1	51.3	17.9		

	The statements	Analysis	Strongly disagree	Disagree	Natural	Agree	Strongly agree	Mean	SD
6	My perceptions that physics is more related to daily-life as result of using this technique to learning.	Frequencies	2	3	12	18	4	3.49	0.97
		Percent	5.1	7.7	30.0	46.2	10.3		
7	My motivation to learn physics increased as result of using this technique to learning.	Frequencies	2	2	13	17	5	3.54	0.96
		Percent	5.1	5.1	33.3	43.6	12.8		
8	I feel my understanding of physics subjects improved as result of using this technique to learning.	Frequencies	1	4	5	20	9	3.82	0.99
		Percent	2.6	10.3	12.8	51.3	23.1		
9	My ability to fluency in expression and intuitive developed as result of using this technique to learning.	Frequencies	3	5	6	19	6	3.51	1.14
		Percent	7.7	12.8	15.4	48.7	15.4		
10	My ability to grasp the relationships between things developed as result of using this technique to learning.	Frequencies	2	6	12	16	3	3.31	1.00
		Percent	5.1	15.4	30.8	41.0	7.7		

Table 5.27 shows the overall mean value (3.60) and SD (0.21) in perceived learning outcomes for Iraqi students who were exposed to the brainstorming learning approach. The majority of the Iraqi students in the second grade intermediate level were very positive in terms of the effects of learning via the brainstorming technique.

The Iraqi students characterized the brainstorming as one of the effective student-centered approaches (3.44); The learning activities in the brainstorming group were enjoyable (3.85); the interest in learning physics increased as a result of using this technique to learning (3.92); students' felt their learning of physics were enhanced (3.44); the students confidence was also enhanced as a result of using this technique (3.77); their perceptions that physics is more related to daily-life increased as a result of using this technique to learning (3.49); the students motivation to learn physics increased as a result of using this technique in learning (3.54); students felt their understanding of physics improved as a result of using this technique in learning (3.82); the ability to improve their fluency in expression developed as a result of using this technique to learning (3.51); and the ability to grasp the relationships between things developed as a result of using this technique in learning (3.31).

From the results, the researcher of the present study can conclude that the brainstorming technique has good features to make it a powerful technique for teaching physics. It appears to have helped students to improve their understanding of physics topics and thinking abilities as a result of the procedures of brainstorming which involved cooperative and collective learning approaches which led to better interaction between students. The rules of the brainstorming technique probably made the learning of physics more fun and enjoyable for the students. All these factors are effective for the learning process and makes students feel that the brainstorming is an effective technique for teaching physics.

5.4.3 Open-Ended Questions Part C

In this section, data were gathered to complement the numerical data described previously to better understand the participants' views of the implementation of the brainstorming technique in teaching physics. Open–ended questions were administered to the Iraqi second- grade intermediate students in the Saba school at the end of the intervention (see APPENDIX D).

The data suggests that as far as the brainstorming technique is concerned the students were positive in their feedback about the brainstorming technique. The data were analyzed and classified into several themes according to the students' answers. The following sections will present these themes.

5.4.3.1 Characteristics of the Physics Lessons

Analysis of the open-ended questionnaire data indicated that the selected Iraqi students' characterized teaching of physics via the brainstorming technique into three characteristics: cooperative learning; entertaining and exciting; and self- expression.

i. Cooperative Learning

Cooperation is necessary for learning. The brainstorming technique is based on the principle of positive interaction and cooperation between the individual and the group because the creative ideas are not the product of an isolated student's brain, but are the result of interaction with others. The group of students utilizing the brainstorming technique comprise of a mixed level of students (high, middle, and low achievement) cooperating with each other to solve the problem and reach the best solution. Each student has gained respect and appreciation for the opinions of others and benefit from

their ideas through the development and building on the ideas of others. One rule of brainstorming is the non-discrimination among students; all students participate in the discussion and generate ideas. The kind of ideas does not matter, there is no right or wrong ideas, all ideas are accepted. More than half of the participants' expressed that the activities encouraged cooperation among students. Below are some students' feedback:

> *"the activities makes my classmates unselfish that retains all the information and ideas to himself, but rather encourage my classmates to express ideas and opinions to be taken advantage of the rest of the students and me in understanding the topic and increase information"*. (Zafar, open-ended question, 21/5/2013).

> *"Physics lessons have grown spirit of cooperation between the students and for me without the cooperation with my colleagues I cannot solve the question alone"*. (Warda, student feedback journal, 9/4/2013).

> *"Learning was based on cooperation; my group members were cooperating with each other in solving the questions"*. (Ahmed, open-ended question, 21/5/2013).

> *"This method has been increased spirit of cooperation among students, unlike the usual way that develop individual learning and independence"*. (Nizar, student feedback, journal 16/4/2013).

> *"Cancellation of individual differences among students during physics lessons encouraged all my group members to cooperate"*. (Shaima, open-ended question, 21/5/2013).

The researcher through students' feedback found that this collaboration appeared to have helped the participants work better as group members. At the end of the intervention, the participants seemed to appreciate the importance of cooperation within the group to get best results.

ii. Entertaining and Exciting

Students' data seemed to point to the fact that the brainstorming technique creates an atmosphere of entertainment and fun which keeps boredom and teacher pressure at bay. Secondly, the data revealed that the students' found the classes entertaining and gave rise to an exciting feeling. Most participants emphasized they were satisfied during brainstorming activities which provided them more freedom and less pressure. Below are some students' comments.

> *"I not forget this experience because I was very excited and I did not feel bored during lesson as well as the time passed quickly"*. (Asal, interview, 30/4/2013).

> *"I felt happy and comfort and there is no pressure from the teacher to pay attention and listen to the lesson for that I did not feel tired"*. (Sarah, student feedback, 7/5/2013, journal).

> *"In short, lesson shifted from routine and bored to fun and enjoyable"*. (Reem, open-ended question, 21/5/2013).

> *"The physics lessons were enjoyable and fun I felt happy and gained spirit of adventure to discover new information"*. (Khalil, open-ended question, 21/5/2013).

> *"Interesting, I was busy listening to the thoughts and opinions of students especially that some of the students to have information on the subject from outside the book"*. (Nizar, student feedback journal, 26/3/2013).

According to the students' feedback above, the researcher asked the physics teacher about her opinions about the students feeling during brainstorming sessions. The physics teacher mentioned that her students were very happy. They were learning physics topics with smiley faces. In contract, in the usual lesson students' faces looked tired and did not show interest to learn.

iii. Self Expression

The brainstorming technique gave opportunity to the students to express their views and opinions in full freedom without criticism from students or fear of the teacher. In every brainstorming session, all students in groups were required to give many ideas, conduct discussion with group members and judge ideas so that they can come up with the best explanation and solution to their problems. Thus this learning activity appears to remove inactivity and shyness among students which encourage them to be more self-confident by giving as many ideas and opinions without being hesitant. The participants' had a common feedback that is that the new teaching method (brainstorming technique) helped them to express their views and opinions without fears. Below are some students' comments.

> *"I had the opportunity to express my thoughts and my opinions freely".* (Ammer, open-ended question, 21/5/2013).
>
> *"I'm very shy in expressing my thoughts and views in front of the teacher, but through the activities I saw all my colleagues are expressing their opinions so I encouraged putting up my opinions without shame".* (Zahraa, student feedback journal, 2/4/2013).
>
> *"I introduced my thoughts and my views to my classmates that I cannot express it in regular lessons".* (Noor, open-ended question, 21/5/2013).
>
> *"I am encouraged to express my thoughts, even if some of my ideas were useless".* (Iaa, open-ended question, 21/5/2013).
>
> *"During physics lessons I expressed my views with much more confidence".* (Ali, student feedback journal, 2/4/2013).

Brainstorming also appears to contribute to the sense of achievement of learners themselves and the value of their ideas. For example,

> *"My ideas that I posed to solve the problem of physics contributed to reach a solution".* (Mayssam, open-ended question, 21/5/2013).

> *"My confidence increased when my group members depend on my ideas to reach solutions to the physics problem" (*Rafal, students feedback journal, 2/4/2013).

The researcher found that the brainstorming technique took out students from only listening to the teacher to engage in the process of learning to express freely their opinions and ideas to the physics problem without fear or hesitation. Students can express their ideas in front of their peers, who are not allowed to criticize any idea or opinion of any student, but to accept all ideas and to encourage all students to express everything that is going on in their mind to the group in order to take advantage of ideas and information in generating ideas.

5.4.3.2 Learning Outcomes

Analysis of the open-ended questionnaire data indicated that students felt they learned and gained three principle learning outcomes: better understanding; communicating skills; and physics related to daily life.

i. Better Understanding

Deeper understanding for physics was most frequently mentioned among participants in the open- ended questions, students' feedback journal, and students' interviews. The learner in the brainstorming technique sessions has to make an effort to reach a solution and get it, and this is what enables the student to focus on mental skills to find solutions to the problems given. The participants asserted that learning through the brainstorming technique helped them to gain a deeper understanding of the physics concepts, better memory of the physics content, and gained a lot of knowledge, information, and

experience. It seems these positive learning outcomes were due, to the characteristics' of brainstorming technique perceived by participants.

> *"I Gained lots of information from peer which it help me to understand the topic".* (Mohamed, student feedback journal, 26/3/2013).
>
> *"My knowledge and understanding of the topic increased because I interacted with my group members who possess information and capabilities better than me".* (Dania, interview, 5/3/2013).
>
> *"I understood the physics topic by my group members better than the teacher way".* (Rafael, student feedback journal, 9/4/2013).
>
> *"My group members submitted information and ideas that not offered by the teacher in the normal lesson".* (Zahraa, interview, 30/4/2013).
>
> *"I gained a lot of information which it helped me to understand the physics topic".* (Mannar, student feedback journal, 26/3/2013).

The interactive sessions through the brainstorming technique appeared to have impacted and modify the cognitive structure of the students and reduce misconceptions. This is what was confirmed by some of the students:

> *"I had misconceptions about some physics concepts, but I have corrected it and I obtained much new information".* (Isra, interview, 23/4/2013).
>
> *"My group member helped me to correct many of physics concepts that I learnt in previous learning stages"* (Mustafa, student feedback journal, l2/4/2013).
>
> *"During brainstorming sessions I discovered I had a lot of misconception about some physics theories and laws, by interactive with my group I corrected and modified it"* (Shaima, student feedback journal, 26/3/2013).

Miss Zainab the teacher stated that "I noticed my students improve in their understanding of physics content and they started asking good questions, recall previous information and link between physics laws. I acquired a new teaching experience; I am

really benefited from the application of the brainstorming technique in my physics lessons". (Miss Zainab, teacher comments, 30/4/2013).

ii. Communication Skills

Open and effective communication contributes to student learning. The brainstorming technique encourages students to learn more about the physics topics through the active sharing of information, ideas, experiences, and opinions, which leads to the increase of the morale of the students and develop a group spirit among them and integrate them into lesson activities. The flow of communication is the interaction between all students rather than individual recitation and response between the students and the teacher. More than half of students stated that the activities in the physics lessons encouraged them to improve the ability of communication with others as a result of interactive group discussions and the exchange of ideas and information among students. Some of the students' comments were:

> *"I was able to communicate and consult with my colleagues where I built relationships with new colleagues were I not have a relationship with them before".* (Dania, student feedback journal, 26/3/2013).

According to the students, brainstorming stresses the importance of communication with others in order to able students to solve the physics problem.

> *"I realized how important communication process with others in for a new and useful information".* (Warda, open-ended questions, 9/5/2013).

> *"Through my participation with my group I gained a lot of daring and new social relationships and I discovered that my colleagues have a lot of physics information and high mental skills".* (Shamia, interview, 19/3/2013).

iii. Physics in Daily –Life Situations

Using a variety of activities that are associated with the environment can raise the interest of students and attract their attention. Nature itself is a huge physics laboratory, therefore the problems given during the brainstorming sessions increased students' concentration on natural phenomena and the related forces, and the formulation of laws. The brainstorming technique seemed to have helped students realise that physics is more related to their daily-life and many natural phenomena. For example,

> *"I thought that the phenomena in the physics book abstract theory not natural, I concentrate on conservation information was not aware that the interpretation of natural phenomena return to the physics, for example, the phenomenon of refraction that I experience its by myself before that I thought the laws interpreted the phenomenon no relationship to the physics".* (Ammar, interview, 30/4/2013).

> *"Physics for me is abstract curriculum contains laws and facts and concepts, I never occurred in my mind that link laws with the natural phenomena in my daily life. New method attracted my attention to a lot a lot of natural phenomena that I was not aware it linked to physical laws".* (Hassoun, interview, 5/3/2013).

Students discovered that the physics is closely related to their daily lives and this appears to have assisted in increasing interest and tendency towards learning physics. One student (Ibrahim) stated in the interview that:

> *"I saw many phenomena in my daily-life but I don't know the reasons, so I was very interesting to explore the reasons through the physics lessons".* (Ibrahim, interview, 2/4/2013).

> *"I like studied physics because I participated in the experiments and discovered a lot of information I did not know in addition to the factors of fun and entertainment with friends".* (Duha, student feedback journal, 16/4/2013).

5.4.3.3 Problems Faced Students

Despite the positive feedback for brainstorming as a technique for teaching physics, a few students stated that they encountered some problems during the implementation of the brainstorming sessions. The researcher of the present study classified the problems that students reported in the open-ended questionnaire, interviews, and student feedback journals, into three main themes namely lack of participation; noises; and time management. The next three sections give full details about these themes.

i. Lack of Participation

There are many processes during brainstorming sessions that requires all members in the group to participate to try and come up with the solution to the physics problems being discussed. For example, in the evaluation session students need help from peers to evaluate and select ideas. However, some of the students in the groups did not really cooperate with group members.

> *"Some members of my group not all of them do not participate in the discussion or in the generated ideas to solve the problem".* (Mannar, students' journal feedback, 17/4/2013).

> *"Lack of cooperation between members of my group, where relying to solve questions on the leader of group and two members of the group". (*Mustafa, interview, 12/3/2013).

> *"Ali, a member of my group is not serious and not participates with the group in the discussions and to give ideas and opinions, he depends on the others and receives ready solution from the group".* (Asra, interview, 17/4/2013).

Other students mention that some students did not participate in the group discussion because they were busy talking about other matters that were not related to the physics problem.

> *"Ghassan and Amir did not participate in the debate because they were too busy to speak of non related to the problem".* (Iaa, students' feedback journal, 20/3/2013).

However, some students reported that they did not encounter any problems during the brainstorming sessions.

> *"I did not encounter any problems or difficulties due to the existence of the spirit of cooperation and democracy, between members of my group".* (Nassam, student journal feedback, 2 /5/23013).

ii. Noises

Although there were procedures and directions given by the teacher to ensure that there was less noise, some of the students complained about the noise in the classroom during the conduct of the activities. Students expressed this in the interviews and feedback journals that:

> *"I could not focus well on physics problems because of the uproar in the classroom".* (Zafar, interview, 30/4/2013).
>
> *"Group behind me was discussing with each other loudly where prevented me from focusing with my group".* (Abel Raman, student feedback journal, 2/4/2013).

However, the physics teacher explained to the researcher about the noise in the physics lessons. She commented that: "I tried to control the noise in classroom but I did not use rough style so students are not frightened or frustrated their activity trend the activities" (Miss Zainab, teacher comments, 30/4/2013).

iii. Time Management

The use of time effectively is a key element of the success of the brainstorming session. Therefore, the researcher of the present study specified the time required for the various activities and students' roles throughout the lesson (see Chapter 4, section 4.5). The leader of the group is responsible for the management of the dialogue, provide opportunity for all students to participate without bias, encourage the group members to present their ideas and carefully listen to what group members say. However, the most

common criticism from students was that the brainstorming sessions were not long enough. While each classroom intervention lasted for about forty minutes, students felt more time was required to explore and express all their ideas. This is a significant point to consider when applying these techniques in the future. Some students comment that:

> *"Leader lacks of control on the members of the group during discussions. Some members take a long time in the debate is not to give an opportunity for others to discuss and express opinions"*. (Obeida, open-ended questions, 21/5/2013).

> *"During some of brainstorming sessions, there is insufficient time to express all my ideas for my group members because some of my group members late of displayed his ideas. Thus my group wait him until finished generate ideas". (*Yasser*,* student feedback journal, 9/4/2013).

Some students like to intervene and interrupt and claim knowledge during the discussion sessions and take a long time to talk without giving a chance for other students to talk and share information.

> *"I'm a genius because I know a lot of physics information that is not known by my colleagues, so I can find a solution to the problem quickly"*. (Sarah, student feedback journal, 9/4/2013).

> *"Muammil is one of my group members who talk too much out of physics problems thus he waste the time and some of my group member such as Isra did not have time to discuss with us"*. (Mannar, interview, 17/4/2013).

5.4.3.4 Suggestions for Improvements

The researcher of the present study had one question in the student feedback journal and in the interview that is to ask the student to give suggestions for improving the brainstorming technique. The researcher found that the secondary second-grade intermediate Iraqi students gave very powerful points for improving brainstorming technique for teaching physics. There were two main themes reported from students as described below.

i. Exchange Group Members

A number of Iraqi students in the selected second-grade intermediate level suggested improving the brainstorming as a technique in teaching physics by changing the group leaders and members from one session to another.

This finding was as a result of some members of the group have worked together for a long time during the intervention (four months), and they found that the leader and the members of the group were proposing similar ideas and solutions to the physics problem and it was difficult for students to generate new creative ideas. Therefore, students suggested to change members of the group from one session to another in order to stimulate the group and obtain the variation in the information and different experience and backgrounds of students in order to help the group members in generating many and varied ideas. On student reported that:

> *" I suggested that members of the group substitution between one period and another in order to not dependent some members on one or two members of the group in the discussion and generate ideas and to reach a solution to the physics problem".* (Cardana, open-ended question, 21/5/2013).
>
> *"Substitution of students' groups from each lesson or two lessons to be a group consisting of a mixture of good and non good levels to be a contrast in the information and urges the students to think and put ideas".* (Nassm, student feedback journal, 7/5/2013).
>
> *"My suggestions to improve this method are change group students from one lesson to another contribute to the acquisition of new information and experiences in addition to the formation of new relationships between members of group".* (Hamad, interview, 19/3/2013).

The researcher of the present study asked Miss Zainab for any suggestions to improve the brainstorming to be a powerful teaching technique for teaching and learning physics. She commented that, " First, I agree with the proposal of the students in the exchange of group members from time to time because it allows students the opportunity to benefit from the experiences and information of other, and obtain a

variety of skills. Second, I suggest to divide the brainstorming procedures to two lessons – one lesson to generate ideas and the second lesson to evaluate ideas, as this will give a great opportunity for students to think and debate in depth about physics problem". (Miss Zainab, teacher comments, 30/4/2013).

ii. Provide Multiple Sources of Knowledge

The second suggestion to improve the brainstorming technique recommended by the selected second-grade intermediate Iraqi students was to provide at least one computer for each group which can help the students to browse the Internet and search and obtain a variety and sufficient information in relation to the physics problem, especially when members of the group do not have enough information to solve the problem. The students' comments were:

> *"Provide each group computer with Internet helps members of the group to get extensive and value information of the physics problem and make it easier for the group to reach a solution faster".* (Amna, student feedback journal, 2/4/2013).
>
> *"Internet helps the group to access a lot of information and examples related to the problem as opposed to the book that gave only one example or the accountability of the problem".* (Asal, open-ended question, 21/5/2013).
>
> *"Some students in my group do not have sufficient information or ideas to solve the physics problem provided by physics teacher (Miss Zainab). The existent of the Internet in the laboratory of physics make it easier for students to obtain adequate information to help them to reach a solution to the problem".(*Cardana*,* student feedback journal, 2/4/2013).

Miss Zainab had other ideas. Miss Zainab commented that," I do not agree with the suggestion of students to provide physics laboratory with internet because some of the sites contain inaccurate information that lead to wrong understanding of the physics concepts. Therefore, I suggested to provide physics laboratory some of the accredited physics books which contain the accurate information this to help students obtain many and varied information". (Miss Zainab, teacher comments, 30/4/2013).

5.5 Chapter Summary

This chapter presented the research findings and discussion for the research questions. The research questions focused upon how the brainstorming technique helped the selected Iraqi students in second-grade intermediate level to enhance creative and critical thinking skills in physics. Additionally, this chapter also considered Iraqi students perceptions of brainstorming technique.

The results indicated that there were obvious differences between the brainstorming technique and the traditional method in favour of the brainstorming technique in the creative thinking test in total and in the sub-skills (fluency, flexibility, and originality). For the critical thinking test there were differences between the brainstorming technique and the traditional method in total and the three sub- skills (recognizing assumptions, interpretation, and evaluating arguments) in favour of the brainstorming technique. However, there were no major differences revealed for the brainstorming and traditional groups in two sub-skills (inference and deduction). As for the students' perceptions about learning physics via the brainstorming technique, the students were mainly positive. The majority of the Iraqi students felt that they benefited from brainstorming compared in comparison with the traditional learning. They were self-directed in their learning, ready to learn, exchanged a lot of physics information with group members, use physics lessons time more effectively without feeling bored or fearful, and more engaged in learning.

In the next chapter, implications of the study, suggestions for future studies and the conclusion will be discussed.