# CHAPTER 4

# METHODOLOGY

## 4.0 Introduction

In this study, the significant difference of creative and critical thinking skills for selected secondary Iraqi physics students after utilizing the brainstorming technique (which focused on an active student role in the learning process and authentic problem–solving) compared with the traditional method of teaching was investigated. The research also studied and described the enhancement of creative and critical thinking skills among the selected students. Lastly, the study sought students' perceptions of the brainstorming technique.

This study used both quantitative and qualitative techniques of data collection in a concurrent (parallel) mixed method design. The sample of the study consisted of secondary students in the second grade intermediate level in the Saba Iraqi School. Based on the research objectives of the study, three tests, namely a creative thinking test, a critical thinking test, a physics achievement test and a survey to elicit students' perceptions of the brainstorming technique were utilized in this study. The validity and reliability of all tests were determined. In this chapter, the researcher will discuss the following: (i) the research design; (ii) research variables; (iii) research sample; (iv) research instruments; (v) data collection; (vi) procedures of the preparation and implementation of the brainstorming technique; and (vii) data analysis.

## 4.1 Research Design

The selection of an appropriate research design is important as a plan for the implementation of the study which will determine the research results. The study employed a concurrent mixed method design. For the quantitative approach a Quasi-experimental approach was used because of its relevance to the problem and the objectives of the research as well as the researcher's inability to control all external variables (Campbell, Stanley, & Gage, 1963). Additionally a survey to elicit the perceptions of the students about the brainstorming approach was employed. To describe the development of creative and critical thinking skills a qualitative approach was utilised with collection of data through teacher and student interviews, teacher journals and observations. Furthermore, to elicit the perceptions and experiences of the students with the brainstorming technique an open- ended question section was added to the survey and the students were also interviewed.

The experimental group was taught using the brainstorming technique to determine the impact of this approach in the development of creative and critical thinking skills. Whereas, the control group was taught by using traditional methods. Thus, three dependent variables were measured simultaneously for both the experimental and control groups by the pre-post tests at two different times before and after intervention.

This study involved an intervention of the utilization of the brainstorming technique for 16 weeks as follows:

1. Pre-tests of (creative thinking test, critical thinking test, physics achievement) were administered during the first week before the intervention;
2. Intervention utilizing the brainstorming technique for the experimental group was for 16 weeks. On the other hand, the control group was taught following the traditional method; and
3. Post-tests of creative thinking test, critical thinking test and a survey of students' perceptions of the brainstorming technique were administered to the experimental group during the week after the intervention.

The research design consists of the intervention, experimental group and control group as illustrated in Table 4.1 below.

Table 4.1 Quasi-Experimental structure for the quantitative approach used in this study

| | **Time** | | |
|---|---|---|---|
| **Group** | **Week before intervention** | **Intervention** | **Week after intervention** |
| Experimental | 1- Pre-test of creative thinking<br>2- pre-test of critical thinking<br>3- pre-test of physics achievement | Brainstorming Technique | 1- Post-test of creative thinking test<br>2- post-test of critical thinking test |
| Control | | Traditional Method | |

### 4.1.1 The Researcher and the Participating Teachers

For the present research, the positioning of the researcher and the participating teachers needs to be explained further. The researcher contacted many schools and finally two teachers (Miss Zainab and Miss Roaa – not their real names) from the Saba Iraqi School were willing to participate in the study.

In order to reduce bias, the researcher planned the research in a way that data could be collected as effectively as the strict school situation allowed to answer the research questions. Miss Roaa was trained by the researcher to uitlise the observation and interview protocols during conducting the class observations and interviews. Miss Zainab was trained in utilizing the brainstorming technique. Miss Zainab, who taught two physics classes in the selected school, utilized the brainstorming technique for one class and taught the other class in the usual traditional manner.

One other aspect was that every brainstorming class session was video-audio recorded. These data were scrutinised and analysed by the researcher and triangulated with the data collected by Miss Roaa. More in depth details about the researcher and the participating teachers will be discussed further in several parts in this chapter.

## 4.2 Research Variables

As illustrated in the conceptual framework in Chapter 3, the independent variables in this study are the teaching methods (the brainstorming technique and the traditional method) and the dependent variables are creative thinking and critical thinking.

### 4.2.1 Independent Variables

The independent variables of this study are variables that cause, influence, or affect outcomes (Johnson & Christensen, 2010). The variables manipulated in this study are the teaching methods, which consist of two different teaching approaches, the brainstorming technique and the traditional method.

The brainstorming technique as described in Chapter 1 is "A teaching technique which relies on a set of six steps leading to provoke and stimulate the minds of Iraqi students in the second grade intermediate in physics to generate the largest possible number of physics ideas and evaluate these ideas in a certain period of time". It is a collaborative student-centred process where students are presented with a problem.

On the other hand, the traditional method in teaching physics for the Iraqi school is the teaching approach that is teacher-centered and as described in Chapter 1 is "Teacher controls the educational process by providing ready information for the learner and displays physics problems and solutions without giving an opportunity to the learner to inquire and explore". Learners receive information rather than explore and discuss. In addition, this method is based on the text-book, chalk and talk, as well as the focus is on completing the curriculum according to the prescribed plan. Thus, the teacher has full control of the teaching and learning activities in the traditional method.

### 4.2.2 Dependent Variables

The dependent variables in this study are variables that change because of another variable (the effect or outcome variable - Johnson & Christensen, 2010). There are two dependent variables in this study:

i. Creative thinking score, based on the creative thinking test in Appendix A, and
ii. Critical thinking score, based on the critical thinking test in Appendix B

The two tests were conducted before and after intervention for both the experimental and control groups for the secondary physics students in the Iraqi Saba school.

### 4.3 Research Sample

For the purpose of this study, the researcher selected the Saba school in Iraq according to the following criteria:

(i) Willingness of the school and two physics teachers' to take part in the study;

(ii) A Physics laboratory is available;

(iii) Two intact classes of students in the second-grade intermediate level were available, and

(iv) All students in the Saba school live in a close social, economic and cultural environment.

The Saba school is a secondary school with students from grades 7 to 12. The sample of this study consisted of two intact classes of students in the second grade intermediate level in the Iraqi Saba school. The second-grade intermediate level was deemed more appropriate to apply the brainstorming technique in the teaching of physics because the Iraqi students at this stage are supposed to have the ability to think abstractly, put forward scientific hypotheses, organize and interpret information. Furthermore, these students are thought to be able to discover general principles or rules, facts and events and be able to solve problems. A total of eighty (80) students were involved. One intact class was the experimental group and had 39 students and the other class was the control group and had 41 students. The equality of the two groups was investigated using pre-tests (creative thinking, critical thinking and physics achievement test).

The experimental group was taught using the brainstorming technique, whereas the control group was taught using the traditional method as shown in Table 4.2.

Table 4.2 Sample distribution for experimental and control group

| Group | Intervention | Gander | Number of Students |
|---|---|---|---|
| Experimental | Brainstorming technique | Male 19<br>Female 20 | 39 |
| Control | Traditional method | Male 20<br>Female 21 | 41 |

## 4.4 Research Instruments

This section discusses in detail the quantitative and qualitative techniques of collecting data that were used in this study. The use of multiple sources of data will increase the quality of the information collected. A total of four instruments were used in this study; three were tests, and one was a survey. The administration of the instruments was conducted in two broad phases, before and after the intervention.

Before the intervention:

i. Pre-test of creative thinking (APPENDIX A);
ii. Pre-test of critical thinking (APPENDIX B), and
iii. Pre-test of physics achievement test (APPENDIX C).

After the intervention:

i. Post-test of creative thinking;
ii. Post-test of critical thinking, and
iii. Survey of students perceptions of the brainstorming technique (APPENDIX D).

### 4.4.1 Quantitative Data Collection Methods

The quantitative data was collected in this study using the four instruments tests as stated above: creative thinking test, critical thinking test, physics achievement test and a survey of students' perception of the brainstorming technique. Each of these instruments is now described in turn.

#### 4.4.1.1 Creative Thinking Test

After the researcher had reviewed the various creative thinking tests (Cheng, 2011; Guilford, 1950; Hu & Adey, 2002; Pekmez, et al., 2009; Rabari, et al., 2011; Torrance, 1966; Wallach & Kogan, 1965), the researcher adapted ideas which involved physics situations from the Torrance Test of Creative Thinking (TTCT), the Scientific Creativity Test by Hu and Adey (2002), and the Scientific Creativity Test by Pekmez, Aktamis, and Taskin (2009) to measure the three creative abilities' fluency, flexibility and originality for the selected secondary Iraqi students in the second grade intermediate level in physics. The major rationale of choosing and adapting items from these tests was because the chosen tasks and items related to the science of physics phenomena.

The creative thinking test constructed for the present study consists of six sub sections, and these sections are distributed as follows:

i. Asking Questions: Students are requested to generate the largest possible number of questions based on the picture given;
ii. Guessing the Cause: Students are requested to write all the reasons or introductions that led to what appears in the picture given;
iii. Guessing the cause of an occurrence or an event: Students are requested to write all that could entail or result from the situation or incident;

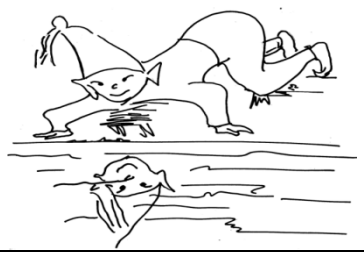
iv. Improving Products: Students are required to write all amendments or additions that can be added to improve the product;

v. Alternative Uses of Common Materials: Students are requested to write the largest possible number of scientific uses for empty plastic bottles that people usually throw, and

vi. Supposing: Students display a possible default position that can happen and are asked to write everything that can result from the occurrence of this situation on the assumption it is possible to do so, and students have to write all the ideas and guesses that can arise from this event occurs.

Some questions of the original tests (Hu & Adey, 2002; Pekmez, et al., 2009; Torrance, 1966) have been modified as shown in Table 4.3 and some other questions are the same with the original questions. Moreover, the researcher added photographs and one physics example with an answer is given for each task to help the students understand what is required.

Table 4.3 Example of a modification made from the original creative thinking tests

| **Original Questions** | **Modified Question** |
|---|---|
| Task 2: Guessing the Causes<br><br>List down as many incidents as you can think might be the cause concerning to the picture below.<br><br>  | List down as many incidents as you can think of that might be the cause related to the picture below, list your answers in the blanks provided.<br><br>For example, the person sees his image on the water because of the phenomenon of reflection. |

By reference to the score standards, Torrance Test of Creative Thinking (TTCT) (Torrance, 1990), the researcher prepared a list of criteria for the basis of scoring student responses in each of the skills - fluency, flexibility and originality for the creative thinking test as shown in the Table 4.4 below.

Table 4.4 Scoring criteria of creative thinking skills

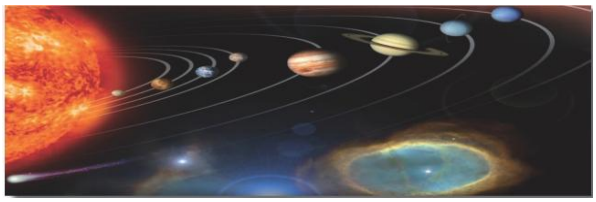
| Skills | Statement |
|---|---|
| Fluency | Number of student responses to each question of the six test questions, have been allocated one score (point) for every idea or an appropriate response, and the exclusion of inappropriate ideas. The collection of scores for the skill fluency obtained by the student for each question of the test questions will be calculated; the total score reflects the creative skill, fluency. |
| Flexibility | Number of varied responses by each student for each question of the six test questions, have been allocated one score (point) for each category of responses that have the same content (similar). The collection of scores for the skill flexibility obtained by the student for each question of the test questions will be calculated; the total score reflects the creative skill, flexibility. |
| Originality | As proposed by Torrance, one score (point) each not exceeding response percentage recurrence (5%) and the exclusion of any response over the percentage recurrence of this point. The collection of scores for the skill originality obtained by the student for each question of the test questions will be calculated; the total score reflects the creative skill, originality. |

To determine the total score of a student in the creative thinking test, the scores obtained for each of the skills fluency, flexibility and originality was totaled.

#### 4.4.1.2 Pilot Study of the Creative Thinking Test

Pilot studies are a crucial element of a good study design. Therefore, the researcher conducted a pilot with the creative thinking test on an exploratory sample of 30 students in the Al atemad school in Iraq in order to find out the validity and reliability of the test. The pilot study facilitated the refinement of the data collection plan and led to develop better questions for the actual research (Rather, 2004). Example of a modification made after the pilot study is as illustrated in Table 4.5.

Table 4.5 Example of a modification made for creative thinking test after the pilot study

| Before the pilot study | Modification after the pilot study |
|---|---|
| If you can take a spaceship to travel in outer space and go to a planet, what scientific questions do you want to study? | If you can go to the planets, what scientific questions would you want to research? List your questions in the blanks provided. For example, is it possible for humans to live on other planets?  |

**i. Validity of the Creative Thinking Test**

A valid test is one that measures what it is supposed to measure. The validity of the creative thinking test was verified in two methods:

**a) Content Validity**

After preparing the test, the researcher offered the creative thinking test to selected experts (Faculty of Education lecturers – specialisation in thinking and creative thinking - University of Babylon- Iraq), (Faculty of Education - science education -

Ain Shams University- Egypt), (Faculty of Education- physics education- Baghdad University- Iraq, and (Faculty of education- psychology and counseling- University of Malaya- Malaysia**)** to find out the clarity and suitability and verify the adequacy of the questions for the study. Then test was given to five experienced physics teachers in different Iraqi schools to verify the appropriateness of the test for the level of the student sample. Based on the experts and the physics teachers' feedback, the test was modified and finalized into six questions.

**b) Internal Consistency Validity of the Creative Thinking Test**

Internal consistency validity is the strength of correlation scores for each item of the test for total scores to which it belongs. The internal consistency validity of the test was verified via application of the test on the pilot sample. Pearson's correlation coefficient for each item was calculated using the statistical program SPSS and is as shown in the Table 4.6 below.

Table 4.6 Correlation coefficients between each creative thinking skill and the total score of the test

| **Skills** | **Correlation Coefficients** |
|---|---|
| Fluency | 0.751 |
| Flexibility | 0.671 |
| Originality | 0.552 |

Correlation coefficients in Table (4.6) are acceptable and statistically significant. Thus, the test was ready to be applied to the study sample.

### ii. Reliability of the Creative Thinking Test

A reliable test is one where results are similar if applied to the same sample more than once under the same condition. The researcher ensured the reliability of the test of creative thinking and suitability for the Iraqi environment by applying on a sample of (30) students from outside the study sample.

The researcher utilized the method of (re-test) on the pilot sample after two weeks from the first application. The correlation coefficient was calculated between the two tests of the first application and the second application via using Cronbach's alpha equation for consistency procedure through the program (SPSS) statistical.

Table 4.7 Cronbach alpha coefficients for creative thinking skills

| Skills | Cronbach's alpha coefficient |
|---|---|
| Fluency | 0.79 |
| Flexibility | 0.739 |
| Originality | 0.570 |

The values of the Cronbach alpha coefficients are appropriate to achieve the objectives of this study, which confirms the safety of the use of test creative thinking in judging the creative abilities of the respondents.

#### 4.4.1.3 Critical Thinking Test

Since one of the objectives of the current study was to try and develop critical thinking among the selected secondary Iraqi physics students utilizing the brainstorming technique, this required the preparation of a test for critical thinking. After the researcher had reviewed a number of studies and tests for measuring critical thinking

(Alwani, 1999; Burns, et al., 1985; Monica, 2005; OECD, 2000; Rabari, et al., 2011; Watson & Glaser, 1980), the major rationale of choosing these tests was because all tasks in these tests related to the science and physics phenomena.

Finally, the researcher prepared the critical thinking test, with a total of seventy (70) items involving physics situations. The items were adapted from the various tests and modified to suit the research context. The critical thinking test was constructed by referring to ideas put forward in the Watson and Glaser (1980) of Critical Thinking Test (WGCT). Watson and Glaser's test consists of five skills to measure the mental abilities of critical skills as shown in Table 4.8 below.

Table 4.8 Distribution of contents in the critical thinking test

| Skills | Items | Description of Statements |
|---|---|---|
| Inference | 15 | Student ability to decide whether suggested inference is true, probably true, false, probably false or insufficient information to come up with a conclusion. |
| Recognizing assumption | 14 | Student ability to judge and recognize proposed assumptions based on the statement given. |
| Deduction | 15 | Student ability to make deductions and conclusion for a statement given. |
| Interpretation | 13 | Student ability to judge whether or not each of the proposed conclusions are logically based on information given. |
| Evaluating arguments | 13 | Student ability to distinguish weak and strong arguments for each statement given. |

Some questions of the original tests (Alwani, 1999; Burns, et al., 1985; Monica, 2005; OECD, 2000; Watson & Glaser, 1980) have been modified as shown in Table

(4.9) and some other questions are the same with the original questions. Moreover, the researcher gave one physics example as an answer for each task to help the students understand what is required.

Table 4.9 Example of modifications made for items from the original critical thinking tests

| Original Questions | Modified Question |
|---|---|
| Test 3: Deduction<br>Stone falling from the top of a building to the Earth due to gravitational forces, but when we move away from the Earth heading towards space, the Earth's gravity towards things become very little.<br><br>1. The Earth's gravity is absent while moving away to great distances from Earth.<br>2. Attraction in space affects the attraction of the Earth for the body.<br>3. A big mass will reach the Earth before a small mass. | All objects are attracted to the gravity at the same speeds. A folder and a bit of paper are objects.<br><br>1. A folder with a bit of paper will fall to the Earth at different speeds, and the bit of paper will arrive before the folder.<br><br>2. A folder and a bit of paper will fall to the Earth at the same speed, and the bit of paper will arrive before the folder.<br><br>3. A folder and a bit of paper will fall to the Earth at the same speed and will therefore arrive at the same time |

The researcher used the same scoring system for items as in Watson and Glaser‘s original test (1980) that is (1) score (point) for a correct answer and (0) score (point) for a wrong answer or if the student had marked more than one alternative, the score for the critical thinking test ranged between a score of 0 and 70.

#### 4.4.1.4 Pilot Study of the Critical Thinking Test

To identify the clarity of instructions and test items as well as to measure the time taken to answer, the test was applied to the pilot sample of 30 students from the second grade intermediate students in the Al Atemad school in Iraq. It was found from the pilot that the test instructions and items are clear and could be understood and the time taken by the students to answer all the items was (80) minutes. The validity and reliability of the test were concluded as discussed below.

**i. Validity of Critical Thinking Test**

Validity refers to the accuracy of the inferences or interpretation made from the test scores. Therefore, for verification purposes, the validity of the critical thinking test, the researcher used two methods to check the validity of the test.

**a) Content Validity**

The researcher offered the critical thinking test to experts with experience and specialization in (physics, teaching methods, measurement and evaluation, and educational psychology). (Faculty of Education -Solid State Physics- University of Babylon- Iraq), (Faculty of Education – special in thinking and creative thinking - University of Babylon- Iraq), (Faculty of Education - science education - Ain Shams University- Egypt), (Faculty of Education- physics education- Baghdad University, and (Faculty of education- psychology and counseling- University of Malaya- Malaysia**)** As a result, some of the test items have been modified based on the experts' feedback.

### b) Internal Consistency Validity of Critical Thinking Test

The internal consistency validity of the critical thinking test was calculated via application of the test on the pilot sample of 30 students from the Al Atemad school in Iraq. The Pearson's correlation coefficient for each item was calculated using the statistical program SPSS. As shown in the Table 4.10 below.

Table 4.10 Correlation coefficients between each critical thinking skill and the total score

| Skills | Correlation Coefficient |
|---|---|
| Inference | 0.54 |
| Recognizing assumption | 0.411 |
| Deduction | 0.691 |
| Interpretation | 0.543 |
| Evaluating argument | 0.587 |

The correlation coefficients in Table 4.10 are acceptable and statistically significant.

## ii. Reliability of Critical Thinking Test

Reliability refers to the consistency or stability of test scores (Johnson & Christensen, 2010). The researcher used the method of (Test-Retest) in order to establish the reliability of test. The Critical thinking Test was piloted among the 30 students and the period between the first application and the second was two weeks. The researcher used Cronbach's alpha equation for the consistency procedure through the statistical programme (SPSS) to determine the reliability for five critical thinking skills. As shown in Table 4.11 below.

Table 4.11 Cronbach's alpha coefficient for critical thinking skills

| Skills | Cronbach's alpha coefficient |
|---|---|
| Inference | 0.67 |
| Recognizing assumption | 0.62 |
| Deduction | 0.73 |
| Interpretation | 0.66 |
| Evaluating argument | 0.58 |

Table (4.11) indicates that the alpha values for each critical thinking skill are statistically significant at a significance level of (0.05). This indicates that the test has good reliability which fulfills the requirements of the current study. After confirming the validity and reliability of the test, the test was ready for use in trying to achieve the objectives of this research.

#### 4.4.1.5 Physics Achievement Test

The researcher developed the physics achievement test, specifically for this study. The main purpose of administering this test before intervention for both experimental and control groups was to investigate what prior knowledge students' possessed in physics related to the physics topics involved in the intervention and to check the homogeneity between the experimental and control groups.

The development of this test was based on physics knowledge presented in the physics text books for the second grade intermediate secondary level, which involved four topics (light and reflection of light, refraction of light, thin lenses and colour and electromagnetic spectrum). The researcher of the present study utilised the physics teacher guide for the second grade intermediate level issued by the Republic of Iraq,

Ministry of Education, and the General Directorate of curriculum (the Iraqi Embassy of Education, 2010) in the construction of the physics achievement test. The final version of the text consisted of 30 multiple-choice questions. Each correct response was given one point; the range of scores was between (0-30).

#### 4.4.1.6 Pilot Study of the Physics Achievement Test

To identify the clarity of instructions and test items as well as to measure the time taken to answer, the test was applied to the pilot sample of 30 secondary students from the second grade intermediate students in Al Atemad school in Iraq. It was found from the pilot that the test instructions and items were clear and could be understood and the time it takes to answer all items was (40) minutes. The validity and reliability of the test were concluded as below.

**i. Validity of Physics Achievement Test**

The researcher used the content validity method to check the validity of the achievement test. The content validity of the test was checked by a set of physics teachers and a physics professor who had some 15-years of teaching experience (Faculty of Education -Solid State Physics- University of Babylon- Iraq), (Faculty of Education – special in thinking and creative thinking - University of Babylon- Iraq), (Faculty of Education - science education - Ain Shams University- Egypt), (Faculty of Education- physics education- Baghdad University). As a result, some items were modified based on the physics teachers and professor's feedback. An example of a modification made after the pilot study as illustrated in Table 4.12.

Table 4.12 Example of a modification made for the physics achievement test after the pilot study

| Before the pilot study | Modification after the pilot study |
|---|---|
| Why do you see a rainbow after it rains?<br>A) Due to the refraction of light in rain drops.<br>B) The speed of light in air bigger than in water.<br>C) Due to the polarization of light.<br>D) Due to the Light reflections randomly. | Why do rainbows appear during and after it rains?<br>A) Due to the refraction and internal reflection of light rays that enter the drop.<br>B) The light velocity in air greater than in water.<br>C) Due to the light transverse electromagnetic waves.<br>D) Due to the light reflection in different directions.<br>  |

**ii. Reliability of the Physics Achievement Test**

The researcher chose the Split-Half Reliability to check the reliability coefficient of the physics achievement test. This method reflected the internal consistency between the test items. The test is split in half (odd / even), representing first the odd items of the test, while the second is a representation of even items. To verify the homogeneity of halves, the researcher calculated the alpha ratio and the value calculated was (1.41) and when compared to the Table value (4.0012) which shows that it is not significantly different (random difference). Thus, this achieves the requirement of homogeneity between the halves. The researcher used the Pearson equation to find the reliability coefficient between the two halves which was (0.76). The correlation value was adjusted and reevaluated using the Spearman-Brown formula which increases the estimate reliability even more. The Spearman-Brown formula reached its final value (0.86) and this is a good consistency for the physics achievement test.

#### 4.4.1.7 Students' Perceptions of the Brainstorming Technique

The researcher developed the survey to understand students' perceptions of learning and teaching via the brainstorming technique. There were 40 items based on a Likert Scale. The Likert Scales consisted of:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Three main parts were constructed in this survey: Part A consisted of learning outcome questions and was divided into sub-sections: application of knowledge and skills, communication, and independent learning. Items in each part were based on the learning steps used in the brainstorming technique and included creative thinking, critical thinking, science process skills and problem solving. Part B consisted of questions that asked respondents to reflect on specific features of the brainstorming technique. It comprised 10 items with a 5- point Likert Scale.

Finally, part C consisted of six open-ended questions about the brainstorming technique utilised in learning physics.

The content validity and face validity of this survey were evaluated by measuring the reliability of Cronbach alpha, which for item from 1 to 40 (part A and part B) was 0.87, and the survey was checked by experts (Faculty of Education – specialisation in thinking and creative thinking - University of Babylon- Iraq; Faculty of Education - science education - Ain Shams University- Egypt; Faculty of Education- physics education- Baghdad University, and Faculty of education- psychology and

counseling- University of Malaya- Malaysia**)**. Some of the items were modified according to the experts' feedback. An example of modification is as illustrated in Table 4.13 below.

Table 4.13 Example of modification made for survey of student perceptions

| Original question | Modification question |
|---|---|
| What did you find to be least useful about learning using brainstorming technique? | What are the disadvantages of learning via brainstorming technique? Could you add any suggestions for how this technique may be improved or made it more useful for learning physics? |

### 4.4.2 Qualitative Data Collection Methods

As stated earlier the study design is a concurrent mixed method design and qualitative data was collected throughout the study. Qualitative data in this study aimed to gather richly descriptive data of students' perspectives on how students learn physics via the brainstorming technique (Trochim, 2005). The qualitative technique was also used to investigate how, where and when students activate their minds to generate and evaluate physics ideas (Denzin & Lincoln, 2005).

Qualitative data were collected in this study using four techniques: observation of students; students' feedback journals; teacher comments and students' interview to assist the researcher to look at the phenomenon from different angles. Video data of the teaching sessions were also recorded. Herriott and Firestone, (1983) suggested that the evidence from multiple sources are often considered more compelling, and the overall study is therefore regarded as being more robust. Each of these techniques is now described in turn.

#### 4.4.2.1 Observation of Students

Observation is a systematic data collection approach. It involves careful identification and accurate description of relevant students' interactions and processes (Benedek, Franz, Heene, & Neubauer, 2012). The observation data served to supplement interview data, and in turn, provided support for the interpretation of interview data. Therefore, there were two observation protocols designed by the researcher for the experimental and control groups as shown in (APPENDIX E). These two protocols employed in this study were to gather rich descriptive data by noting down the events, students' behaviours, classroom management, teaching and learning processes during the physics lessons observed.

The physics teacher who taught the experimental class was Miss Zainab. The researcher did not teach to minimize biasness in the study. To further reduce the biases of the observations written by the researcher and to receive suggestions, ideas and resources from someone else' eyes, the observation field notes were taken by a teacher Miss Roaa (not her real name) for four months. Miss Roaa had majored in physics for her master's degree in science education, and she is a physics teacher for second–grade intermediate students at the Saba School. The researcher trained Miss Roaa in using the observation protocol before the study began. Additionally, the researcher observed the interaction between the students- students and students – teacher through watching the recorded videos to support the data collection reliability and validity.

Miss Roaa was familiar to the students which minimised the observer effect on students' behaviour. In all observations, Miss Roaa acted as a non- participant observer, she usually sat in the back of the class and according to the observation protocol noted down the events which happened during the physics lessons (Ostrower, 1998). After each physics lesson, Miss Roaa passed the observation protocol to the researcher

directly to help the researcher in understanding the students' interactive behaviour during the brainstorming session, classroom management and the teaching and learning process.

For instance, Miss Roaa found that during the teaching of the topic refraction of light, two students in group 2 were not interested in doing the activities with the other group members and they were standing up and sitting down many times and laughing with each other. They did not engage with the members of the group to solve the physics problem while the rest of the group members were working and discussing the problem at hand. This observation was noted down by Miss Roaa:

> *"Leader and secretary in group 2 were not interested to do the activities and solve the physics problem with group members. They were busy talking loudly with each other out of the physics problem and laughing, only the other group members tried to solve the problem". (Miss Roaa, observation, refraction of light topic, 12-03-2013).*

#### 4.4.2.2 Audio and Visual Data

All physics lessons were recorded with a video camera and audio taped for four months (16 weeks) in the physics classroom as well as to maximize the accuracy of observational reports by the observer (Miss Roaa's field notes) and for the researcher to be able to replay the recording to focus on particular aspects of the lesson. This process ensured objectivity and minimum biasness. It gave the researcher the opportunity to sit down and really focus on and analyze what is happening in the physics lessons and to view the lessons in an objective way (Gibbs, Friese, & Mangabeira, 2002). In addition, group discussions during the brainstorming phases were audio recorded from the start of the implementation of the brainstorming technique until the administration of the post-instruments tests. All physics lessons were conducted in the classroom and the physics laboratory.

As stated earlier, Miss Roaa had observed that two students in group 2 were not interested to engage with the other group members to solve the physics problem and the rest of the group members were discussing and trying to solve the problem. By watching the video, the researcher found that:

> *"Two students in group 2 did not participate in the discussion with group members to solve the problem and they were busy talking and laughing with each other. They were highly mobile and lack of attention for the activities". (00:44- 42:31, Video part 1, refraction of light topic, 12-03-2013)*

Although the researcher faced challenges trying to transcribe the video-audio files into Microsoft Word files as translation needed to be done, the conversation among students in-group 2 is presented below (Note: the two students were Ghassan and Emir – not their real names).

Ghassan: It's hard for me to think of physics problems.

Emir : Me too.

Mariam : I am watching this phenomenon in my daily life and I do not know why let's try together to solve the problem.

Ghassan : I did not participate in solving the problem, you tried and you give me the results.

Nassim : Let's discuss together to find out the best solution.

Ahmed : Mariam, and Nassim the physics problem is very interesting let's start thinking and try to solve it.

All video- audio files were transcribed into Microsoft Word files by the researcher of the present study to use it for triangulating with other data from the various sources of collection techniques.

#### 4.4.2.3 Students' Feedback Journal

Students' feedback provides reliable and valid information about the teaching and learning process (Shaheen, 2010). The researcher could not possibly interview every student in the experimental group. Thus, the students' feedback journal was the third type of qualitative data collection source in this study to provide some insight as to the brainstorming technique in developing creative and critical thinking skills in physics. Students in the experimental group were asked to keep and write a feedback journal to describe the learning process via the brainstorming technique during the physics lessons, as well as to describe feelings and problems faced during learning. This individual feedback journal was submitted by each student while learning physics by utilizing the brainstorming technique as well as after completing the physics lessons. The researcher of the present study prepared some questions to encourage students to write their feelings and opinions (see APPENDIX F). Students were given about 15 minutes to write a feedback. The physics teacher had informed the students that the feedback journal would not influence their physics examination scores. The feedback received from the students provided the researcher further opportunity to better understand about what had occurred in the brainstorming technique sessions. Based on students' feedback journals some questions were developed to prompt them during interviews. In the next section, the data collection technique with respect to the physics teacher comments is explained. Example of a student's feedback journal as illustrated below from (Duha, feedback journal, refraction of light, Group 8, 12/3/2013).

For the first question:

> *"I have gained from these activities; I used my mind during learning and did not rely only on conservation and the information in the book only. I raised my thoughts freely, boldness to talk, I have gained a lot of information and ideas on the physics subject from the members of my group. I do not know this information before, which is useful in the future; I have gained a cooperative spirit, sharing ideas and views as well as the spirit of competition between the*

*members of the group. The most important I have gained from these activities is better understanding of the subject compared with the previous method of teacher. I have understanding the topic from my group better from the teacher".*

For the second question:

*" I felt enjoy and fun. I see my friends happy and see my teacher smiling. My group members help me to correct my thoughts and my Information. I did not feel tired or bored".*

For the third question:

*"I suggest change the members of groups from time to time to be able to acquire new information and experiences, reduce the number of group to the three, group must be composed of members of the high, medium and low levels".*

For the fourth question:

*"I am never forgetting this experience".*

(Note: The original language that the students wrote in is Arabic)

#### 4.4.2.4 Teacher Comments

After each brainstorming session, the physics teacher and the researcher had an informal discussion to ask her about her opinions and notes as well as her suggestions to improve the process of teaching via the brainstorming technique. All teacher comments were noted down by the researcher in a journal.

Comments from Miss Zainab based upon Miss Roaa's observations and the video audio file about the situation in group 2 was also triangulated. Miss Zainab also stated that Ghassan who was the leader of the group 2 and Emir who was the secretary of the group 2 were not serious in doing the activities with the other group members while the rest of the group members were discussing and trying to solve the problem at hand. The teacher's comment is given below,

> *"In group 2 Ghassan and Emir were least interactive with the group members and were busy talking and laughing with each others. On other hand, the rest of the group members were very serious to do activities and try to solve the problem".* (Miss Zaniab's comment, refraction of light topic, 12-03-2013)

The researcher also interviewed some students in the experimental group to explore how the brainstorming technique stimulated them in activating their minds in developing creative and critical thinking skills. This is explained next.

#### 4.4.2.5 Student Interviews

The interview is a useful tool for obtaining rich details about the perspectives of participants for the brainstorming technique and learning outcomes and to check the accuracy of the observations (Seidman, 1998). Semi-structured interviews were conducted in this study with the students in the brainstorming group. However, the challenge in using this type of approach consists of reducing the interviewer effect and bias (Benedek, et al., 2012). In-depth interviewing is aimed to understand the ways students generated and evaluated ideas during the brainstorming technique session.

Interviews were conducted after finishing the intervention at the end of the semester. The students were asked a set of questions about learning experiences and learning outcomes as well as posing additional questions to clarify or expand on a particular issue. The researcher of the present study provided Miss Roaa with the interview protocol as shown in APPENDIX G and had a training session with her. She also had previous experience in listening and observing; and was mindful of ethical issues.

Miss Roaa interviewed the students in the physics laboratory before the school session started to avoid interruption to students' formal lessons. Each interview lasted approximately half an hour for each student. The interviews were flexible and

encouraged students to express their opinions and views in their own words; the students could clarify the questions with the interviewer; and could also raise their own questions as a result of what the interviewer said. In the training session with Miss Roaa the researcher of the present study suggested some phrases to use during the interviews (you said a moment ago. . . Can you tell me how, where, why, when, who?). These types of questions helped the interviewer elaborate on the topic or helped the researcher to understand the student views without imposing the same questions and to gain additional information. To ensure data accuracy, Miss Roaa asked for confirmation and feedback from each student after transcription of their interviews (member checks). However, some students were feeling uncomfortable in speaking out in front of their peers or the interviewer. To mitigate this, the researcher further developed open-ended survey questions to gather descriptive data to help students to express their thoughts more freely. This is shown in part C of the students' perception survey of the brainstorming technique.

Data from all interviews were captured on audiotape to help the researcher follow how the interviews were going, and ensure an accurate account of everything said. The researcher always kept track of all of the interviews and sorted and grouped the interview data into categories. Thus, the interview data were used to further support the research findings.

### 4.5 Training of Physics Teacher to Use the Brainstorming Technique and the Observer

The teacher plays a prominent role during the brainstorming session and therefore needs to possess the ability to successfully manage and lead in the classroom and to intervene in the discussions in a timely manner. The teacher must also be able to explain the four

rules (previously described) to the students. In the present study, in order to minimize bias, two teachers of the selected school assisted in the process of data collection.

Miss Zainab is a physics teacher at the Saba School, Babylon, Iraq who volunteered to participate in this study and was willing to implement the brainstorming technique in her physics classroom. Before volunteering for this research, she had taught physics by utilizing the traditional method (chalk and talk method). She had never utilized a teaching method which encourages students to think or to discuss together to find the solution for physics problems. On the other hand she focused only on the transfer of information from the textbook to the students' minds.

The researcher of the present study provided the physics teacher with a theoretical framework for the brainstorming technique, and steps required for the teacher to follow in order to achieve the objectives of the lesson, activities and educational media required by the teacher during her presentation of the physics topics. The researcher provided two types of lesson plans to the physics teacher. The first type were teaching plans adopted for the brainstorming technique to teach the experimental group, and the second type of teaching plans were for the traditional method of teaching the control group. Four physics topics (light and reflection of light, refraction of light, thin lenses and colour and electromagnetic spectrum) were covered by utilizing the brainstorming technique as well as the traditional approach. The researcher trained the physics teachers in implementing the brainstorming technique in teaching physics for students in the experimental group. In order to increase the confidence of the teacher to teach according to the technique of brainstorming, the researcher watched the teacher several times during the implementation period of the intervention, after each lesson the researcher gave feedback to the teacher. The teacher also gave her suggestions and comments which were noted down by the researcher during informal discussions with

the teacher. One of the things stressed was that the best length of time is about 30 - 45 minutes within which time the energy levels are high among students in the short session by following these steps:

Table 4.14 Instructions for the physics teacher during brainstorming sessions

| Steps | Teaching process | Time (min) | Teacher's role |
|---|---|---|---|
| Initial phase | i. Divide class into eight groups; each group consist of five students and one group consist of four students.<br>ii. Remind students of brainstorming rules.<br>iii. Assign session leader and secretary.<br>iv. Identify physics problem as question | 5 | Organized and management of brainstorming session and encourage students to keep thinking about problem<br>Notes the extent of the students' understanding required<br>Notes the extent of the application of the rules of brainstorming. |
| Active phase | i. Students in each group start free discussion together and analyse physics problem for gathering information.<br>ii. Generation of ideas individually by writing ideas in own paper. | 15 | Gives cognitive guidance to students using the discussion group<br>Notes how they interact with each other |
| Post phase | Secretary collecting ideas to give it to the leader.<br>i. Leader and his group start discussion, evaluation and classification of ideas.<br>ii. Leader and his group select right ideas to apply to solve physics problem at hand. | 15 | Facilitator monitors students' progress for each group to ensure the participation of all in dialogue and debate. |
| Teacher feedback | Group discussion between the teacher and groups where the teacher focuses on the various creative solutions that have been generated by the groups. | 10 | Teacher notes down on the blackboard all the answers proposed by each group to solve the problem |

After conducting the activities, Miss Zainab Miss Roaa and the researcher discussed each session. The conversation with Miss Zainab was smooth and she gave full cooperation. The researcher always gave many direct and indirect suggestions for improvement in relation to teacher performance in the brainstorming sessions.

## 4.6 Research Intervention

In this section, first the steps of the brainstorming session as was carried out in the classroom will be discussed. Second, the details about how the actual intervention was planned and executed are described.

### 4.6.1 The Steps of the Brainstorming Session

The brainstorming procedure as originally designed by Osborn (1953) with the specific goal of stimulating thinking skills to solve problems was not intended for schools. Nevertheless, research using brainstorming procedures in education has found that brainstorming make students spend their time thinking about and organizing the salient concepts or points of the topic instead of simply recording information and listening. The stages of the brainstorming technique are consistent with modern trends in the teaching of physics, which emphasizes on making the learner the center of the educational process (Seeler, Turnwald, & Bull, 1994). In order to activate students' mental abilities, brainstorming generally follows four stages:

Stage1: Problem identification;

Stage2: Idea generation;

Stage3: Idea evaluation and selection; and

Stage4: Implementation

The first stage is the key to generating a great number of ideas “identification of the problem”. Dewey (1903), the philosopher, is famous for his quote “a problem well-stated is a problem half-solved." Brainstorming is intended to open fresh perspectives and allow learners to address the original problem from a new point of view. For this to be effective, students must be able to understand the problem, understand abstract principles for reversing data, and to use them in a new situation (Starko, 2009). The brainstorming problem should be specific, not general and leads itself to many possible answers, otherwise the brainstorming session will fail to solve the problem (Wood, 1970). A good problem should be presented as a question, for instance questions such as, What is the purpose? Why is this important? Who is affected? etc. These kinds of problems would help learners to activate prior knowledge and generate more ideas. In essence, by clearly viewing the problem from all angles, it is easier to start the brainstorming process. It is also imperative when brainstorming in a group that all members understand the questions to the answered before suggesting solutions. If some group members misinterpret the problem, they will not be contributing to the solution, and they may slow down the brainstorming process.

The second stage is the actual brainstorming for the generation of solutions (ideas). During the generative process, it is believed that learners would activate the right brain (divergent thinking) to generate and the synthesise a set of novel mental models as potential solutions to the problem by linking new knowledge with old knowledge or making connections between various concepts (DeHaan, 2009). Critical restraints are minimized to encourage free creativity in generating lots of ideas and building upon one another’s ideas (in group brainstorming) to generate even more ideas. Inventors can afford to think freely, by consciously trying to see in a new way, to imagine new possibilities without critical restrictions, because they have the security of

knowing that their wild ideas will not be acted on prematurely before these ideas have been critically evaluated during the editing phase that follows (Rusbult, 1997).

The third stage is the evaluation of ideas. The first step of evaluation is simply to choose ideas, which are potential solutions for the problem. In this stage, a learner would employ critical thinking abilities (convergent thinking) to analyze and evaluate each idea to ensure the ideas would actually be useful or effective in some way. Only at this time are similar ideas combined, criteria for judging the ideas determined, and the best ideas would be selected (Finney, 2008 ).

The final stage involves acting upon the best ideas and evaluating the results (e.g., run the experiment and determine if the hypothesis is proven or not: Jessop, 2002). In this stage, a learner needs to blend between creative and critical thinking to solve the problem. Thus, in the brainstorming technique the processes of creative and critical thinking are equal partners in cognition, which function in tandem in the learners mind for solving problems (Finney, 2008 ).

Based upon the above discussion, the researcher of the present study prepared a fundamental three stage brainstorming technique of six steps of how creative and critical thinking can come into play as illustrated in Figure 4.1.

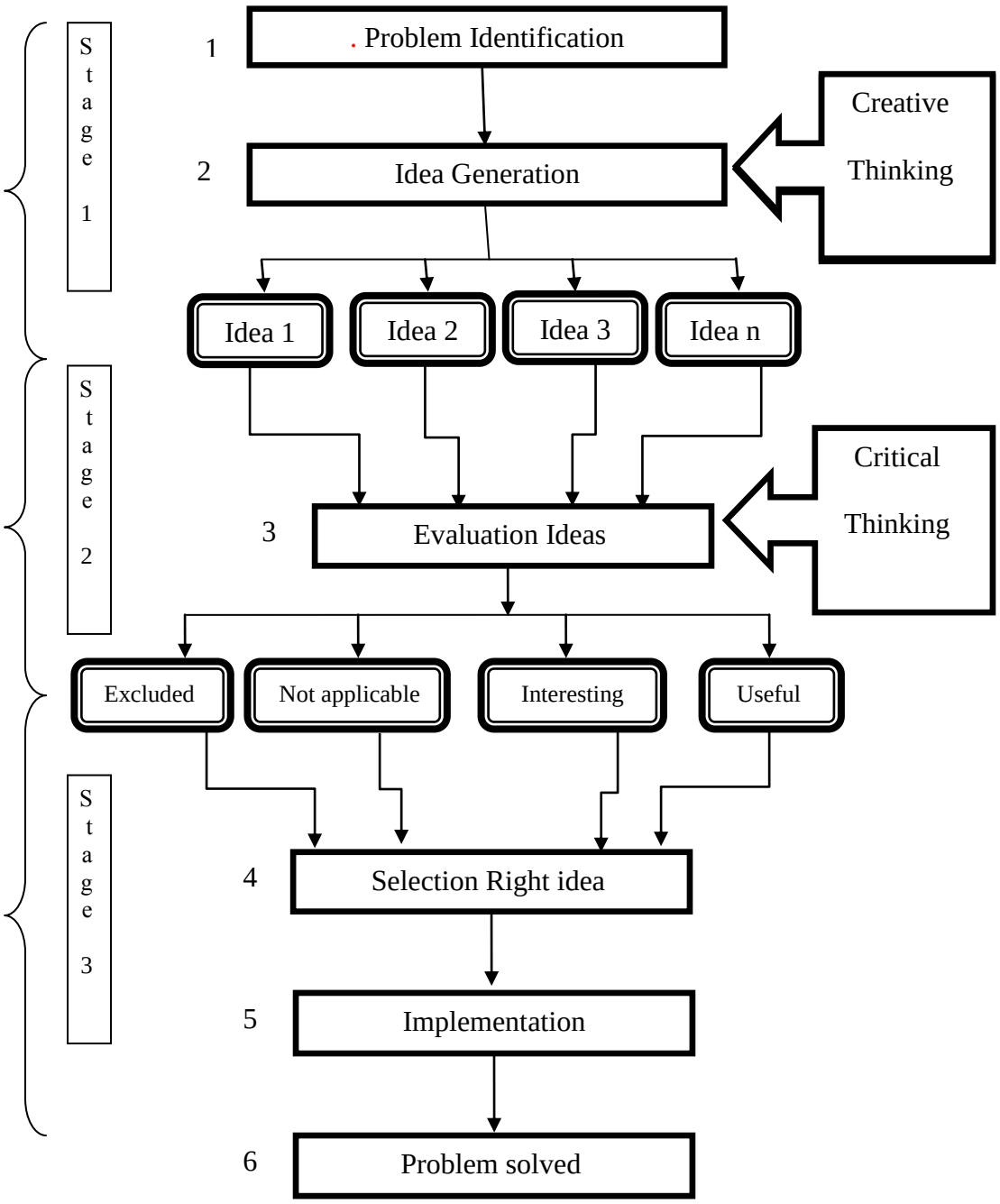



Figure 4.1 The six steps in the Brainstorming processing stages

Although the four processing stages were recognized by Osborn, much of the previous research has largely ignored the last stage. Goldenberg and Wiley (2011) have stated that without the last stage, brainstorming may not be a suitable technique for developing critical thinking. The researcher of this study used all four stages in the study.

### 4.6.2 The Planning and Execution of the Intervention

The research intervention was conducted over 16 weeks (with the actual intervention being 14 weeks) beginning in February until May 2013. During the first week of the intervention, all pre-tests (creative thinking, critical thinking and the physics achievement test) were administered to evaluate the homogeneity between the experimental and control groups and to measure the creative and critical thinking skills level among the secondary Iraqi students. The experimental group was sub-divided into eight groups each group consisting of (3-5) students (see APPENDIX I).

The intervention began in the second week, and the experimental group was exposed to the brainstorming technique while the control group followed the traditional method for 14 weeks. There were two class periods each week; each physics problem needed one week to complete. This is illustrated in Table 4.15.

All classes were conducted by the physics teacher (Miss Zainab) in the Saba school. The teacher's role was one of a facilitator to facilitate and monitor's students' progress for each group. Throughout brainstorming activities, each leader in the group would facilitate and motivate his group to keep thinking about potential solutions to the problems, encourage students to recall the relevant information related to the problem, pose more questions to make his group think more deeply and drive interactive discussion between participants in his group. In addition, the leader would ask students in his group to engage in the implementation of the ideas generated and drawing conclusions about the problem. Table 4.16 shows an example of a task for students' activities and the process and learning outcomes using brainstorming procedures for the experimental group.

Furthermore, Table 4.17 also shows the learning activity for the control group by using the traditional method. Post-tests of creative and critical thinking tests were

administered for both the experimental and control groups after finishing the intervention. In addition, a survey of students' perceptions of brainstorming was administered for the experimental group after completing post-tests. All test papers were marked by the researcher guided by a marking scheme. The researcher used the SPSS programme for the analysis of statistical data.

Table 4.15 Brainstorming technique procedure used for the experimental group

| Week | Physics Content Topic | Brainstorming Activity | Creative Thinking | Critical thinking |
|---|---|---|---|---|
| 1 | None | None | Pre-test | Pre-test |
| 2 | Light | Identify physics problems<br>Problem 1<br>Why does light penetrates glass but does not penetrate wood? | Generation of ideas | Inference<br>Interpret<br>Deduction |
| 3 | Reflection of Light | Problem 2<br>How your eye does see the objects? | Generation of ideas | Assumption<br>Interpret |
| 4 | Mirror | Problem 3<br>Why is the word ‘ambulance’ written inverted at the front of ambulances? | Generation of ideas | Deduction |
| 5 | Refraction of Light | Problem 4<br>Why the pen appears broken when you look at the surface of the water cup? | Generation of ideas | Inference |
| 6 | Real Dimension and Virtual Dimension | Problem 5<br>Why is it that ornamental fish placed in the aquarium seem close to the surface when looking from the top of the aquarium? | Generation of ideas | Interpret<br>Evaluate |

| Week | Physics Content Topic | Brainstorming Activity | Creative Thinking | Critical thinking |
|---|---|---|---|---|
| 7 | Dispersion of light by prism | Problem 6<br>How does a prism separate white light into seven colours? | Generation of ideas | Assumption<br>Deduction |
| 8 | Fiber Optics | Problem 7<br>How Does an optical fiber Transmit Light? | Generation of ideas | Inference |
| 9 | Thin Lenses | Problem 8<br>Why farsightedness treated using glasses with convex lenses? | Generation of ideas | Interpret<br>Deduction |
| 10 | Focus and Focal Length | Problem 9<br>Do you can collect light rays at one point using a concave lens? | Generation of ideas | Assumption<br>Inference |
| 11 | Optical Instruments | Problem 10<br>Why use a magnifying glass in the repair of watches? | Generation of ideas | Inference<br>Evaluate argument |
| 12 | Color and Electromagnetic Spectrum | Problem 11<br>How we invest X-rays and gamma rays in the field of medicine and security? | Generation of ideas | Inference<br>Evaluate argument |
| 13 | Mixing Color of Light | Problem 12<br>Mixing colors of the visible light spectrum gives a white colour? | Generation of ideas | Assumption<br>Interpret |
| 14 | None | End | Post-Test | Post-Test |

Table 4.16 Learning activity for the experimental group by using the brainstorming technique

| **Task example** | **Brainstorming technique** | **Students' activity** | **Process and learning outcomes** |
|---|---|---|---|
| Why does the pen appear broken when you look at the surface of the water cup? As shown in the Figure below.<br>  | problem identification | Leader asks his group: how this problem could be solved?<br>What is the phenomenon that explains the problem?<br>What is the relevant information to this problem? | Students working in groups to discuss the problem and to find relevant information<br><br>Problem solving skills will be used to solve the problem |
| | idea generation | Each student writes his ideas on his own paper. | Creative thinking will be used to generate ideas . |
| | evaluation ideas | Secretary collects papers from group members to give it to the leader<br>Leader discuss with his group all ideas generated by the students | Critical thinking will be used to group and evaluate the generated ideas |
| | selection idea | Leader and his group choose one idea which is solving the problem. | Critical thinking will be used by the group to select a feasible idea |
| | Implementation idea | Apply the chosen idea to solve problem | Creative and critical thinking skills will be used to synthesize and control variables |

Table 4.17 Learning activity for control group by using the traditional method

| **Task example** | **Learning process** |
|---|---|
| Refraction of light | - Introduction<br>Teacher starts the lesson by giving introduction to the subject such as:<br>- Light is the electromagnetic radiation that can be detected by the human eye.<br>- Light travels in straight lines in the middle homogenized.<br>- Students write this information.<br>- Explanations<br>- Teacher uses the blackboard, chalk and physics textbook to explain the phenomena of light refraction by talking and using chalk to write the information on the blackboard.<br>-Teacher explains the experience of light refraction theoretically which is in the physics textbook for student.<br>- Light is reflected at an angle equal to the angle of incidence when it falls on the non-transparent body.<br>- Refraction of light is the change in direction of a wave due to a change in its medium.<br>- Students listen to the teacher without any interaction with him.<br>- Students receive and write information.<br>Conclusion<br>Teacher summarizes the lesson by giving some sentences:<br>- Refraction of light is the change in the light direction when moving diagonally from transparent medium to another differs in optical density.<br>- Optical density is the status for transparent medium depends on the speed of light passing through it.<br>- Optical density is inversely proportional to the speed of light. The speed of light declines when the optical density increases. |

The procedures of the study are illustrated in Figure 4.2.

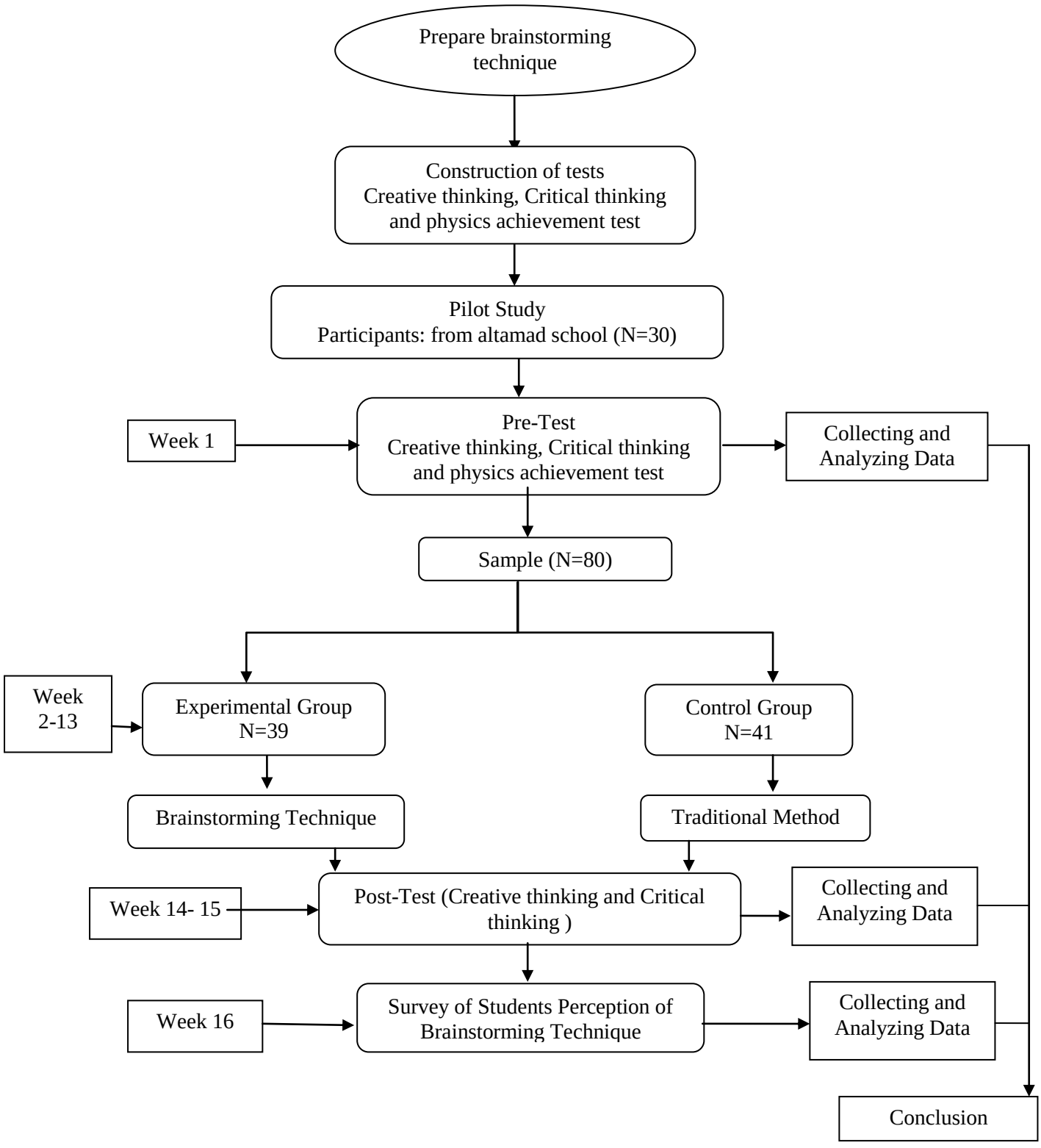



Figure 4.2 Flowchart of procedures of the study

## 4.7 Analysis of Data

Data analysis consists of examining, categorizing, tabulating, testing, or otherwise triangulating both quantitative and qualitative evidence to answer the research questions of this study (Yin, 2003). After the data were collected, both descriptive and inferential statistics were used in this study for data analysis. Descriptive statistics provide simple summaries about the sample and about the observations that have been made. On the other hand, inferential statistics would be used to make judgments of the probability that an observed difference between groups is a dependable one or one that might have happened by chance in this study (Trochim & Donnelly, 2001). The quantitative statistics was done using the Statistics Programme for Social Science (SPSS) version 18 to find arithmetic means and standard deviations for scores of the students in each group for each of the instruments. Details of the data analysis for the quantitative and qualitative data are explained in the next three sections.

### 4.7.1 Test Data

The student sample of this study was measured via pre-post tests for the dependent subject variables (creative thinking and critical thinking). All of these pre-post tests were first analysed for the means and standard deviations. Numerical (Kolmogorov-Smirnov Test and the Shapiro-Wilk Test) and graphical (Q-Q Plot) statistical methods were used to investigate the normality of the sample of the present study. Levene's Test was used to check the verification of the homogeneity of variance between the experimental and control groups. Within-subject contrast test was used for both the experimental and control groups for the three tests to determine the effectiveness of the

brainstorming technique and traditional teaching method in enhancing creative thinking skills and critical thinking skills among secondary Iraqi physics students. Following this, the Analysis of covariance (ANCOVA) and the Multivariate Analysis Of Variance Analysis (MANOVA) were used to identify if there were any significant differences between the experimental and control groups due to the brainstorming technique.

### 4.7.2 Survey Data

The survey of students' perceptions of the brainstorming technique is divided into three separate parts. Part A consisted of questions related to learning outcomes with a 5 point Likert scale. Part B consisted of questions that reflect on the features of the brainstorming technique with a 5 point Likert scale.. Whereas, part C consisted of open-ended questions about the brainstorming technique used for learning physics during the second semester of the academic year.

After the questionnaire was completed, part A and part B of the survey were analysed using frequency, percentage, mean and standard deviation for each statement. While, part C was analysed qualitatively.

### 4.7.3 Observation, Interview, Student Feedback Journal and Teacher Comments Data

Qualitative research data analysis is quite different from analysis of quantitative data (Thurston et al., 2007). Observations, Interviews, student feedback journals and physics teacher comments were captured as data in order to try and determine how is the development of critical and creative thought when utilizing the brainstorming technique in teaching physics. The qualitative data was triangulated to determine emerging

processes that could explain how critical and creative skills thought develop (i.e. to answer Research Question 5).

Besides this, the qualitative data were coded within several pre-established categories (e. g., learning outcomes, characteristics of brainstorming technique, problems or difficulties encounter students during learning, etc.) and can be used to give insight to the numerical data to better understand the students' views of the implementation of the brainstorming technique in physics learning. This data analysis was used to answer the research question number six (RQ6).

All qualitative data were gathered in the Arabic language and then translated to the English language. Therefore, back translation was conducted in three steps (Chen & Boore, 2010), which involved,

i. Forward translation to target language (English), was performed by the researcher of the present study;
ii. Back translation to source language (Arabic), it was done by a professional researcher (Diya), who is pursuing his masters degree in a Babylon university. He has substantial experience in translating; and
iii. Verification of the equivalence of the source and translated version, was checked by the translators. Susan and Nasreen (Both translators are Iraqi - they have obtained their masters degrees in a Babylon University in the department of linguistics) gave comments of the translation. The acceptance rate of the translation among the translators reached 87%. The 13% of discrepancies were resolved through negotiations between the translators.

## 4.8 Management of Data

The data collected throughout the study comprised multiple sources, such as the student feedback journals (source: written feedback journals), observations (source: Miss Roaa, written field notes), brainstorming sessions (source: audio tapes, video tapes, photographs), interviews (source: audio tapes) and teacher comments (source:Miss Zainab's written journals).

All students' interviews on audio tapes were transcribed verbatim. For the audio-taped group discussions, the researcher faced some challenges trying to transcribe them verbatim. Some portions were unable to be transcribed verbatim as a result of students' seating position (e.g., far away from recorder), unexpected noise (e.g., rain), loudness of surrounding students' voices, and interruptions. For the video tapes and photographs, only selected segments were transcribed. These segments were selected after repeated viewing. All audio-based and video-based transcriptions were transformed into Microsoft Word files. Hand-written data (e.g., notes, journals) were also transformed into Microsoft Word files. Whenever the data were needed in hardcopies, the Microsoft Word files were printed or original artifacts were photocopied. Examples of data from each source are provided in the APPENDIX H.

From analysis of the open-ended questions, student feedback journals, and student interviews the researcher coded each sentence containing the same information or same concept with the same word or phrases to reduce the total amount of data. There were two sets of raw data for analysis: one, focused on how selected secondary Iraqi students employed creative and critical thinking skills in the physics lessons during brainstorming sessions and the other focused on the understanding of students' perceptions of teaching via the brainstorming technique.

Questions in the different instruments were provided to the participants in different formats and ways to obtain extra information from the students about the brainstorming technique from all aspects. The six main questions were:

1. How were you able to generate a large number of ideas to solve the physics problem?
2. How were you able to evaluate and select best ideas (solution) to solve the problem at hand?

The last four questions related to uncovering students perceptions of teaching via the brainstorming technique.

3. What are the major characteristics of the brainstorming technique?
4. What are the learning outcomes that you felt you obtained as a result of using brainstorming?
5. What problems did you face during learning process via the brainstorming technique?
6. Do you have any suggestions for improvements?

The information gathered about how selected secondary Iraqi students employed creative and critical thinking skills in physics lessons during the brainstorming sessions were coded into categories. The researcher of the present study derived the categorizing and grouping the data according to the frequency themes mention by the participants' responses on questions given in the different qualitative data collecting techniques (Kawulich, 2004) as illustrated in Table 4.18. The emerging themes were presented to and discussed with 4 experts in the field (University of Malaya) to validification.

Table 4.18 Themes derived for understanding the development of creative and critical thinking (All names used are pseudo-names) - Examples

| Question | Themes | Students responses to the question |
|---|---|---|
| How were you able to generate and evaluate a large number of ideas to solve the physics problem? | Physics problem | "Physics problem was interesting stimulus for me to think and search for information . . ." (Cardana, interview, 5/3/2013).<br>"The problems presented helped me to recall information, laws, concepts and physics theories I learned in previous academic levels. . .". (Isal, student journal feedback, 12/3.2013).<br>"The problem provoked my curiosity in the search, verification and predictability . . .". (Nassm, open ended question, 21/5/2013).<br>*"*After the teacher identified the physics problems, students sit closely to discuss … and most group students seem to work hard to solve the problem. (Miss Roaa, observation, 12/3/2013). |
| | Lessons rules | "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. . .". (Isal, student feedback journal, |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | 9/4/2013).<br><br>(Changing the rules of physics lessons made students very active and interested to learn physics without fear from the teacher's rules…. (Miss Roaa, observation, 12/3/2013).<br><br>"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 . . ." (Amer interview, 23/4/2013). |
| | Classroom climate | "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; . . .".(Dania, open-ended question, 21/5/2013).<br><br>"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).<br>"The Lesson climate in brainstorming sessions was one of |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | freedom and security which helped in the expression of ideas ……(Miss Roaa, obsevation, 19/3/2013). |
| | Motivation | "I no longer sit down to listen to the teacher's lecture, . . .; 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).<br>"The biggest motivation for me to learn. . .". (Manar Mohamed, students' journal feedback, 2/4/2013).<br>"I have never taken part in a physics lesson before while in this new learning experience I am encouraged to solve the physics problem . . .". (Maryam, open-ended question, 21/5/2013.)<br>"I feel stimulated to participate in the search for information, . . ..". (Mohammed, interview, 19/3/2013).<br>I observed that most students were motivated to engage in doing physics experiments to get results |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | and solve problems…….(Miss Roaa, obsevation, 21/5/2013). |
| | Associate new and old knowledge | "I built a bridge between associated and non-associated ideas with the problem. . .". (Iaa, interview, 2/4/2013).<br><br>"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).<br><br>"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).<br><br>"I linked between my ideas and my friends ideas to generate largest possible of physics ideas". (Ahmed, interview, 30/4/2013). |
| | Cognitive conflict | "I discussed with members of my group, there were conflicting ideas pushed me to rethink . . ..". (Obedia, interview, 19/3/2013).<br><br>"I took a long time to decide and choose the right idea . . .".(Muammil, interview, |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | 30/4/2013).<br><br>"I carefully thinking and I seriously tried and I discuss with the members of the . . .". (Ali, open-ended question, 21/5/2013).<br><br>"Differing views among the group members prompted me to think deep . . ..". (Zahraa, student feedback journal, 20/3/2013).<br><br>"After reviewing my group's ideas, the problem is brewing in my mind and I understood it's from all dimensions. . . ." (Iaa, interview, 23/4/2013).<br><br>"The differences between my idea and my group ideas pushed me to more checking and thinking again . . ." (Suhad, student feedback journal, 7/5/2013).<br><br>"I stimulated more to solve the problem after I read and listen to the ideas of the group members. . ." (Mohammed, interview, 5/3/2013). |
| | Social construction | "I greatly benefited from the information and experiences raised by each member of my |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | group during discussion time . . .". (Mariam, student feedback journal, 16/4/2013).<br><br>Social interaction between different levels in a group brainstorming and blending different ideas make students enjoy during the session…….(Miss Roaa, obsevation, 21/5/2013).<br><br>"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).<br><br>"I used the information which obtained from peers to generate ideas. . . .". (Mustafa, interview, 23/4/2013). |

The researcher of the present study derived the categorizing and grouping the data according to the frequency themes mentioned by participants' responses to the questions offered in different qualitative instruments. As illustrated in Table 4.19. The emerging themes were presented to and discussed with the same panel of 4 experts in the field (University of Malaya) to validification.

Table 4.19 Themes derived for understanding the perceptions of students of teaching via brainstorming technique (All names used are pseudo-names) - Examples

| **Question** | **Themes** | **Students responses to the question** |
|---|---|---|
| What are the major characteristics of the brainstorming technique? | Cooperative learning | "Physics lessons have grown spirit of cooperation between the students . . ." (Warda, student feedback journal, 9/4/2013).<br><br>The cooperation between the students encourage each other to integrate thinking with the group and encourage teacher and give humour and fun, stir up ideas of students and facilitate the process of thinking (Miss Roaa, Observation, 21/5/2013).<br><br>"Learning was based on cooperation; my group members were cooperating with each other. . ." (Ahmed, open-ended question, 21/5/2013).<br><br>"This method has been increased spirit of cooperation among students, . . ." (Nizar, student feedback journal 16/4/2013).<br><br>"Cancellation of individual differences among students during physics lessons encouraged all my group members to cooperate." (Shaima, open-ended question, 21/5/2013). |
| | Entertaining and exciting | "I not forget this experience because I was very excited and I did not feel bored during lesson . . ." (Asal, interview, |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | 30/4/2013).<br><br>“I felt happy and comfort and there is no pressure from the teacher . . . “(Sarah, student feedback, 7/5/2013, journal).<br><br>“Group members were very happy and enjoy during class all the time. They discuss with each other, sitting close and are comfortable with the rules and steps of the educational method.”. (Miss, Roaa, Observation, refraction of light, 12//2013).<br><br>“In short, lesson shifted from routine and bored to fun and enjoyable”. (Reem, open-ended question, 21/5/2013). |
| | Self-expression | “I had the opportunity to express my thoughts and my opinions freely”. (Ammer, open-ended question, 21/5/2013).<br><br>“I'm very shy in expressing my thoughts and views . . .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).<br><br>“I introduced my thoughts and my views to my classmates . . . “(Noor, open-ended question, 21/5/2013).<br><br>“I am encouraged to express my |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | thoughts, even if some of my ideas were useless". (Iaa, interview, 5/3/2013). |
| What are the learning outcomes that you felt you obtained as a result of using brainstorming? | Better understanding | "I Gained lots of information from peer which it help me to understand the topic". (Mohamed, student feedback journal, 26/3/2013).<br><br>"My knowledge and understanding of the topic . . ." (Dania, interview, 5/3/2013).<br><br>"I understood the physics topic by my group members . . . "(Rafael, student feedback journal, 9/4/2013). |
| | Communication skill | "I was able to communicate and consult with my colleagues . . .." (Dania, student feedback journal, 26/3/2013).<br><br>"I realized how important communication process with others . . ." (Warda, open-ended questions, 21/5/2013).<br><br>"Through my participation with my group . . . I discovered that my colleagues have a lot of physics information and high mental skills". (Shamia, interview, 19/3/2013). |
| | Physics in daily-life | "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. . . ." (Hassoun, interview, 5/3/2013). |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | "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". (Mary, interview, 2/4/2013).<br><br>"I like studied physics because I participated in the experiments and discovered a lot of information . . ." (Duha, student feedback journal, 16/4/2013). |
| What problems did you face during learning process via the brainstorming technique? | Lack of participation | "Two students in group 2 were not participating to do the activities ……only the other group member tried to solve the physics problem.". (Miss Roaa, Observation, Refraction of light topic, 12-03-2013).<br><br>"Some members of my group - not all of them participate in the discussion . . .." (Mannar, students' journal feedback, 17/4/2013).<br><br>"Lack of cooperation between members of my group, . . ." (Mustafa, interview, 12/3/2013).<br><br>"Ali, a member of my group is not serious and not participates with the group . . ." (Asra, interview, 17/4/2013). |

| Question | Themes | Students responses to the question |
|---|---|---|
| | Noises | "I could not focus well on physics problems because of the uproar in the classroom". (Zafar, interview, 30/4/2013).<br><br>"Group behind me was discussing with each other loudly . . ." (Abel Raman, student feedback journal, 2/4/2013). |
| | Time management | "…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).<br><br>". . .I can find a solution to the problem quickly". (Mehdi, student feedback journal, 9/4/2013). |
| Do you have any suggestions for improvements? | Exchange group members | "I suggested that members of the group substitution between one period and another . . ." (Cardana, open-ended question, 21/5/2013).<br><br>"Substitution of students' groups from each lesson or two lessons . . ." (Nassm, student feedback journal, 7/5/2013).<br>"My suggestions to improve this method are change group students from one lesson to another . . ." (Hamad, interview, 19/3/2013). |
| | Provide multiple sources of knowledge | "Provide each group computer with Internet . . .." (Amna, student feedback journal, 2/4/2013). |

| Question | Themes | Students responses to the question |
|---|---|---|
| | | "Internet helps the group to access a lot of information and examples . . ." (Asal, open-ended question, 21/5/2013). |

### 4.9 Reliability and Validity Issues of the Findings

Creswell (2009) and Merriam (2009) recommend many strategies in editing and revising coding, and to improve the reliability and validity of the findings. These strategies included triangulation, member checks, and peer reviews.

**Triangulation.** The purpose of triangulation in qualitative research is to increase the credibility and validity of the results. Triangulation is a powerful technique that facilitates validation of data through cross verification from two or more sources. In the context of this study, the data sources considered perspectives of different people such as the researcher (through observation), the teacher (through teacher's comment) and students (though interviews). Furthermore, the data were also collected from different periods and methods, such as group discussions (during the brainstorming sessions), students' feedback journals (after the brainstorming acitivity), and interviews (during and after intervention). For the findings reported in the present study, the researcher had cross checked the data (if possible) with various peoples' (e.g., researcher, two teachers, students) voices. The researcher will now show an example of how triangulation was utilised to identify the theme "motivation" through the utilizing of the brainstorming technique. The following excerpt shows this clearly.

> *"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).

*"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).

The physics teacher (Miss Zainab) asked 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 remembering 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).

Similarly as above for the other data interpretation, the researcher tried to cross check with various data.

**Member Checks**. Lincoln and Guba (1985) posit that this is the most crucial technique for establishing credibility. Typically, member checking is viewed as a technique for establishing to the validity of an account. This is when data, analytic categories, interpretations and conclusions are tested with members of those groups from whom the data were originally obtained. The Positive Aspects of Member-checking is that it gives participants the opportunity to correct errors and challenge what is perceived as wrong interpretations, additional information which may be stimulated by the playing back process, provides an opportunity to summarize preliminary findings as well as to confirm particular aspects of the data. In the context of the present study, printed transcripts, which included students' interviews and teacher's comments, were taken back to the research site. The teacher informed the purposes of checking the transcripts to the students. The teacher and students were given time to check the interview transcripts. These transcripts were verified by the respective informants.

**Peer Review.** (or peer debriefing) whereby another qualitative researcher analyses the data independently. The process of peer review involves at least one other suitably experienced researcher independently reviewing and exploring interview transcripts,data analysis and emerging themes. The rationale of carriying out this process may help to guard against the potential for lone researcher bias and help to provide additional insights into theme and theory development (Bumard, et al., 2008). in the present study, when the data collection and initial analysis was accomplished, peer reviews were organised to review the findings. The physics teachers who are also currently pursuing their post-graduate degrees reviewed the findings. Several sessions were conducted to review the research findings. The findings that have been peer

reviewed included students' feed back journal, students interview, students' answers in the open-ended questions, and teacher comments.The data analysis was being explained to peers who were not familiar with the present study. Then, the findings were presented. Next, the peers asked questions and the researcher tried to explain and sometimes justify and rationalise the actions. The peers' comments were taken into consideration to improve the analysis of data. As the researcher and teacher were the coders, it is believed that these peer review sessions have minimised the bias on coders' interpretation. The methodolology of the present study discussed above is shown in Figure 4.3 below.

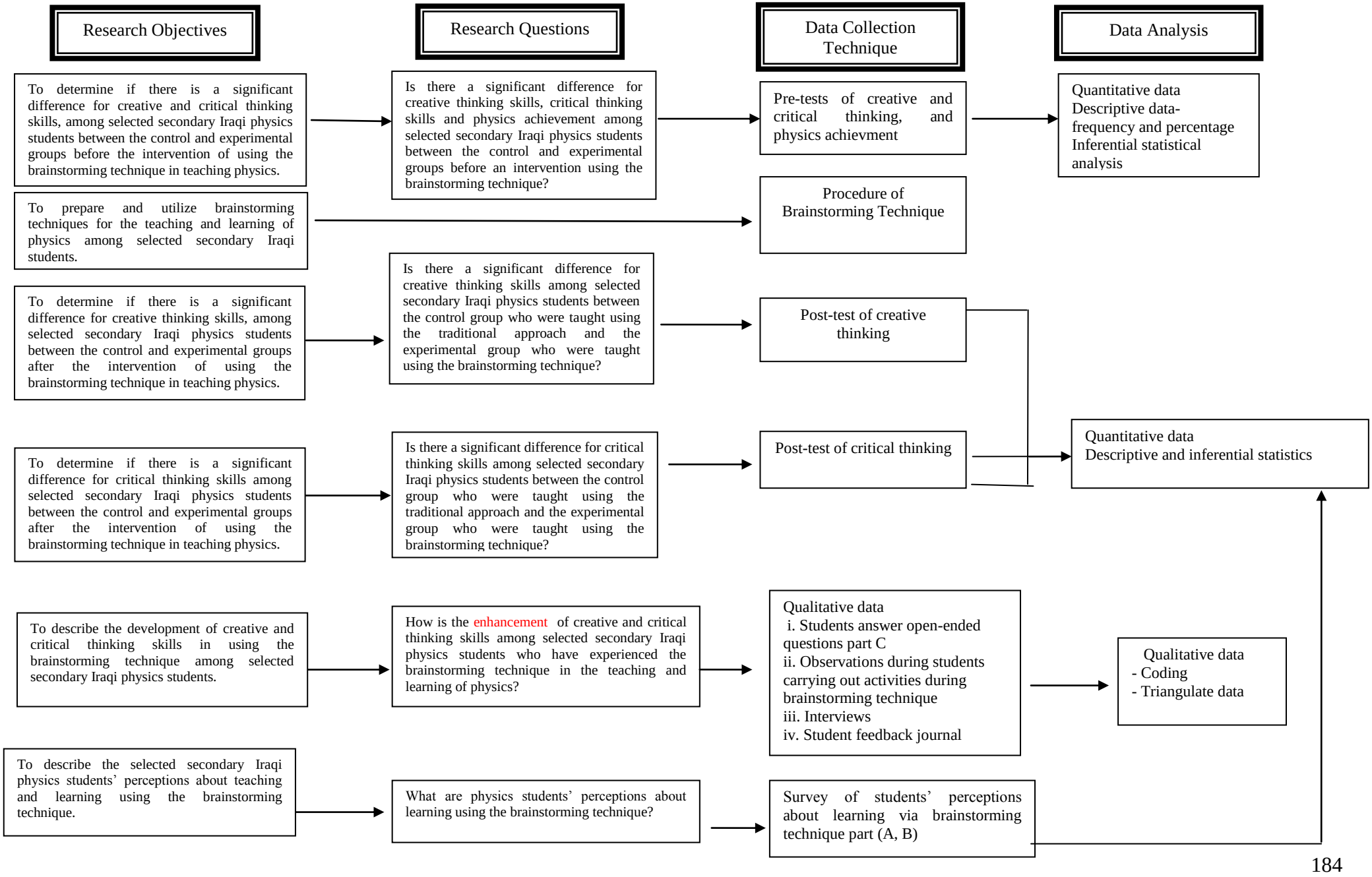





Figure 4.3 Design of the study

## 4.10 Chapter Summary

This chapter described the research methodology used in the study. The research reported in this study employed a concurrent mixed method design, which included a quasi-experimental method, and with pre-test-post repeated measures to investigate the effectiveness of the brainstorming technique. Concurrently, in-depth qualitative data was collected to attempt to describe the enhancement of creative and critical thinking skills. The research was conducted among secondary Iraqi physics students (second grade intermediate students) at the Iraqi Saba school, involving (80) students in total and the intervention took 16 weeks. The experimental group was taught physics based on the process of the brainstorming technique, whereas the control group was taught physics based on the traditional method.

To achieve the research objectives, a researcher prepared four instruments which were creative thinking test, critical thinking test, physics achievement test, and survey of students' perception of brainstorming technique. In addition, the researcher developed protocols for observations, interviews and students' feedback journal. The validity and reliability of instruments were taken into account. A number of statistical tests were used to analyse the data and help address the research questions. The statistical tests were employed using the Statistical Package for the Social Science (SPSS) version 18. Qualitative data from observations, open-ended questions, interviews, students' feedback journals and teacher comments were captured and coded to establish emerging thought processes of creative and critical thinking. The multiple sources of data were triangulated to arrive at conclusions for the research questions. The next chapter will discuss the research findings for this study.