CHAPTER 3

CONCEPTUALIZATION OF THE STUDY

3.0 Introduction

The review of the literature presented on brainstorming techniques, creative thinking, and critical thinking in the previous chapter underpins the research questions set out in Chapter 1. The present chapter focuses on how the current study is framed and the underlying theoretical framework for this study.

Although, thinking skills are at the heart of learning, it has been asserted that thinking skills among Iraqi students in science education is very poor (Cheng, 2011; Dagher & BouJaoude, 2011; Faour & Muasher, 2011; UNESCO, 2011). Therefore, the present study prepared a brainstorming technique for secondary Iraqi physics students (second grade intermediate) to infuse creativity and critical thinking in physics.

Brainstorming has existed for many years. However, empirical studies explaining theories and cognitive processes underlying brainstorming, and how the learning occurs during brainstorming are limited (Wang, et al., 2011). Procedures of applying the brainstorming technique in the classroom are usually incorrect due to ignorance of some of the brainstorming stages that makes brainstorming an invalid technique for learning physics (Goldenberg & Wiley, 2011; Holubová, 2010). In addition, the literature of physics learning is devoid of studies establishing the ties between creative thinking and critical thinking (Rabari, et al., 2011).

This chapter is presented under seven subheadings, which are the conceptual framework, theoretical framework, developing procedures or steps for the brainstorming technique used in this study, thinking skills; problem solving, research scope and the chapter summary.

3.1 Conceptual Framework

In exploring the research objectives and questions, the researcher required constructing a diagram of the conceptual framework in seeking the relationship between the present problem with the literature review of the brainstorming technique, and to explain the importance and anticipated contribution of the proposed research.

Several researchers have highlighted the effectiveness of brainstorming in teaching and learning (Butler & Kline, 1998; Cheng, 2004, 2011; DeHaan, 2009; Harbi, 2002; Hobson, 2001; Holubová, 2010; Jessop, 2002; Mased & Yamin, 2012; Paulus & Paulus, 1997; Wang, Rosé, et al., 2006; Wood, 1970) and are illustrated in Table (3.1). There are still insufficient studies on the utilization of brainstorming techniques in physics learning. Moreover, most of the empirical studies showed brainstorming as a technique for developing only creative thinking.

Most of the empirical studies ignored the later processing stages of the brainstorming technique, which includes critical thinking (Goldenberg & Wiley, 2011). In contrast Scott, et al., (2004) asserted that the efforts to enhance creative abilities should begin with establishing the relationship between critical thinking and divergent thinking.

Therefore, the procedure of brainstorming technique in the present study is designed with the specific goal of enhancing creative and critical thinking through following four stages which are problem identification; idea generation (which is represented as creative thinking); idea evaluation and selection (which is represented as critical thinking); and implementation. As a result of this, it is believed that students will be able to activate two sides of their minds to solve physics problems and make a decision.

Table 3.1: Past studies pertaining to the brainstorming technique

Author	Year	Contents
Wood	1970	Brainstorming an effective teaching technique for all levels of learning.
Paulus & Paulus	1997	Group brainstorming increase productivity, learning, and creativity for gifted and regular education.
Butter & Kline	1998	A comparison of brainstorming, hierarchical, and changing perspective to determine which produced the most, best, and the most creative solutions.
Hobson	2001	Using brainstorming as an interactive technique for teaching physics.
Harbi	2002	Brainstorming develops critical thinking skills and academic achievement in biology lessons.
Jessop	2002	Brainstorming and critical thinking skills to expanding students' brainpower in chemical and biochemical engineering.
Cheng	2004	Enhancing creativity in physics by using brainstorming technique and other different strategies.
Wang et al	2006	Virtual brainstorming to support productive group for collaborative creative idea generation in science education.
Alaatari	2006	using brainstorming method in teaching science on developing the creative thinking of the second grade intermediate pupils in Arar City
DeHaan	2009	Using brainstorming technique to promote creative problem solving in science.
Holubova	2010	The effectiveness of brainstorming technique as modern teaching methods in teaching physics.
Mohammed	2010	Using brainstorming for developing science processes skills among fifth secondary students in biology.
Chang	2011	Brainstorming technique for infusing creativity into regular science lessons.
Fanona	2012	Using brainstorming in the development of concepts and the attitude towards biology for the eleventh grade Male students.
Mased & Yamin	2012	A comparison of problem based learning and brainstorming technique on developing critical thinking.

Most of the previous empirical studies focused on loss of productiveness of group brainstorming and compared them with an individual group. The productive loss occurs for group brainstorming during the idea generation stage due to the impact of various inhibitory processes (blocking, free riding, and evaluation) as illustrated in the previous chapter as well as the competition between students over the time available for the expression of ideas. These variables make physics teachers believe that brainstorming is not a suitable technique for physics learning (Cheng, 2011; Holubová, 2010).

In contrast, to minimize the impact of these variables, the procedures of brainstorming should be planned as a mixture of individual and group brainstorming. Individual brainstorming should be encouraged after group brainstorming (Paulus, et al., 2011). During the first stage, all students in the group would first discuss and analyze the problem to stimulate each other and to activate prior knowledge related to the problem. Then each student would generate solutions (ideas) by writing down these ideas on their own piece of paper (brainwriting) to minimize the productive loss. In the evaluation ideas stage all students would share thoughts to evaluate and select the right idea and implement it. This is an optimal procedure for students to express fully ideas without social anxiety as well as to save time during brainstorming session.

The brainstorming technique proposed in the present study is to try and infuse both creative and critical thinking. This is not found in previous research as far as the present researcher has tried to uncover past research (Rabari, et al., 2011). Therefore, it is an important step towards filling this gap, in the present study where the researcher prepared a brainstorming technique and utilized it to try and enhance creative and critical thinking skills among physics students in an Iraqi Saba school. The overall conceptual framework of this study is presented in Figure 3.1.

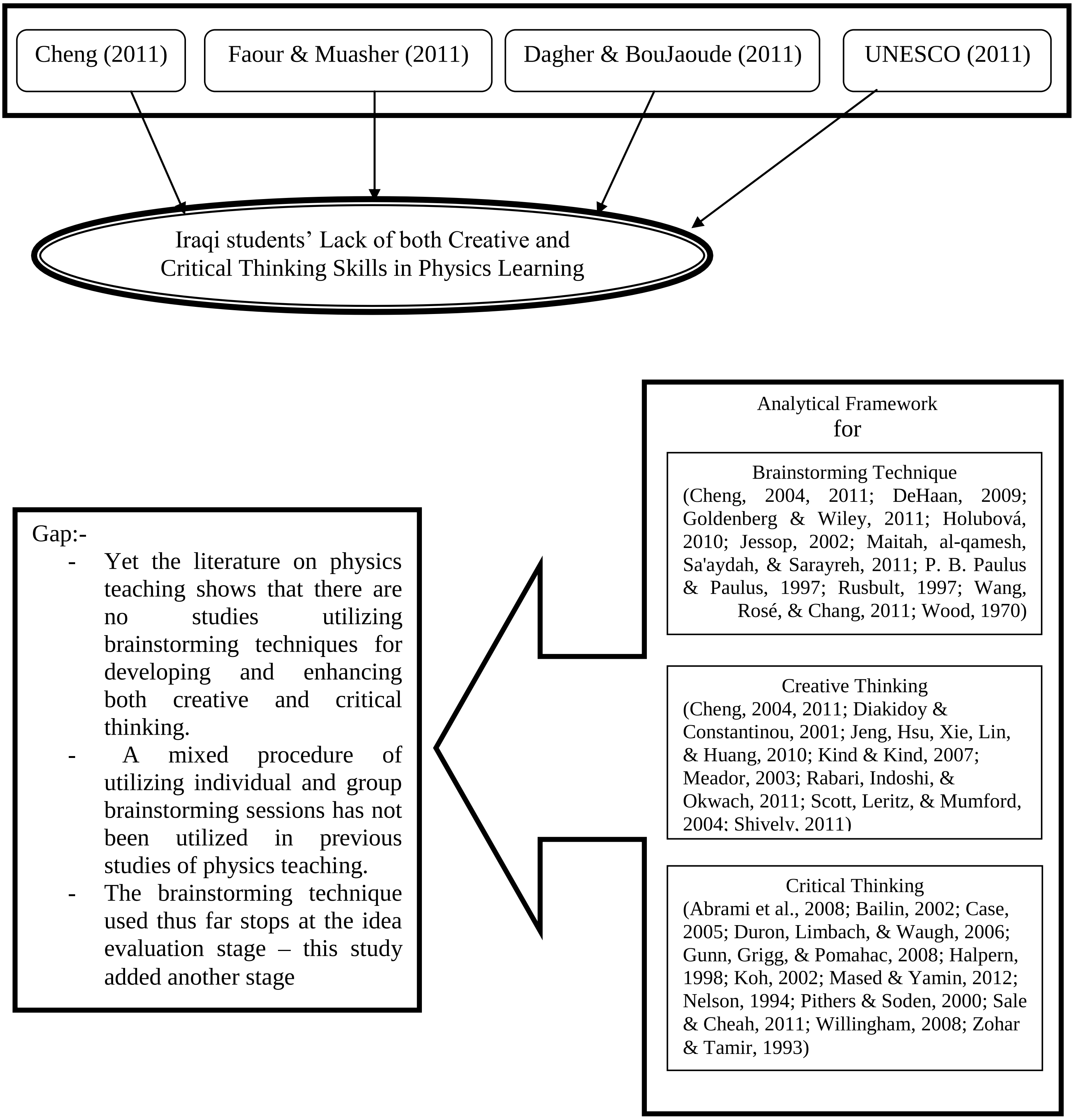

Figure 3.1 Conceptual framework of the study

3.2 Theoretical Framework

The theoretical framework has been developed in the context of this study to identify a set of theories connected with the research conducted and showing how they fit together or are related in some way to the present study. Thus, here the researcher describes key theories of brainstorming technique, models of thinking processes and problem–solving models in order to address the research questions of this study.

3.2.1 Developing Theories of Brainstorming Technique

Osborn (1953) introduced brainstorming as a technique to increase group creativity. However, he did not provide a theoretical basis for the brainstorming technique (Butler & Kline, 1998). In addition, there are a few empirical studies that offer an evidence base for an understanding of how brainstorming leads to learning (Wang, et al., 2011).

However, there are three cognitive theories adopted in this study to explain the cognitive processes underlying brainstorming and how the learning occurs during utilization of the brainstorming technique. These theories are: Search for Idea in Associative Memory theory (SIAM) (Nijstad, 2000; Nijstad, Stroebe, & Lodewijkx, 2002; Nijstad, et al., 2003), Piaget's Cognitive Development theory (1929), and Vygotsky's Socio-cultural theory (1978). All these theories play an important role in explaining how knowledge is generated and how learning occurs during brainstorming to help students develop cognitive structures.

Cognitivist learning theory is the theory that students generate knowledge through sequential development of an individual's cognitive abilities, such as the mental processes of recognize, recall, analyze, reflect, apply, create, understand, and evaluate. The Cognitivists Piaget, (1929) and Vygotsky, (1978) asserted that the learning process is actually an adoptive learning of techniques, procedures, organization, and structure to develop the internal cognitive structure that strengthen synapses in the brain.

The learner requires assistance to develop prior knowledge and integrate new knowledge. Therefore, the purpose in education is to develop conceptual knowledge, techniques, procedures, and physics problem solving using verbal/linguistic and logical/physical intelligences. The learner requires scaffolding to develop schema and adopt knowledge from both society and the environment. Teachers should use instructional methods that combine between constructive, prior knowledge as well as a collaborative process to achieve the learning objectives.

Learning from brainstorming comes from the constructive, inferential process of learning building on prior knowledge as well as from the collaborative process of students building on one another's ideas (Wang, et al., 2011).

Therefore, this study attempted to combine the three cognitive theories in the classrooms, SIAM theory for retrieval of knowledge from long-term memory (activation prior knowledge) and idea generation, Piaget's ideas to promote disequilibrium and self-discovery, and Vygotsky's ideas to promote social interaction and instructional conversations (scaffolding and collaborative process).

3.2.1.1 Search of Idea in Associative Memory Theory (SIAM)

Search of idea in associative memory is a cognitive theory developed to explain the cognitive processes underlying idea generation in the brainstorming technique. It is an extension of Raaijmakers and Shiffrin's (1981) Search of Associative Memory (SAM) model of memory retrieval. The SAM model explained that learning occurs from the short-term memory control process (coding, rehearsal and decision) and retrieval of a variety of long-term memory structures followed by the formation of new associative relationships between the retrieved structures. SIAM is similar with the SAM model and assumes that there are two memory systems: short-term memory and long-term memory (Nijstad, 2000; Nijstad & Stroebe, 2006; Nijstad, et al., 2002, 2003).

i. **Short-Term Memory**

Short Term Memory or sometimes called a limited capacity Working Memory (WM), can only handle a small number of "units" or "chunks" at one time. It is fragile, often lasting only a few seconds without specific activities to prolong it. The major role of WM is used as a working space for control processes of all sorts, including plans, coding, rehearsal, and decision (Nijstad, 2000).

ii. **Long–Term Memory (LTM)**

An unlimited capacity consists of elements that are a richly interconnected network of cognitive nodes that is called a (semantic network). Long-term memory contains a vast quantity of relationships, schemes, frames, and rules for how to use and process them (declarative and implicit memory). It is highly stable and can store data for decades. However, long-term memory for physics learning is not just having the memory, but being able to use it and make the associations that bring it into working memory. This is important for students to understand knowledge of physics to be functional (Nijstad, et al., 2002, 2003).

SIAM assumes that LTM and WM memory are essential elements of the brainstorming process because brainstorming repeatedly searches for ideas in associative memory and their integration in working memory.

Thus, the first stage of the brainstorming technique is that active prior knowledge (image, concept or idea activation) in LTM and retrieval knowledge from LTM interact. The new ideas cannot be immediately retrieved from memory; new ideas require a significant knowledge store in order to retrieve and elaborate on new ideas. The activation of knowledge is a controlled process in which search cues are applied, which image or concept is activated is probabilistic and depends on the strength of association between the search cue and the concept.

Concepts that are more similar to one another have many strong connections with currently active ideas than concepts which are very different from one another. When a particular idea or concept is activated other ideas or concepts with strong connection to that ideas are also activated, therefore, they are analyzed automatically in a series of stages along many parallel paths. This analysis results in activation of information in LTM (Dugosh, Paulus, Roland, & Yang, 2000).

The initial stage for knowledge retrieval is that the physics teacher should stimulate students for activation of a particular knowledge to solve the physic problems by identifying a problem as a question to guide students for a retrieval plan of knowledge from LTM to answer the question. The retrieval plan includes an initial decision such as what is the physics law that should be employed to solve the problem and what combinations of probe cues should be employed. Next, basic to the retrieval plan, the probe cues of information have to be assembled in the WM to be used in the retrieval of knowledge from LTM. Generally, these cues will include information related to the physics problem.

The next three phases of the retrieval process concerns searching of knowledge, determining relative knowledge and recovery from LTM. These three stages will determine what image is sampled and how much of the information in the sampled image becomes available to the problem. Finally, when the recovery process has brought enough information to solve the problem, this information will be subject to the evaluation and decision-making. The evaluation stage includes deciding whether the sampled information was indeed on the list being tested, whether the sampled image matches the problem, whether a response should be output (knowledge has been activated), and whether the research should be continued. If the research is continued the process loops back to the retrieval plan to start the next step in the retrieval process. Figure 3.2 illustrates the process of knowledge activation in LTM.

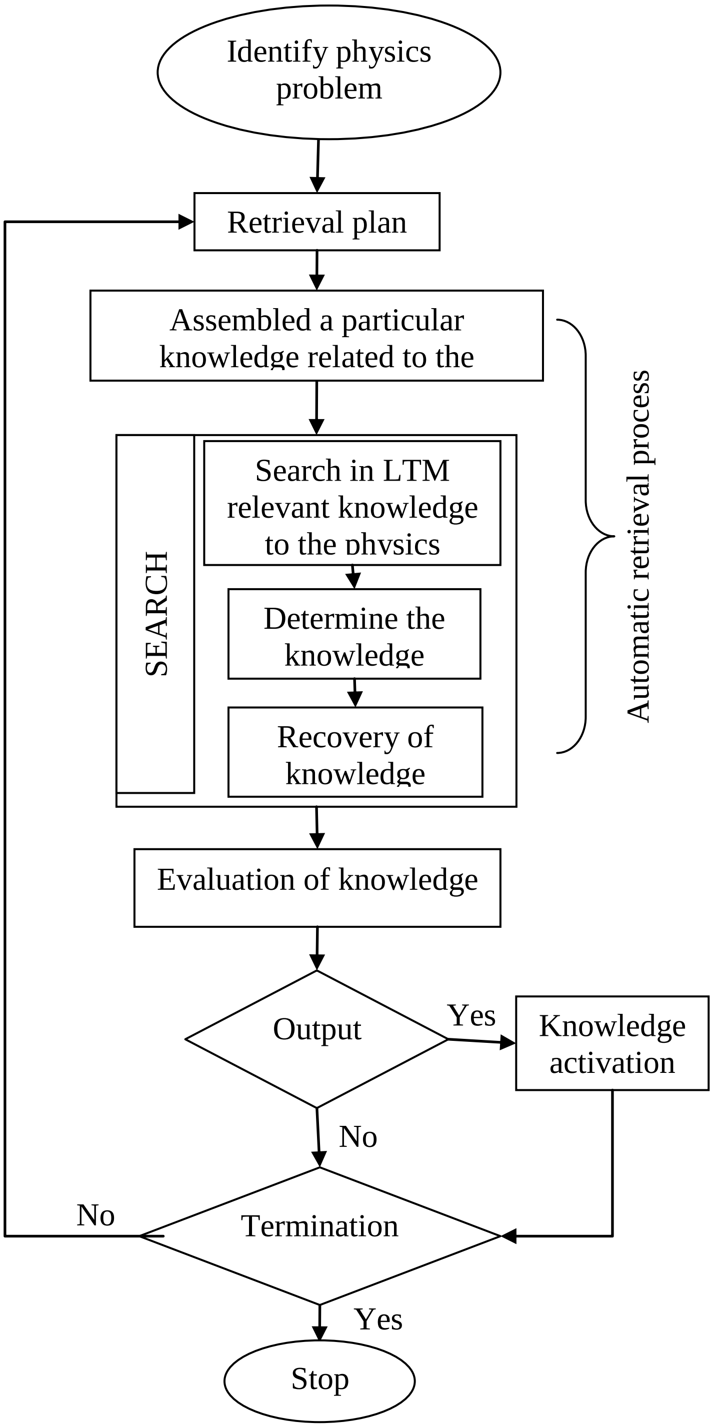

Figure 3.2 Stage1 process of knowledge activation in Long-Term Memory from Raaijmakers and Shiffrin (1981)

According to the SIAM, theory when the knowledge has been activated in LTM the second stage of brainstorming technique is idea generation. Knowledge activation in LTM can be used to construct new ideas by associating new knowledge with the old, build new links, rearrange or reverse knowledge, connections between various concepts, forming new associations, or applying knowledge to a new domain in order for the learner to attain to equilibrium of thought.

One idea can be used to produce different ideas and these ideas should be semantically more closely related than ideas developed from different ideas. Further ideas can be added to the search cue to activate new ideas in LTM. Because semantically related ideas are assumed to have strong mutual ties, successively activated images will often be semantically related. This results in a ‘‘train of thought’’ a rapid accumulation of semantically related ideas. When a train of thought no longer leads to new ideas, a new search cue must be assembled, a process which takes some time. The new cue is then used to probe memory and results in the activation of new images and the generation of additional ideas.

This process continues until the time specified has elapsed (Brown & Paulus, 2002; Nijstad, et al., 2003). The evaluation stage includes deciding whether the ideas generated were indeed on the list being tested, whether the ideas generated matched the problem, whether a response should be output (implement ideas), and whether the research should be continued. If the research is continued the process loops back to the search of knowledge in LTM to start the next step in the knowledge activation. The researcher of the present study has interpreted the above ideas of the stage two of idea generation for the brainstorming technique as shown in Figure 3.3.

After the ideas have been evaluated, the group members can begin to implement the ideas to solve physics problem.

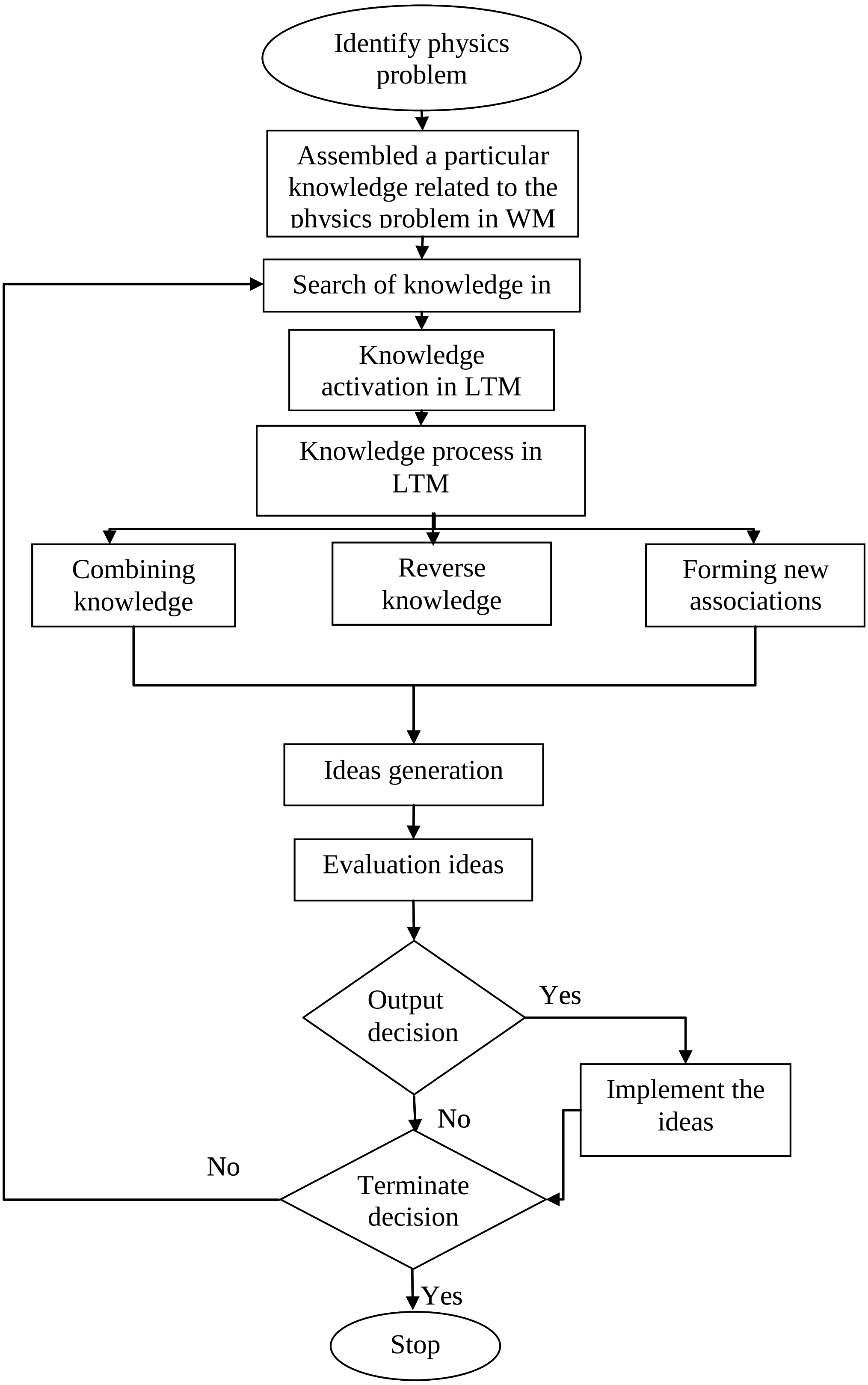

Figure 3.3 The researcher's interpretation the stage2 (Ideas generation) of the brainstorming technique

3.2.1.2 Piaget's Cognitive Development Theory (1929)

Piaget's (1929) saw learning as the process of creation and innovation. It is not just attempts that may lead to a successful response as seen by Thorndike, or just the gradual accumulation of responses till the full achievement as seen by Skinner. Piaget emphasized that the need for education is to develop critical minds instead of false education (pseudo-learning) which makes learners accept ideas without being scanned.

Piaget believed that the process of thinking and learning requires four processes:

Schema: Mental structures which organize past experiences and provide a way of understanding future experiences. Schema combination and construction; offer a clarified view of Piaget's concepts of assimilation and accommodation.

Assimilation: Incorporate new information into existing schemas. In other words, the process of modified experience and new information to suit what an individual knows in advance, and occurs when the individual is facing a new situation and tries to modify the experience with the appropriate the cognitive structure, it is a process of changing experiences to become familiar.

Accommodation**:** A mental process that restructures existing schemas so that the new information is better understood.

Equilibrium**:** The process of seeking mental balance.

Piaget believed that the learner always experienced equilibrium and disequilibrium when the existing knowledge is incompatible with the new experience of the individual. The more times the equilibrium of the student is lost and then restored, the better the learner's ability to cope with new situations. Equilibrium influences structures because of the internal and external processes through assimilation and accommodation. When in balance with each other, assimilation and accommodation generates mental schemas of the operative intelligence. When one function dominates over the other, they generate representations, which is said to belong to figurative intelligence.

Mutual stimulation within brainstorming processes increases the likelihood of cognitive conflict. Cognitive conflict is the mental state in which learners become conscious of gaps in their understanding, which increases their receptivity to cognitive restructuring and learning.

The brainstorming process forces students to develop existing cognitive structures and create new structures. Hence, a student would actively seek re-equilibrium when he/she faces a new physics problem. The learner internalizes hypothetical-deductive question asking and generates answers which involve the acquisition of linguistic skills associated with hypothesis testing and leads ultimately to the development of hypothesis testing schemes and patterns of discussion with his/ her group member if his answers are correct or not. He/she must rely on others for this so when left on his/her own he/she simply generates ideas and for the most part, uses them for better or for worse. At this point, a successful assimilation has occurred. When assimilation is accomplished by the learner, he/she would refine and be ready to solve the physics problem. As a result, students would attain equilibrium again.

In contrast, if new knowledge cannot be linked to the cognitive structures that are already available in the learner's mind, students who go through the active phase of the brainstorming procedural steps would discuss and analyze the physics problem with his\her group to generate and hypothesize ideas by combining new knowledge with the old, forming new associations, rearranging or reversing knowledge for solving the physics problems. After that, students will evaluate each other's ideas together and select one right idea to apply in solving the physics problem. At this point, successful accommodation has occurred. As a result, students would achieve mental equilibrium. Thus, a student would increase individual cognitive development.

In summary, a series of assimilation and accommodation are continuous during the brainstorming session until the learner implements the right idea to solve physics problems. At this point, learners reach mental equilibrium and develop his\her cognitive structures. The researcher has interpreted of Piaget's theory for the present study as illustrated in Figure 3.4.

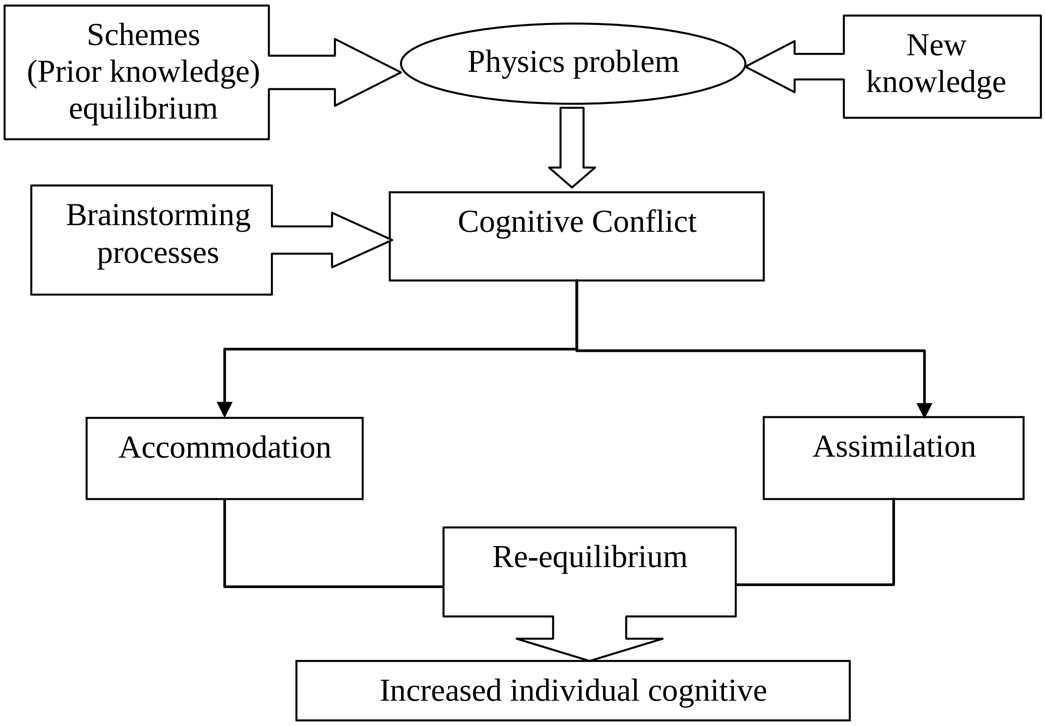

Figure 3.4 Theoretical framework of the study by interpreting Piaget theory (1929)

3.2.1.3 Vygotsky's Socio-Cultural Theory (1978)

Vygotsky had developed a socio-cultural approach to cognitive development. Individual development cannot be understood without reference to the social and cultural context within which it is embedded. Higher mental processes in the individual have their origin in social processes. The individual cannot learn without communication from others.

Vygotsky (1978) believed that learning always precedes the development in the ZPD. Zone of Proximal Development (ZPD) is "the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" p. 86.

Scaffolding is the support given during the learning process which is tailored to the needs of the student with the intention of helping the student achieve his/her learning goals via focused questions and positive interactions. Individualized supports, such as small-group learning, are provided based on the learner's ZPD. The idea is to build on prior knowledge with the teacher supporting the learner's development to get to the next level and reduces uncertainty or difficulties so learning is maximized.

In the context of this study, the students need assistance (scaffolding) to solve the physics problems during the brainstorming procedure. Therefore, the teacher could facilitate the learning process and scaffold learners by: -

i. Working collaboratively within a group;
ii. Identifying a good problem to stimulate the mind of students;
iii. Encourage members of the group to discuss and dialogue;
iv. Provide each learner paper to write down ideas for solving the problem;
v. Instruct students to analyze the problem by dividing it to the sub-problem;
vi. Instruct students to synthesize and organize the information, and
vii. Instruct students to discuss and evaluate the result

Successful scaffolding results in increased cognitive development for learners and develops creativity, critical thinking and problem-solving skills. The researcher has interpreted of Vygotsky's theory for the present study as illustrated in Figure 3.5.

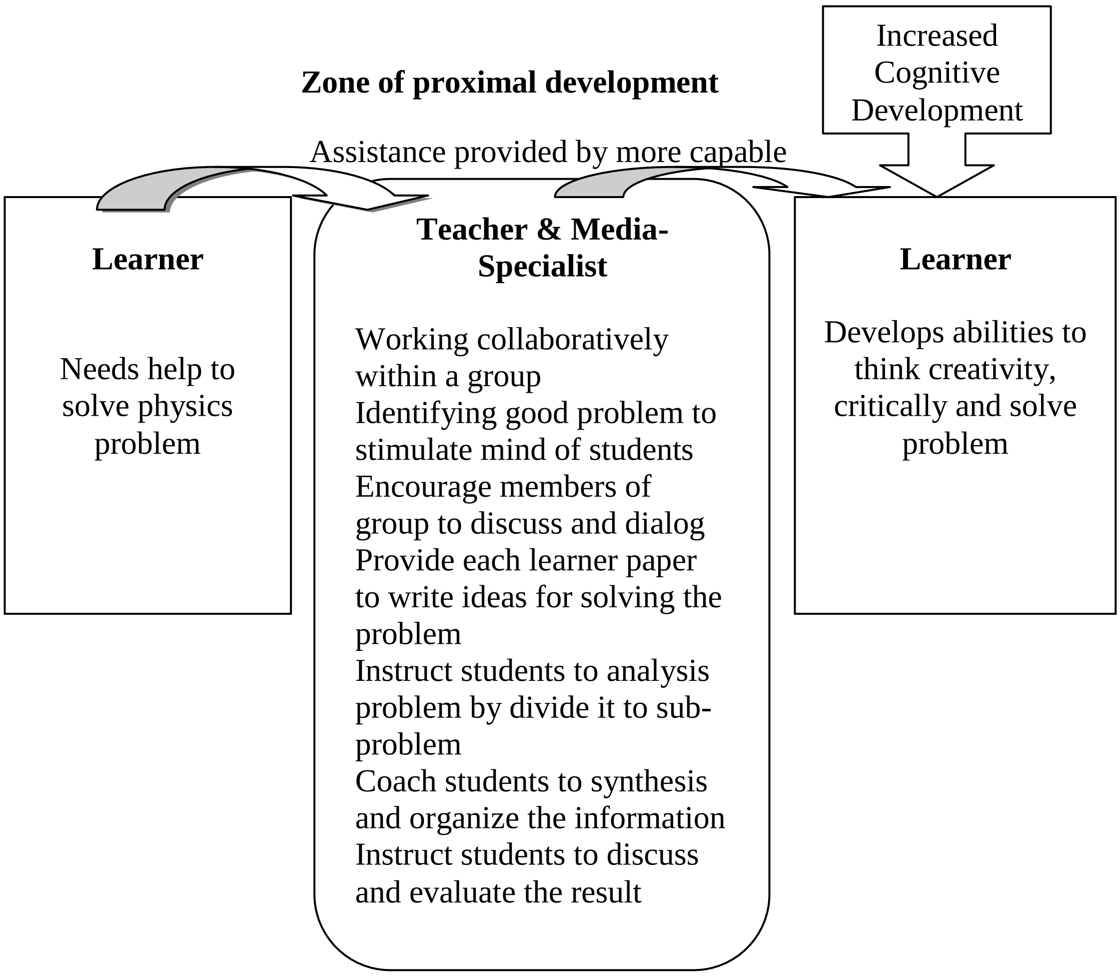

Figure 3.5 Theoretical framework of the study by interpreting Vygotsky's theory (1978)

3.2.2 Interpretation of Search for Ideas in Associative Memory, Piaget's Theory and Vygotsky's Theory for the Present Study

In the present study, the researcher has synthesized and interpreted the three cognitive theories Search of Ideas in Associative Memory (SIAM) theory (2003), Piaget's cognitive development theory (1929) and Vygotsky's social-cultural theory (1978). The SIAM theory has shown how a learner retrieves knowledge from LTM and how a learner generates ideas; whereas Piaget's theory has shown how a learner reaches, mental equilibrium and develops his\her cognitive structures. Lastly, Vygotsky's theory shows how teachers and peers could assist a learner to develop abilities to think creativity, critically and solve the problems. Figure 3.6 illustrates the cognitive processes interpreted by the researcher of the present study for a learner during the brainstorming technique by interpreting the (SIAM) theory (2003), Piaget's cognitive development theory (1929) and Vygotsky's social-cultural theory (1978).

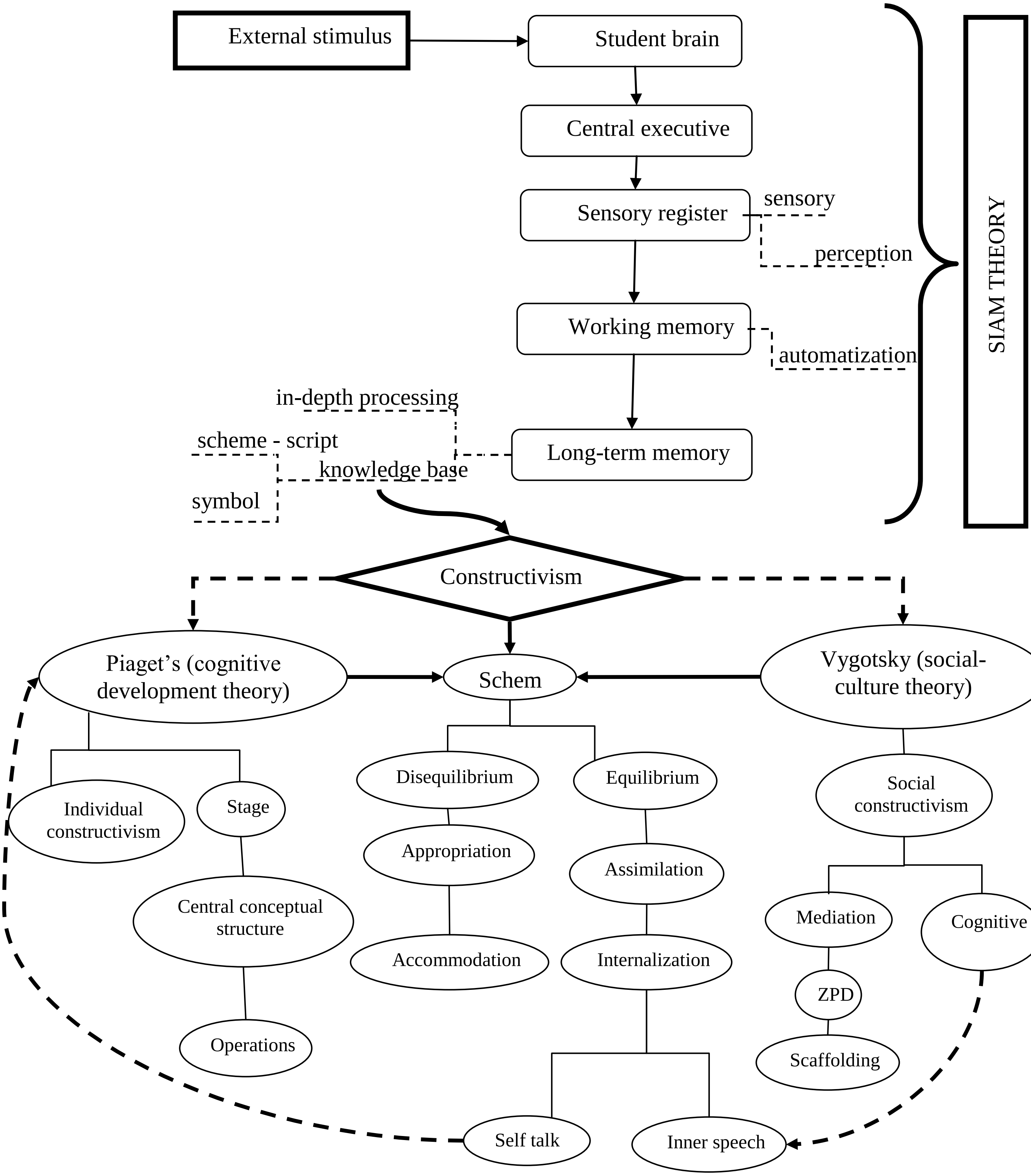

Figure 3.6 Synthesis of SIAM, Piaget and Vygotsky for learning during brainstorming technique

3.3 Preparing Procedural Steps of the Brainstorming Technique for Use in this Study

The literature presented in Chapter 2 linking brainstorming with problem-solving skills, creative thinking and critical thinking, inspired the researcher to use the brainstorming technique to try and enhance creative and critical thinking among student's intermediate second grade in physics. This teaching technique is not only to help students gain knowledge, but also thinking skills and learning skills as part of their brainstorming experiences. The next two sections will describe in detail how the thinking models and problem solving models have been employed in this study to prepare procedural steps for the brainstorming technique.

3.3.1 Thinking Models

According to the literature, there are many theories and models have been proposed for the thinking process. However, in the context of this study, the thinking process model would help learners to solve physics problems and make decisions during learning via the brainstorming technique which is consistent with the Swartz and Parks Thinking Skills Model (1994).

Swartz and Parks (1994) classified thinking skills and thinking processes into three basic thinking domains: thinking for clarifying and understanding ideas; creative thinking; and critical thinking. These thinking skills and processes now are summarized in turn.

1. Thinking for clarifying and understanding ideas

The main objective of this type of thinking is for deep understanding and accurate recall. Learners should seek clarity and use relevant information; these require two main skills:

a. Analyzing Ideas

i. Comparing and contrasting;
ii. Classification and definition;
iii. See relations of parts and whole relationships and
iv. Sequencing

b. Analyzing Arguments

i. Finding reasons and conclusions; and
ii. Finding assumptions

2. Creative thinking

The main objective of the creative thinking is to generate ideas. Learners should seek unusual and original ideas; these require two main skills:

a. Generating Possibilities

i. Producing many ideas (Fluency);
ii. Producing a broad range of ideas (Flexibility);
iii. Producing uncommon ideas (Originality); and
iv. Developing ideas (Elaboration)

b. Creating metaphors

Analogy and metaphor

3. Critical thinking

The main objective of critical thinking is critical judgment and assessing the reasonableness of ideas. Learners should base judgments on good reasons; and should be open-minded, these require three main skills:

a. Assessing basic information

i. Accuracy of observation, and
ii. Reliability of sources

b. Evaluate inference- Use of evidence

i. Causal explanation;
ii. Prediction;
iii. Generalization, and
iv. Reasoning by analogy

c. Evaluate inference-Deduction

Conditional reasoning

Thinking skills from each of the three domains blend together for thoughtful decision making and problem solving.

1. Decision making

The main objective here is to make well founded decisions, and the strategy is to consider options, predict consequences, and choose the best option. The main skills for decision making are generating ideas, clarifying ideas, and assessing the reasonableness of ideas.

2. Problem solving

The main objective is to get the best solution, and the basic strategy involves considering possible solutions, predicting consequences, and choosing the best solution. The skills incorporated here are generating ideas, clarifying ideas, and assessing the reasonableness of ideas.

The thinking process and thinking skills in Swartz and Parks (1994) model are consistent with the process and skills in brainstorming technique which most learners use in order to solve the problem. Therefore, this model employed was in this study to prepare the brainstorming technique in order to enhance creative and critical thinking skills.

The next section will elaborate on problem-solving models and how these thinking skills are associated in the learning context to solve problems, especially in physics education.

3.3.2 Problem-Solving Models

Many researchers in science education have proposed problem-solving models, which could be adapted for developing thinking skills by taking the interactive character of the problem tasks into account (Cartrette & Bodner, 2009; Lawson, McElrath, Burton, & James, 1991; Pizzini & Shepardson, 1992; Taasoobshirazi & Glynn, 2009). However, in this study, the researcher developed a model of problem solving based on the problem-solving process in the brainstorming technique because the researcher sought to establish links between science process skills, creative and critical thinking with problem solving. This is because each of these variables is related, either explicitly or implicitly.

Effective problem solving in physics learning requires a controlled mixture of critical and creative thinking (Mayer, 1992). Critical thinking includes skills such as comparing, contrasting, evaluating and selecting. "It provides a logical framework for problem-solving and helps to select the best alternative from those available by narrowing down the range of possibilities" (a convergent process) p. 22. Creative thinking is a divergent process, using the imagination to create a large range of ideas for solutions." It requires looking beyond the obvious, creating ideas, which may, at first, seem unrealistic or have no logical connection with the problem" p.23 (Stevens, 1988). Moreover, science process skills such as observing, predicting, classifying, interpreting, communicating and experimenting are the foundations of problem solving in physics and the scientific method.

In the context of this study, the researcher wanted to establish links between creative thinking, critical thinking and problem solving in order to enhance higher-order thinking skills among physics students. Torrance (1966) and Gardner (1993) provide a bridge between problem-solving, critical thinking and creativity (see Chapter 2, pag46). In addition Morehouse, (2011) in his model asserted that creative thinking, critical thinking, and problem solving are closely related. These three higher order cognitive skills can be conceived as the three vertices of a triangle as shown in Figure 3.7. It can be said that the situation will dictate which construct predominates and affects the others. For instance, when the learner encounters a problem, it is possible that creative thinking generates many solutions. A unique way could be discovered, which could solve the problem, by doing a critical analysis. Clearly, critical thinking and creativity skills play a central role in solving problems.

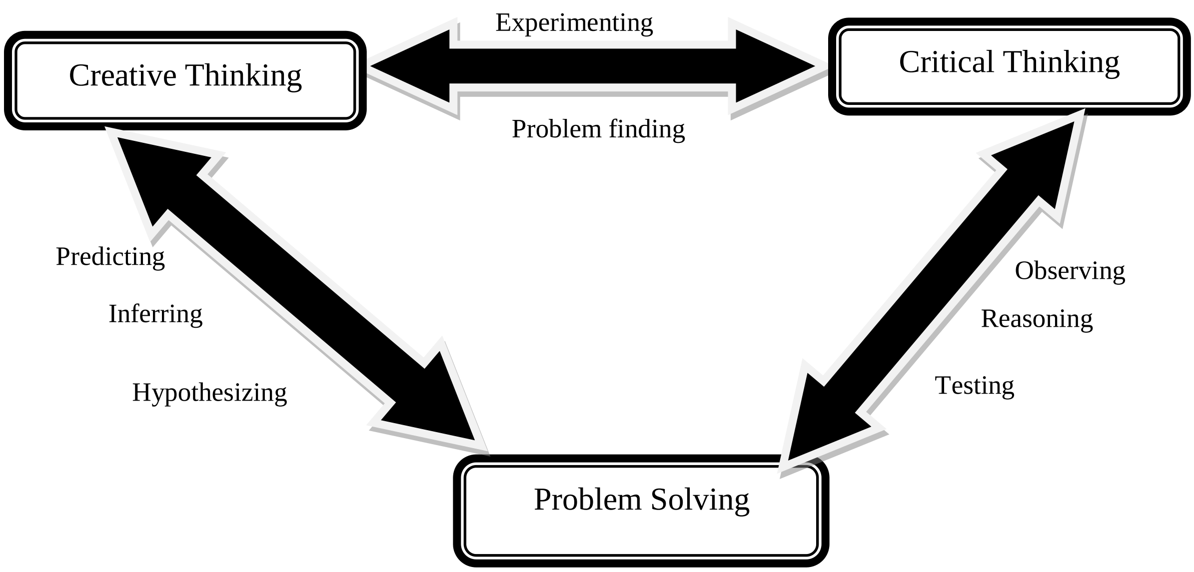

Figure 3.7 Merger of three types of cognitive skills to solve the problem

Since the brainstorming technique is described as the problem-solving procedure (Clark, 1958; Osborn, 1953). The problem-solving developed in this study is referred to as the brainstorming technique in order to enhance creative thinking, critical thinking and problem-solving skills for secondary Iraqi (second intermediate physics) students. Thus, in this study, the students worked through the problem-solving process in the brainstorming technique model. Table 3.2 illustrates the links between the four skills discussed.

Table 3.2: Link between the problem-solving process, science process skills, creative thinking, and critical thinking investigated in this study

Problem-Solving Steps (in this study)	Science Process Skills	Creative Thinking	Critical Thinking
1- Problem identifies.	Observation Communicating		Analyzing Explaining
2- Ideas generation	Inferring Predicting Hypothesizing Measuring and using the number Using space-time relation	Generate ideas Synthesizing Inventing Visualizing Inference	
3- Ideas evaluation	Classifying Controlling variables Communicating		Comparing Evaluate Grouping
4- Ideas selection	Deducting		Conclusion
5- Ideas implements	Experimenting Communicating	all creative thinking skills	all critical thinking skills

The procedure of problem solving used in this study is based on the three cognitive theories (Search of Ideas in Associative Memory (SIAM) theory (2003), Piaget’s cognitive development theory (1929) and Vygotsky’s social-culture theory (1978) and the thinking model represented in this chapter, as well as the literature on creative thinking, critical thinking and problem solving (Chapter 2). Problem solving procedures involve scientific methods such as to identify and organize any existing knowledge about the problem, analysis of the problem to clarify the different facets of the problem, construction of hypotheses to explore the possible solutions, evaluate the optimal solution for the problem, and all groups will communicate to share their problems and their solutions with the class. Thus, these procedures provide opportunities for learners to develop and enhance science process skills, problem solving skills, creative thinking skills, and critical thinking. This will in turn, will enhance their performance in terms of physics understanding and content knowledge. The researcher of the present study has illustrated in Figure 3.8 the possible learning outcomes from using the brainstorming technique.

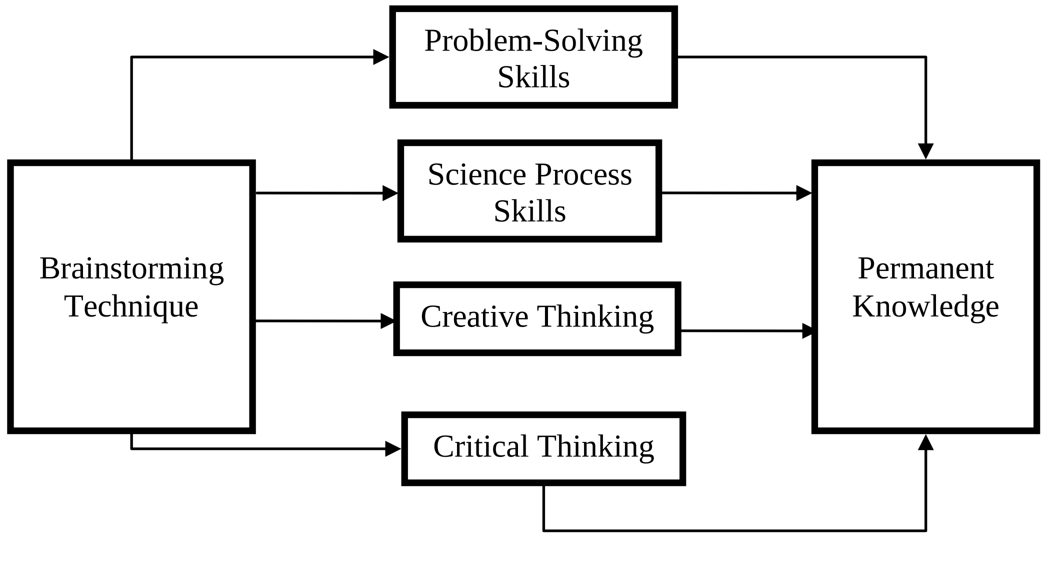

Figure 3.8 Learning outcomes from the brainstorming technique in this study

Therefore, the brainstorming procedures for learning and teaching consist of a number of steps that must be carefully prepared to 'force' students to be more careful in thoroughly analyzing ideas and allow the 'observation' by students to visualize the thinking process (Patrick, 1993). When brainstorming is done correctly, it taps into the brain capacity for creative and critical thinking (Conklin, 2007).

The brainstorming model for this study was constructed based on cognitive theories, thinking models and problem solving models describe above. The brainstorming procedure developed in this study consists of three phases as following:

1. Pre-Brainstorming Phase (initial preparation);
2. Active Brainstorming Phase; and
3. Post Active Brainstorming Phase

1. Pre-Brainstorming Phase (initial preparation)

In the pre brainstorming phase, the researcher as a facilitator was required to do the following steps before the physics lesson:

i. Divide the class into the brainstorming groups: Fewer group members are generally more productive and easier to control than larger groups. An appropriate group size is each a group of (3-5) members (Starko, 2009);

ii. Selection of a group leader and secretary: A leader is in control of the session, initially defining the problem to be solved with any criteria that must be met, and then keeping the session on course. The leader should try to keep the brainstorming on subject, and should try to steer it towards the development of some practical solutions;

iii. Advise participants to keep the rules and principles in mind during idea generation for the success of the brainstorming process. These rules are (combine and improve ideas, no criticism, focus on quantity, and freewheeling is welcomed);

iv. Select the brainstorming topic: The problem must be clear, not too big, and captured in a definite question. If the problem is too big, the leader should divide it into smaller components, each with its own question. Groups can be more creative when they work on problems that have multiple parts. A problem cannot be solved using only one strategy and different sources of knowledge are needed;

v. Identify the problem: The problem must require the generation of ideas rather than judgment. Define the problem clearly and lay out any criteria to be met. To increase the originality of ideas to be produced in brainstorming, the brainstorming problem should be defined narrowly (Rietzschel, Nijstad, & Stroebe, 2010). The problem should be simple rather than complex and the teacher should make the problem clear and specific by suggesting questions such as: What? , Why? , When, Where, Who, How? Good problems can force students to search about a lot more concepts in their minds and retrieve them. All problems should be based on topics in the physics curriculum in Iraq; and

vi. Keep to the time limit: allocating a specific amount of time can focus attention and be seen as a challenge to generate more ideas. The mind can only stay stimulated for a certain period of time. That means, if the sessions are stretched out to more than thirty minutes, it may not be as effective.

2. Active Brainstorming Phase

In the active brainstorming phase, the teacher as a facilitator can inform students, that there are no 'right' or 'wrong' answers for questions and no danger of teacher correction. To help students obtain a sense of competence and feel more confident in making intelligent guesses, as well as to help the researcher stimulate students, the following steps can be carried out:

i. Begin the discussion by making or by having the leader give a positive statement relative to the problem and ask participants such as how the problem could be solved?. This should serve to stimulate the “train of thought” for the participants;

ii. Analyze the brainstorming problem: The leader and the group can divide the problem to sub-problems to help them to solve it. The teacher will provide the leader with questions to ask his team: what exactly are you doing? why? what results do you expect? why? what does the answer tell you? how would that prove this law? what equation are you using? why? what would a different answer mean?, and

iii. Generating the Ideas: After a discussion and analysis of the physics problem between all group members, the leader can ask his group members to write down all the solutions that come to mind (even trivial ones) on their own paper. In this stage, learners begin examining their existing resources and identifying gaps in their knowledge. The learners seek to organize existing knowledge in their own minds and create a series of connecting ideas. Relevant existing knowledge (content schema) can be called up from long-term memory and can provide a context which supports comprehension and production to the problem. The free association nature allows learners to become involved in the generation of ideas to use for solving the physics problems.

3. Post Active Brainstorming Phase

In the post brainstorming phase, the teacher as a facilitator can provide each leader a set of group instructions, which include the following steps:

i. Stop: leader stops the ides generation step after the time specified has elapsed;

ii. Collecting the ideas: The secretary collects papers from each student to give it to the leader to start discussion and to evaluate each idea;

iii. Evaluate the ides: The leader and his group members would evaluate all the solutions that have been written down by all group members to determine the best idea to solve the problem. All the generated ideas would be kept visible. As a flip chart page becomes full, it can be removed from the pad and taped to a wall so that it is visible to all. This "combined recollection" is helpful for creating new ideals;

iv. Selection of an idea: At this step, the learners will be better oriented to the problem and better motivated to fill the gaps in their knowledge. After ideas have been evaluated, it is time to select a solution by using a show of hands, for example, allows each student to vote for as many ideas on the original list. Put the ideas into a matrix. Put each idea into its own row (first column). Then label the columns using whatever criteria are most applicable to the students' problem, as shown in the figure of the matrix below.

Generated Ideas	Excluded	Not applicable	Interesting	Useful (help other processes)	Total

The leader would write the vote tallies next to the idea. Once the voting is completed, the leader would delete all ideas with no votes. Next, working one column at a time, ask the group to evaluate each idea in how it compares to the others. Repeat this for all columns, and

(v) Implementation: the leader and his group member implement the idea, which has been selected to solve the physics problems.

After the session ends, the teacher can draw the students' attention to the large number of ideas generated and show them that the many of ideas enabled them to develop and choose the best to solve the problem, and that this would not have occurred if everyone thinks alone. The above discussion is illustrated in Figure 3.9.

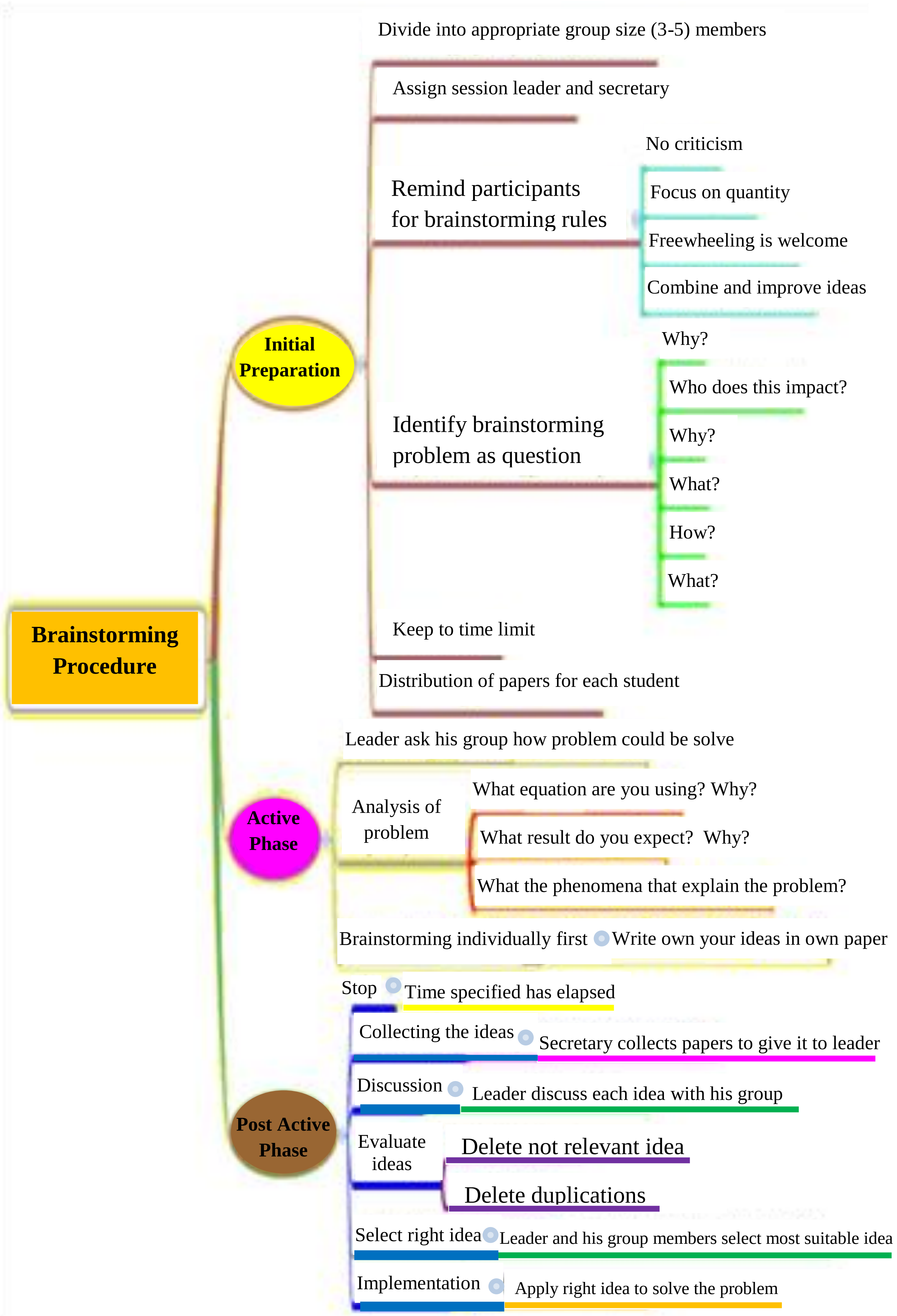

Figure 3.9 Procedural steps for brainstorming technique in this study

3.4 Scope of the Study

The main focus of this study is to try and enhance creative and critical thinking among secondary Iraqi (second grade intermediate) students in physics via using the brainstorming technique. The notion of teaching and learning via the brainstorming technique has existed for many years. However, a number of factors have restricted its widespread adoption such as it needs time, and it lacks spontaneity and can sometimes feel rigid and restrictive where the group loses the synergy that comes from an open session (Holubová, 2010). Therefore, it is hoped that the research reported in this study can improve the implementation of the brainstorming technique for second grade intermediate physics Iraqi students and enhance their creative and critical thinking skills.

In the context of this study, the researcher linked between problem-solving, creative thinking and critical thinking based on the literature presented in Chapter two to prepare a model of brainstorming technique to use in addressing the objectives of the present research. Two tests have also been developed. The first test is the creative thinking test which consists of items for the sub-dimensions of fluency, flexibility, and originality skills. This test is based on the Torrance Test of Creative Thinking (TTCT) (Torrance, 1966). The second test is the critical thinking test which consists of the capability of students to make inferences, to check assumptions, make deductions, interpret and evaluate arguments. This test is based on the Watson Glaser Critical Thinking Appraisal test (WGCTA) (Watson & Glaser, 1980). All items in the creative and critical thinking tests were adapted to investigate skills related to physics. The data collected were through (i) the pre-post test of the creative and critical thinking tests, (ii) the survey of students' perceptions of the brainstorming technique utilized for learning physics, (iii) observations of students during the implementation of the brainstorming technique and (iv) interviews with students after finishing the intervention.

3.5 Chapter Summary

In this chapter, the researcher has developed a theoretical framework of the brainstorming technique by adopting three cognitive theories. These theories are: Search for Idea in Associative Memory theory (Nijstad, 2000; Nijstad, et al., 2002, 2003), Piaget's Cognitive Development theory (1929), and Vygotsky's Socio-cultural theory (1978). Then, the intertwined relationship between problem solving, creative thinking and critical thinking was also discussed.

The model of brainstorming technique prepared in this study involves three phases (pre-brainstorming phase; active brainstorming phase; and post active brainstorming phase). These procedures provide opportunities for learners to develop their science process skills, problem solving skill, creative thinking skills, and critical thinking.

After a thorough discussion of the framework and scope of this study, the next chapter will provide a comprehensive discussion of the methodology employed.