# DEVELOPMENT OF A HIGHER ORDER THINKING TEACHING MODEL FOR BASIC EDUCATION STUDENTS IN SCIENCE

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FACULTY OF EDUCATION
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**THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY**

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## ABSTRACT

The purpose of the study was to develop a higher order thinking (HOT) teaching model for science among basic education students. The development of the model was aimed at overcoming basic students' needs in terms of developing their higher cognitive skills in science education. The study adopted the Design and Development Research Approach. Based on the approach, the study was conducted in three phases namely, needs analysis, design and development and evaluation phase.

In order to identify the needs to develop the model, two instruments were used in phase1. First, a Higher Order Thinking Level Test (HOTLT) was developed based on the Bloom's taxonomy of the cognitive domain and consisted of 25 multiple choice questions. The test was distributed to a randomly chosen sample comprising 418 7th grade students in the Iraqi-Kurdistan region. Second, a Strategy Use Survey Questionnaire (SUSQ) was developed to investigate the strategies used by 7th grade science teachers in science. The questionnaire consisted of 31 questions with a 5-point Likert scale and distributed among 212 7th grade science teachers in the Iraqi-Kurdistan region. Data for this phase were analyzed using descriptive statistics via the SPSS program. Phase 2 adopted the Fuzzy Delphi Method (FDM) to develop the model via a panel of 20 experts. The model was developed based on the experts' responses to a seven-Likert linguistic scale survey questionnaire. The threshold value (d) was calculated to determine the experts' consensus for all questionnaire items, while the alpha-cut value > 0.5 was used to select the elements. The ranking process was used to identify the priority of elements for implementation in science class. Phase 3 adopted the partial least square (PLS-SEM) approach to evaluate the model. The evaluation was carried out via 318 science teachers. A two-stage process was employed whereby the measurement model was evaluated followed by an evaluation of the structural model.

The overall findings for phase 1 revealed that majority of the 7th grade students were at a lower level of thinking skills (LOT). The findings also indicated that a variety of HOT teaching strategies were lacking among science teachers and that low processing strategies, such as focusing on students' memorizing of basic concepts were dominant among them. Thus, the findings necessitated the study to develop the model. Findings from phase 2 using FDM resulted in the development of the model that consisted of 5 main stages and 24 sub-stages as the activities that engage basic education students in using their higher cognitive skills in science. Finally, through running factor analysis and PLS evaluation, the findings from phase 3 showed that the HOT teaching model consisted of overall 5 stages and 17 sub-stages that have a positive significance influence on students' HOT ($R^2$ > 0.75); this indicated the model is suitable to be used as a teaching model for enhancing basic education students' HOT in science.

**PEMBANGUNAN MODEL PENGAJARAN PEMIKIRAN ARAS TINGGI UNTUK MURID PENDIDIKAN ASAS DALAM SAINS**

## ABSTRAK

Tujuan kajian ini adalah untuk membangunkan model pengajaran pemikiran aras tinggi (HOT) untuk sains bagi murid pendidikan asas. Pembangunan model tersebut disasarkan untuk memenuhi keperluan asas murid dari segi membangunkan pemikiran aras tinggi mereka dalam pengajaran sains. Kajian ini menggunakan kaedah kajian reka bentuk dan pembangunan. Berdasarkan kaedah tersebut, kajian ini dijalankan melalui tiga fasa, iaitu analisis keperluan, reka bentuk serta pembangunan dan fasa penilaian.

Untuk mengenal pasti keperluan bagi membangunkan model, dua instrumen digunakan dalam Fasa 1. Pertama, ujian pemikiran aras tinggi (HOTLT) dibangunkan berdasarkan domain kognitif taksonomi Bloom yang merangkumi 25 soalan beraneka pilihan. Ujian tersebut diedarkan kepada sampel terdiri daripada 418 murid gred 7 yang dipilih secara rawak di wilayah Iraqi-Kurdistan. Kedua, soal selidik (SUSQ) telah dibangunkan untuk menyelidik strategi yang digunakan oleh guru gred 7 dalam sains. Soal selidik tersebut mengandungi 31 soalan dalam skala Likert 5-tahap yang ditadbirkan ke atas 212 guru sains gred 7 di wilayah Iraqi-Kurdistan. Data untuk fasa ini dianalisis menggunakan statistik deskriptif dengan program SPSS. Fasa 2 menggunakan Kaedah Fuzzy Delphi (KFD) untuk mambangunkan model menerusi panel 20 orang pakar. Model tersebut dibangunkan berdasarkan respon pakar kapada soal selidik skala linguistik Likert 7-tahap. Nilai threshold (d) telah dikira untuk menentukan konsensus pakar bagi semua item soal selidik sementara Nilai alpha > 0.5 digunakan untuk memilih item-item. Proses ranking digunakan untuk mengenal pasti prioriti elemen untuk diimplementasi dalam kelas sains. Fasa 3 menggunakan kaedah partial least square (PLS-SEM) untuk menilai model. Penilaian tersebut dilakukan menerusi 318 guru sains. Proses dua tahap

digunakan, di mana model pengukuran telah dinilai diikuti oleh penilaian model struktural.

Dapatan keseluruhan bagi Fasa 1 menunjukkan bahawa majoriti murid gred 7 adalah pada tahap pemikiran rendah (LOT). Dapatan kajian juga menunjukkan bahawa pelbagai strategi pengajaran pemikiran tinggi (HOT) kurang digunakan dalam kalangan guru-guru dan strategi pemprosesan rendah, seperti memfokus kepada mengajar murid mengingati konsep asas mendominasi antara mereka. Oleh itu, dapatan kajian menunjukkan keperluan untuk kajian pembangunan model. Dapatan Fasa 2 menggunakan FDM menghasilkan pembangunan model yang merangkumi 5 peringkat utama dan 24 sub-peringkat sebagai aktiviti-aktiviti yang melibatkan penggunaan pemikiran aras tinggi oleh murid pendidikan asas dalam sains. Akhir sekali, melalui analisis faktor dan penilaian PLS, dapatan Fasa 3 menunjukkan bahawa model pengajaran HOT merangkumi 5 peringkat keseluruhan dan 17 sub- peringkat yang mempunyai pengaruh positif dan signifikan ke atas pemikiran aras tinggi (HOT) murid ($R^2 > 0.75$); ini memberi indikasi bahawa model tersebut sesuai digunakan sebagai model pengajaran untuk melonjakkan pemikiran aras tinggi murid pendidikan asas dalam sains.

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| | |
|---|---|
| HOT | Higher Order Thinking |
| HOTS | Higher Order Thinking Skills |
| HOTLT | Higher Order Thinking Level Test |
| RT | Reflective Thinking |
| RTS | Reflective Thinking |
| SPS | Science Process Skills |
| BSPS | Basic Science Process Skills |
| ISPS | Integrated Science Process Skills |
| MOE | Ministry of Education |
| AAAS | American Association for Advancement of Science |
| SPSS | Statistical Package for the Social Sciences |
| CLM | Cyclic Learning Model |
| EFA | Exploratory Factor Analysis |
| CFA | Confirmatory Factor Analysis |
| KMO | Kaiser-Meyer- Olkin |
| AVE | Average Variance Extracted |
| FDM | Fuzzy Delphi Method |
| DV | Defuzzification Value |
| SEM | Structural Equation Modeling |
| PLS | Partial Least Square |

## LIST OF APPENDICES

# CHAPTER 1: INTRODUCTION

## 1.1 Introduction

Our ever-changing and challenging world requires students, our future citizens, to go beyond the building of their knowledge capacity; they need to develop their higher-order thinking skills, such as critical thinking, decision making, and problem solving. Therefore, promoting students' higher order thinking (HOT) has been the focus of education studies and programs (Jones et al., 2011). Research suggested that higher thinking skills are essential for effective learning and a central goal for science education (Avargil, Herscovitz, & Dori, 2012); in the same context, many programs have been proposed such as National Research Council's Study (NRCS) (2000), National Science Teacher Association NSTA (2001) and American Association for Advancement of Science (AAAS,1999). Each of these programs has its own definition of cognitive skills, but all emphasized improvement of these skills as well as higher order thinking skills (HOTS). Research has identified various type of higher order thinking skills (HOTS), such as critical thinking CT, reflective thinking RT, creative thinking CT, science process skills SPS and problem solving PS. Research in science education asserted that reflective thinking (RT) and science process skills (SPS) are important higher cognitive skills that should be cultivated among students (Chien & Chang, 2012; Constantinou & Kuys, 2013; Kim & Tan, 2012). These higher cognitive skills are activated when students encounter unfamiliar problems, uncertainties, questions, or dilemmas. Successful applications of these skills in the science classroom result in explanations, decisions, performances, and products that are valid within the context of available knowledge and experience and that promote continued growth in these and other intellectual skills. Furthermore, higher order thinking skills require students to transfer scientific knowledge and apply it to new situations (Gillies, Nichols, Burgh, & Haynes, 2014).

In addition, an increasing body of research has focused on the relationship between the use of the new teaching model and students' cognitive skills (Avargil et al., 2012; Constantinou & Kuys, 2013; Ewers, 2001; Karami, Pakmehr, & Aghili, 2012; Legare, Mills, Souza, Plummer, & Yasskin, 2013; Rotgans & Schmidt, 2011; Thitima & Sumalee, 2012). However, most researchers in science education have put more emphasis on the role of science curriculum in developing students' cognitive skills and they ignore the role of selecting appropriate models of teaching in order to teach scientific knowledge to students as well as developing their higher cognitive skills (Aktamış & Yenice, 2010; Burke & Williams, 2008; Monhardt & Monhardt, 2006; Rezba, Sprague, & Fiel, 2003).

Practically, teaching methods in science education in the Iraqi Kurdistan region have been criticized in developing student's higher thinking skills (Vernez, Culbertson, & Constant, 2014); therefore, it is important to provide opportunities to all Kurdish students in basic education to develop their higher order thinking skills by giving them the opportunity to think reflectively on knowledge as well as to enable them to participate in solving their day to day problems in society.

## 1.2 Brief Overview of Iraqi-Kurdistan Region Education

The Kurdistan region, also known as southern Kurdistan, is an autonomous region of north-eastern Iraq. The regional capital is Erbil, and the region is officially governed by the Kurdistan region Government. There are three big cities in Kurdistan namely Erbil, Sulaimanyia, and Dohuk. The region is rich in oil, land and water; in order to develop these available resources, Kurdistan is making a great effort in developing its human resources through education.

Traditionally, the education system in Kurdistan is the same as in Iraq which has been based on values and principles derived from the religious, human and national characteristics of society. The most prominent is the belief that education is a sectional process, sensitive to time and place factors. Within this framework, the state ensures the right to free education for all citizens at all levels, compulsory education at the primary level, and the eradication of illiteracy.

The political changes that took place in Iraq after 2003 and the transition to democracy required a reform of the educational system in the Kurdistan region based on a new educational philosophy. This philosophy was finalized in 2009 (Vernez et al., 2014). The educational policy aimed at reorganizing the whole educational system and curricula in such a way to link education with national development plans. In compliance with the National Education Strategy, the overall objectives of education in Kurdistan are to foster a new generation who:

1) Believe in god almighty and his messengers.
2) Love their country and work to consolidate its national unity.
3) Are able to deal with scientific content and methods.
4) Are ethical and respectful of human rights, the cultural heritage and the environment.
5) Are cultivating originality and innovation.
6) Are interested in personal development and lifelong learning.

### 1.2.1 The State of Educational System in Kurdistan

The Kurdistan government pays considerable attention to education. It was agreed from the outset that 12 years of government schooling should be offered free of charge to all Kurdish citizen. It followed an educational ladder, which includes six years in primary education, three years of preparatory education and three years of secondary education. The education system was called “General education”. This educational system used to be described as a linear system in that it focused more on the students’ products rather than process. The lessons were geared more toward knowledge than understanding and application, which led to the observation that secondary school outcomes lacked the essential skills needed for work or study; therefore a gap existed between the Ministry of Education's products and the expectation of other organization, such as institutes, universities and colleges (Gunter, 1993).

The selection process into arts or science stream starts from the second year in secondary school, which is based entirely on student choice. Subjects included in the science stream are Islamic studies, Arabic, English, Mathematics, Physics, Chemistry and Biology. Physical education and drawing are also offered at the secondary level, but are not considered a condition to achieve a "pass". The arts stream includes Islamic Studies, Arabic, English, Mathematics, Economics, History, Geography and the present Islamic world as a condition to achieve a "pass". On completion of the third year of secondary education, students sit for the general secondary certificate examination.

In both streams, at the third secondary level the minimum pass mark is 50% in all subjects. The total mark awarded in each subject is determined by the average marks obtained from the end of the semester examination. In the end, students are awarded the general certificate that indicates final marks in each subject and overall total marks (i.e., a combined average percentage for all subjects).

### 1.2.2 The Educational Reforms and Their Rationale

Two recent developments have made it urgent for the Kurdistan Ministry of Education to introduce reforms into the Regional educational system. The first of these developments involves the globalization of the world economy. The second development is specific to the Kurdistan region, which is the government's policy to promote the regional economy in order to reduce dependency on foreign labour. In order to make the educational system in Kurdistan more responsive to the future needs of Kurdistan society, the new system has been gradually introduced, since 2009. The new system has been defined as a unified educational system provided by the government for all children of school stage. It is now centered more on learners, using an approach based on thinking skills, autonomous learning and lifelong learning. It is providing the basic requirements of information, knowledge and skills and on developing attitudes and values, which enable both male and female students either to continue with further studies or join training programs according to their aptitudes and abilities. Basic education is concerned with integration of theory, practice, thought, work, education and life. It endeavors to develop all aspects of an individual's personality in an integrated way. It also seeks to implant values and practices necessary to achieve skillfulness in learning and teaching in order to meet the intended educational development.

Beginning in 2009, the ministry of higher education (MOE) began implementing an ambitious set of reforms to improve the quality of education in Kurdistan; these reforms had been suggested by a conference of experts held in Erbil in 2007. The goal of these reforms is "to achieve a democratic educational philosophy that will forge the way ahead towards preparing and educating the next generation to become loyal citizens to the homeland with the capacity to think analytically" (Anthony et al., 2015). The reforms included four major changes:

1. Compulsory education was extended from grade 6 to grade 9.
2. A new curriculum was adopted that emphasized the learning, from the early grades, of two languages, Arabic and English, in addition to Kurdish. The curriculum also emphasized the teaching of mathematics and the sciences. Textbooks to support this new curriculum were adapted from current Western textbooks and translated into Kurdish.
3. The traditional system comprise three distinct levels of education primary, intermediary, and secondary in the new educational system, these levels were replaced by a two-level system consisting of basic education (grades 1–9) and secondary education (grades 10–12).

4. Preparation requirements for teachers in the basic level of education were upgraded to require a bachelor's degree. Instead of two years of preparation in MOE-administered teacher institutes following secondary-school graduation, new teachers were to spend four years in teacher colleges (also colleges of basic education) administered by the Ministry of Higher Education. These teachers would graduate with a bachelor's degree.

To support these major changes, several other changes were implemented or encouraged in teacher instructional methods, retention of students, and student assessment. Teachers were encouraged to revise and reform their classical teaching method that was based on memorization into student-centered teaching techniques emphasizing the development of creative and analytical skills. They were also encouraged to give students homework.

The duration of the new educational system in the Kurdistan region is 12 years, which includes Cycle 1 (Grades 1-3) and Cycle 2 (Grades 4-9). This is followed by cycle 3, which includes Grades 10, 11 and 12 is also called "Post-Basic Education." In grade 12, as the last grade in the system, students sit for the National Exams in different subjects including science. Figure 1.1 shows the structure of the general education system and the current reformed basic education.

The educational year starts in September and ends in May; it consists of two semesters, each semester continuing for four months. The actual school days for basic education are approximately 192 working days per year. The length of each period is 45 minutes. There are six working days (Saturday through Thursday) per week. There are 36 periods per week for basic education schools.

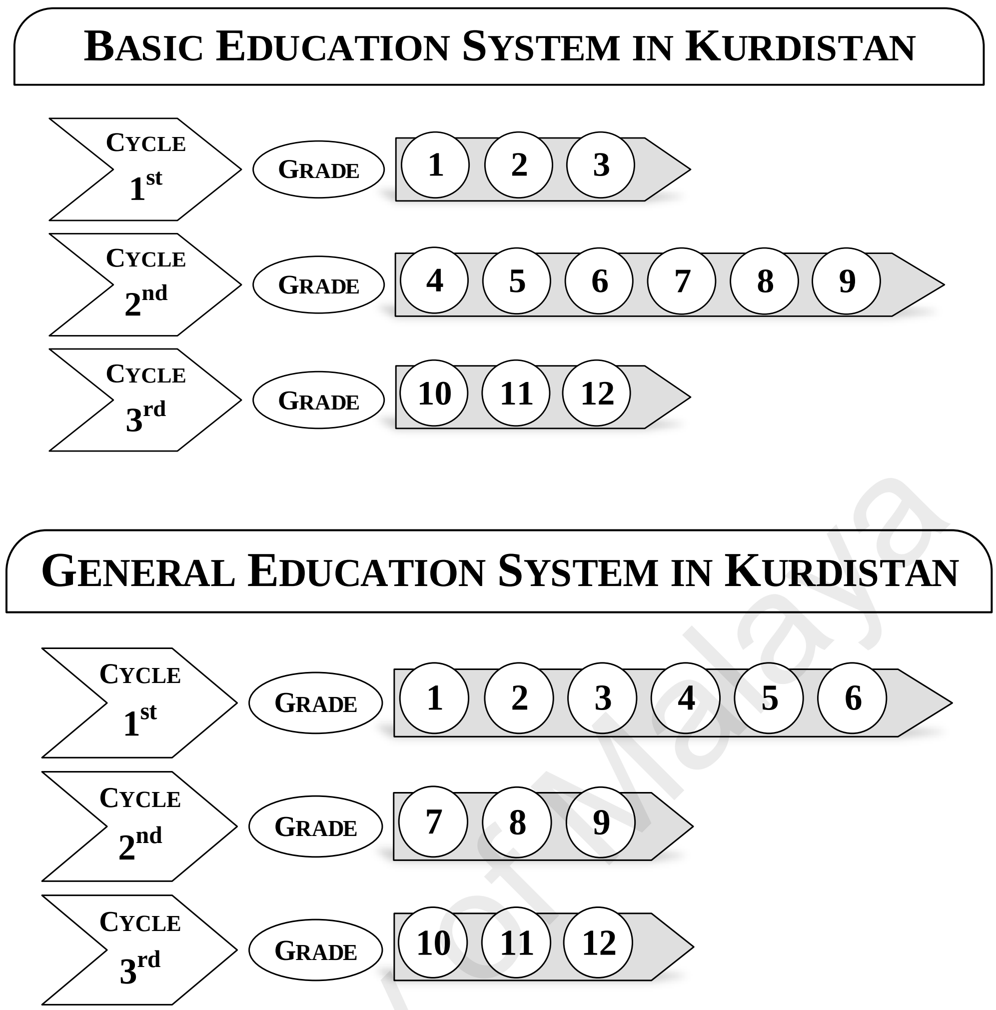



**Figure 1.1:** Structure of Basic Education and General Education System in the Kurdistan Region

### 1.2.3 The State of Science Education in Kurdistan Region

Science learning in Kurdistan is treated as a subject for study rather than a living subject to be applied in daily life. The science consists of three separate text books, physics, chemistry, and biology, and these three subjects are taught separately. Two main reasons make science a difficult subject for most students. First, the teaching of science emphasizes more on teaching student's facts and laws without connecting these concepts with real life. Second, the environment of science learning, in which there was no science lab in most stages in the educational system, even though the science lab is the connection between theory and practice (Vernez et al., 2014).

Throughout the history of curriculum development in the Kurdistan region, major changes have occurred in all curriculum, especially in science curriculum. The Ministry of Education in the Kurdistan region with the support of UNESCO International Bureau of Education in 2009 launched the new science curriculum that combined physics, chemistry and biology in one book named as “Science for all”. The new science curriculum framework consists of three books: the students’ text book, skills book and the teacher guide book. The main education and learning aims envisaged in the new science curriculum framework can be summarized in three domains as follows:

- Cognitive domain, where the main objectives are: to introduce the facts, information and concepts about their natural environment. In order to become successful lifelong learners, students should develop skills in critical and reflective thinking, creative thinking and problem solving, inquiry and information processing, evaluation and decision making.

- Affective domain: enhancing the student’s awareness of the environment, respect of its resources and components and develop their positive investment. In order to become confident and productive individuals, students should develop personal and social competencies, they should be resilient and able to cope with change and they should develop self-respect and respect for others.

- Psychomotor domain: the science curriculum enables students to develop their basic motor skills and enable them to trust science and adopt its methods for the development of their characters, abilities and skills (MOE Kurdistan, 2011; UNESCO, 2011).

### 1.2.4 Science Teaching Method in Kurdistan Region

The world today is much more technologically complex and economically competitive and classroom instruction is increasingly failing to educate students to participate in this new kind of society (Chapman & Aspin, 2013); the main reason is that the conventional classrooms as in the case of the Kurdistan region are about the text book and centred on the text book. Text books in the educational system in the Kurdistan region, are considered the center of the educational process and the point at which students and teachers meet. Teacher as director is not conducive to fostering varied thinking skills and problem solving among students which will enable them to take responsibility for their lifelong learning. According to Vernez et al. (2014) much of the subject matter in the new curriculum is unfamiliar to practicing teachers, who are accustomed to teaching the traditional curriculum, the one they were trained to teach during their years of preparation. Their survey results indicated that less than half of the teachers rated themselves as well prepared or very well prepared to teach the content of the new curriculum. Less than 40 percent of teachers rated themselves and their colleagues as well prepared or very well prepared to use the new curriculum's materials and frameworks, change or add to the curriculum to suit their students' needs, or examine or change the scope or sequence of the curriculum to suit student learning needs. Many teachers also indicated that they received limited support in implementing the new curriculum. Overall, 50 percent of teachers surveyed reported that the teaching materials accompanying the new curriculum provided insufficient guidance and explanation. Moreover, teachers also reported concern over adequately covering the material during the course of an academic year, as well as the quality and availability of textbooks and other curriculum materials (Vernez et al., 2014). Although the teacher colleges in the Kurdistan offer new teachers one general course on the new basic curriculum, this is unlikely to be sufficient. There appears to be no deliberate alignment between the content of the new curriculum and the set of subject matter courses in the teacher colleges. Current teachers surveyed indicated that their four top-ranking priorities were to receive training in (1) curriculum content in the subject that they teach, (2) how to use curriculum materials and frameworks, (3) how to develop daily lesson plans to guide classroom instruction, and (4) how to prepare homework assignments for students. New teachers educated in institutions other than teacher colleges may not receive enough preparation in teaching methods (Vernez et al., 2014).

UNESCO (2011) and Vernez et al. (2014) asserted that a majority of basic education teachers still need training in both subject areas and teaching methodology in order to keep pace with changes in the curriculum. However, the Kurdistan education system currently faces a number of challenges related to improving its quality of education. As students have relatively high rates of failure in annual school assessments, particularly in the upper grades; they repeat grades at high rates (i.e., have high retention levels); and their performance is weak on the IKR's national standardized tests. These are basic indicators of student achievement (Vernez et al., 2014). A variety of changes in the education system can boost student performance. Beside, Vernez et al. (2014) stated three main factors contribute to this issue with quality of education. First, the teaching force lacks the knowledge and training needed to teach the new science curriculum. Second, IKR schools currently provide too little instructional time to cover the new curriculum. Third, there are few opportunities for high-performing students to engage in accelerated learning. Moreover, they asserted that, the teacher colleges do not provide enough training in pedagogy and teaching methods. Over 60 percent of current teachers surveyed indicated that their peers were "not at all" or only "somewhat" prepared in a variety of classroom instructional areas, including applying student-centered approaches, using different strategies to address the varying learning needs of individual students, using various approaches to group students, engaging students in critical thinking, and teaching the new curriculum. There is general consensus across industrialized and other countries that preparing future teachers in teaching methods, including providing them with practical classroom experience, is important (Marshall & Horton, 2011; Qin, 2011).

Based on interviews, focus groups, and survey done by RAND Corporation as well as a review of the literature on teacher training, they recommended Providing ongoing support to practicing teachers as they implement the new curriculum, so as to concrete ways of bridging the gap between the knowledge and preparation of the IKR's existing teaching force and what is required by the IKR's recent education reforms. Focus pedagogy training on techniques most likely to be effective in the IKR's large classrooms and develop curriculum maps to help practicing teachers accurately deliver the content of the new curriculum were recommended. Based on these recommendation, this study was aimed at developing a teaching model based on the aims of the new science curriculum to support science teachers with a practical guide on how to teach the new science curriculum.

## 1.3 Background of the Study

Science consist of two components, scientific knowledge and the acquisition of scientific knowledge (Özgelen, 2012). Facts, laws, hypotheses, and theories contribute to such scientific knowledge. Acquisition of scientific knowledge is represented by applying knowledge to another situation such as problem solving and using science process skills that are the basics for developing students' HOT (Krau, 2011; Miri, David, & Uri, 2007; Nuthall, 1999; Pappas, Pierrakos, & Nagel, 2012; Yao, 2012; Zohar & Dori, 2003).

The processes that improve students in both cognitive and psychomotor domains are science process skills or SPS (Özgelen, 2012). In recent years, educators have recognized the value of these skills which are essential for scientific inquiry as a part of cognitive and investigation skills (Aktamis & Yenice, 2010; Chien & Chang, 2012; Hafizan, Halim, & Meerah, 2012; Kose & Bilen, 2012; Tatar, 2011). In science education there are two levels of science process skills, basic science process skills (BSPS) and integrated science process skills (ISPS) (Cecen, 2012). The basic processes include observing, measuring, inferring, predicting, classifying, and collecting and recording data. The integrated processes skills include interpreting data, controlling variables, defining operationally, formulating hypotheses, and experimenting (Germann, 1991). These processes skills form a hierarchy so that effective use of the integrated processes skills requires utilization of the basic processes. The integrated processes skills, with the exception of experimenting, have been defined as problem solving skills by Gagne (Shaw, 1983). The basic processes skills provide the data or the experiences that the problem solver needs to manipulate and integrate in order to solve a problem. The hierarchy represented by the basic processes skills and the integrated processes skills used by the Commission on Science Education suggests a difference between lower order and higher order thinking skills. Many researchers emphasize developing BSPS among primary and secondary school students (Akinbobola & Afolabi, 2010; Dokme & Aydinli, 2009; Padilla, Okey, & Dillashaw, 2006). Previous studies in ISPS emphasized highly on developing these skills among high school students ( Aktamis, 2012; Balfakih, 2010; Caliskan & Kaptan, 2012; Cecen, 2012; Hafizan et al., 2012; Kose & Bilen, 2012). Fewer researchers have focused attention toward enhancing these skills among secondary school students (Aydinli et al., 2011; Dokme & Aydinli, 2009; Karar & Yenice, 2012).

Another cognitive skill recommended by researchers as a higher order thinking skill is reflective thinking (RT) (Kizilkaya & Askar, 2009). Most studies on RT have put more emphasis on reflective thinking among teachers (Ayan & Seferoglu, 2011; Bannigan & Moores, 2009; Gurol, 2011; Puljic, 2010; Semerci & Duman, 2012). In the context of RT among students, many researchers have focused on high school students (Constantinou & Kuys, 2013; Phan, 2009; Zachariades, Christou, & Pitta, 2013), while fewer researchers have focused on secondary school students (Denton, 2010). However, research advocated that a great number of science teachers are using the traditional teaching method that improve students' lower order thinking skills which were found to be insufficient (Pilten, 2010; Swift, Zielinski, & Poston, 1996; Zawilinski, 2009), while the teacher should use interactive methods that enable students to construct knowledge and improve their higher mental abilities (Eom, Kim, & Seong, 2010; Qin, 2011). Moreover, in the context of the Iraqi Kurdistan region, research indicated that science teachers needs more knowledge to teach the new science curriculum as the existing teaching force as a whole is not adequately prepared to teach the new science curriculum. Several issues are involved, ranging from a lack of needed knowledge and training, to teachers being compelled to teach outside their specializations, to difficulties applying the student-centred learning methods required by the new policy (Vernez et al., 2014). Thus, the present research tried to fill this gap by developing a teaching model that made students the center of the educational process. The new teaching model aimed at enhancing basic education students' higher order thinking skills (HOTS) through using learning activities that encourage them to use reflective thinking skills and science process skills in science learning.

## 1.4 Statement of the Problem

Learning is not in doing, it is in thinking about doing (Dewey, 1933). Cultivating the student's ability to think at a higher level has been an important theme for redesigning and reforming learning systems ( Kim, 2005). A major component of the current reform in science education world-wide is the shift from the dominant traditional teaching for lower order thinking skills (LOTS) to higher order thinking skills (HOTS) (Avargil et al., 2012; Constantinou & Kuys, 2013; Ewers, 2001; Karami et al., 2012; Legare et al., 2013; Rotgans & Schmidt, 2011; Thitima & Sumalee, 2012). As a result, creating a more thoughtful learning environment reflecting contemporary theory and research in instruction and learning has been recommended. Therefore, in 2009 the educational system in the Iraqi Kurdistan region has been reformed and the curriculums have been revamped, in which major changes occurred in the science curriculum. The main aim of the new science curriculum is to improve students' higher cognitive skills so as to enable them to apply the acquired knowledge into real life situation (Vernez et al., 2014). However, after these reformation researchers such as Vernez et al. (2014) and UNESCO (2011) asserted that students in basic education are lacking in HOTS. In order for science education reform to succeed, the new education policy encourages teachers to adopt different methods of teaching, so as to enable them to construct and refine their own framework of fundamental ideas and concepts in science. There is a mandate, for example, to move away from lecture-based instructional methods to student-centered instructional practices. More specifically, the science teacher should use the teaching model that requires active participation of students, by engaging them in generating questions, representing their understanding, solving complex problems and reconstructing their own thinking (Albaaly, 2012; Panasan & Nuangchalerm, 2010; Şimşek & Kabapınar, 2010) so as to improve their higher cognitive skills in science learning which would help them to become decision makers and solve their problems in daily life situations.

According to Barak and Dori (2009) the development of HOT is prominent in order to facilitate the transition of students' knowledge and skills into responsible action; regardless of their particular future role in society. Meeting this challenge requires among others the development of students' capacities of reflective thinking (RT), which is important for solving problems and to logically defend their opinions and enable them to analyze and reflect on science concepts. Many researchers from diverse traditions and perspectives argue that reflective thinking is an important capability to be developed in students. Previous research involving reflective thinking has focused on teachers' reflective thinking (Ayan & Seferoğlu, 2011; Jansen & Spitzer, 2009; Phan, 2008; Russback, 2010; Tuncer & Ozeren, 2012; Vagle, 2009). Several studies have examined the reflective thinking among higher level school students (Ali, 2007; Kim, 2005; Phan, 2009; Vaiyavutjamai et al., 2012). However, little research has focused attention on RT in the context of secondary education (Denton, 2010).

Furthermore, minimal research attention has been directed to the role of teaching methods in developing RTS among secondary school students (Lia, 2011). In addition, Rowicki and Reed (2006) pointed out that the skills helping students to think critically and reflectively are called science process skills (SPS). The American Association for Advancement of Science or AAAS (1996) identified thirteen SPS and classified them into basic science process skills (BSPS) and integrated science process skills (ISPS). Research advocated that ISPS are strongly related to higher thinking skills (Akinbobola & Afolabi, 2010; Lati, Supasorn & Promarak, 2012; Özgelen, 2012; Thitima & Sumalee, 2012). Recent reforms in science education hold great promise for teaching effective thinking skills defined by science process skills to all students. The scientists use these skills to construct knowledge in order to solve problems and formulate results. Educators recognize the value of these skills which are essential for scientific inquiry as a part of cognitive and investigation skills (Özgelen, 2012). Some educators emphasize the importance of teaching science process skills, but more abstractly (Aktamış & Yenice, 2010; Albaaly, 2012; Karar & Yenice, 2012; Taasoobshirazi & Farley, 2013; Thitima & Sumalee, 2012). Moreover, research emphasized that developing reflective thinking as well as science process skills as higher order thinking skills (Lati et al., 2012; Lia, 2011; Özgelen, 2012; Russback, 2010; Thitima & Sumalee, 2012) will help students to solve problems, make decisions and reconstruct their own thinking. These higher cognitive skills can be developed when students engage in the hands-on activities that require them to make a plan to solve the problem, analyze the data and make judgments. Nevertheless, the literature reveals a lack of empirical research aimed at developing effective teaching models and identifying their effects on improving students' HOT. Supporting the idea that teaching models should facilitate the transition of students' knowledge and skills into responsible action, regardless of their future role in society, this study holds the idea that improved teaching models might help students to improve their cognitive skills. Thus, the present study aimed at developing a HOT teaching model for enhancing HOTS among basic education students in science learning.

## 1.5 Objectives of the Study

The overall aim of the study was to develop a HOT teaching model to promote students' higher order thinking in terms of enhancing their RTS and SPS in science learning. The specific objectives of the study were:

1- To identify the students' needs in terms of identifying their higher order thinking skills level in science.

2- To identify the strategies used by science teachers to teach their students' HOTS.

3- To develop the HOT teaching model for basic education students based on experts' opinion and decision.

4- To evaluate the HOT teaching model for basic education students based on the science teachers' opinion and decision.

## 1.6 Research Questions

The development of the HOT teaching model involved three major phases, that is, needs analysis, design and development, and model evaluation based on the design and development research approach. Therefore, a total six questions were expected to be answered in this study:

**Phase One: Needs Analysis**

1.1 What is the current level of higher order thinking (HOTS) among 7th grade students in science?

1.2 What strategies do 7th grade science teachers use to teach their students HOT?

**Phase Two: Design and Development**

2.1 What are the experts' views on the stages and sub-stages (Elements) that should be included in the development of the HOT teaching model?

2.2 Based on the experts' agreement, how should the HOT teaching model stages and sub-stages be arranged in the implementation of the model?

**Phase Three: Model Evaluation**

3.1 Do the stages and sub-stages of HOT teaching model positively influence students' HOT?

3.2 Is the HOT teaching model usable to be implemented in science teaching?

## 1.7 Rationale for the Study

This study was aimed to develop a HOT teaching model for basic education students in science learning. The rationale for the study was stated as follows:

First, the need to help basic school students in science learning, especially to build up their higher order thinking (HOT) which has been an important outcome of science education. Newmann (1987) asserted that, the information learned and processed through higher order thinking processes is remembered longer and more clearly than information that is processed through lower order, rote memorization. Consider for example, the difference between memorizing a formula and explaining the derivation of the formula. Or, the difference between mere memorization of the multiplication tables and a deeper understanding that the multiplication tables represent short cuts for addition. In each case, a student who has the deeper type of understanding will carry that knowledge longer. Moreover, the student with the deeper conceptual knowledge will be better able to access that information for use in new contexts. This may be the most important benefit of high order thinking. Knowledge obtained through higher order thinking processes is more easily transferable, so that students with a deep conceptual understanding of an idea will be much more likely to be able to apply that knowledge to solve new problems. In this study, through employing learning activities that encourage students to use reflective thinking skills and science process skills students would get improvement of their higher order thinking skills. These skills are recommended by the past literature to be implement in teaching science which are essential skills for scientific inquiry and problem solving and enable students to apply their acquired knowledge to real life (Baker, Pesut, Daniel, & Fisher, 2007; Geertsen, 2003; Lia, 2011; Russback, 2010).

Second, to be successful in enhancing students' HOT, the primary goal of science education should not be only teaching the concept, fact, law and theory related to science which are considered as lower order thinking skills (LOTS) (Chien & Chang, 2012; Lati et al., 2012; Miles, 2010). Pilten (2010) believe that teaching and assessment methods have traditionally been directed towards the mastery of content which requires only LOTS, rather than improving higher order thinking skills (HOTS). This is due in part to the traditional approach to science teaching which is commonly based on teachers aimed at presenting large amounts of content in a short time. The development of students' HOTS requires strategies where learners are given opportunities to develop knowledge structures or representations that will allow them to retrieve and use the information in the future. Therefore, this study aimed to develop a teaching model with the focus of the learning activities that engage students with the using of higher cognitive skills in science learning.

Finally, as described earlier, in 2009 the educational system in the Iraqi-Kurdistan region has been reformed in order to meet the challenges of the 21st century, in which the new science curriculum for basic education has focused largely on prompting students' HOT. However, UNESCO (2011) and Vernez et al. (2014) have asserted that the quality of teaching science in the Kurdistan region is unsuccessful to achieve the main goals of the new curriculum and the basic education students are lacking in higher order thinking skills. Thus, the researcher became interested in choosing basic school students in the Iraqi-Kurdistan region as a sample for the present study for enhancing their cognitive skills in science learning.

## 1.8 Significance of the Study

It has been well verified that higher order thinking skills are essential for effective learning and form the central goal of science education. Based on the recent literature, teaching methods play a vital role in enhancing students' acquisition of HOT. Therefore, based on these areas, the main purpose of this study was to develop a teaching model focused on reflective thinking skills and science process skills for basic education students in science learning. Hence, the findings of the study not only have the impact how this model could improve students' HOT in science learning, but also will have methodological impact in design and development of educational strategies to improve students' cognitive skills. Accordingly, the findings of the study could benefit science teachers, instructional designers and policy makers.

First, the findings of the study could support students in improving their higher cognitive skills and engage them in the process of constructing knowledge. Besides, research identified that reflective thinking skills and science process skills are the important higher cognitive skills that should be developed among students (Lia, 2011; Taasoobshirazi & Farley, 2013; Thitima & Sumalee, 2012). Therefore, as the learning activities (elements) of the model are based on these two higher order thinking skills, the findings of the study could assist students in becoming capable thinkers who can solve problems and make judgment. Besides, enhancing students' HOT is also expected to help them approach learning tasks in other learning situations.

Second, science teachers could use the model to guide them in using activities that engage students in class to extend their classroom teaching performance. At the same time, teaching would be more effective and motivating, especially when the students are active and the teacher is a facilitator of the learning process. In short, using effective teaching model could break the monotony of traditional classroom teaching methods and enhance teachers' academic role as a facilitator of the learning process.

Third, instructional designers could use the model to design and develop modules for use in science classrooms to support students' science learning needs. Further, the methodology used in the study could be adopted by instructional designers to design and develop models for other subject areas.

Finally, although this study focuses on developing a model for enhancing students' HOT in science learning, it is expected that the result of this study would probably contribute to the knowledge base of teaching methods in general and science education in particular.

## 1.9 Theoretical Framework

This study focuses on improving students' higher cognitive skills through using effective teaching models. For the development of the HOT teaching model, Bruner's cognitive theory (Bruner, 1966) has been employed as the learning theory to guide how basic school students achieve development in their higher order thinking through discovery learning. Moreover, to support precisely on how students go through the process of learning from using basic thinking skills (BSPS) to more complex (ISPS), Gagne theory of learning hierarchy (Gagne, 1972) has been adopted for this study. To support further, specifically on how the basic education students could gain improvement in their reflective thinking skills (RTS), the experiential learning theory (Kolb, 1984) has been adopted for this study. However, in terms of theoretical framework for the HOT teaching model, cyclic learning model (CLM) (Kim, 2005) is adopted and supported by IMSTRA (Immersion, Structuring, Applying) teaching model (Singer & Moscovici, 2008) for selection of the appropriate elements (stages and sub-stages) for use in the model, in order to create a practical guide for model implementation in the science classroom. Further details on the adoption of these theories and models are elaborated in Chapter two.

## 1.10 Definition of Terms

Several terminologies are used in this study. The following definitions of these terminologies are described in the context of this study.

**Higher Order Thinking (HOT):** Can be conceptualized as a complex mode of thinking that often generates multiple solutions, which involves application of multiple criteria, uncertainty and reflection (Resnick, 1987). In the context of this study, HOT can be defined as the mode of thinking that basic education students use to reflect the acquired knowledge and apply it to real life situations.

**Higher Order Thinking Skills (HOTS):** The skills that students use to solve the problem and make judgment about the solution such as application, analysis, synthesis and evaluation.

**Reflective Thinking (RT):** Reflective thinking (RT) can be defined as an inquiry mental activity that students use when they face scientific problem by analyzing and drawing a necessary plan to understand it until they reach the desired result and finally the students will make judgment about the proposed solution.

**Reflective Thinking Skills (RTS):** The activities that basic education students use to think reflectively about the problem, to evaluate the arguments and make judgment about the solution until they reach a scientific conclusion.

**Science Process Skills (SPS):** Science process skills are defined as an understanding of methods and procedures of scientific investigation. They are related to the proficiency in using various aspects of science and are associated with cognitive and investigative skills. Through these skills such as observation, prediction and inference scientists collect knowledge, put experiments together, analyze data, and formulate results. Science process skills are very important for meaningful learning; because learning continues throughout the life, and individuals need to find, interpret, and judge evidence under different conditions they encounter. Therefore, it is essential for students' future to be provided with science process skills at educational institutions (Harlen, 1999). Moreover, Padilla (1990) defined science process skills as a set of skills that are reflective of the behaviour of scientists, are appropriate to many science disciplines, and are abilities that are broadly transferable to other situations.

In this study science process skills (SPS) are defined as the skills that basic education students use to construct knowledge in order to solve problems and formulate results so as to improve their higher cognitive skills.

**Basic Science Process Skills (BSPS):** The thinking skills that basic education students use to acquire the knowledge in learning science. The science process skills (observation, classification, prediction and inference) are used for gathering information and are categorized as lower order thinking skills.

**Integrated Science Process Skills (ISPS):** The mental ability that basic education students use to analyze the acquired knowledge and apply it into real life situations. The skills such as formulating hypothesis, interpreting data, defining operationally and experimenting are categorized as a higher level of thinking skills.

**Model:** It is an instructional design which describes the process of teaching and producing particular environmental situation which cause the student to interact in such a way that special changes occurs in their behaviour (Joyce, Weil, & Calhoun, 1986). In this study the model is defined as a group of organized steps and procedures (stages and sub-stages) that involve both reflective thinking skills and science process skills, that would be used by science teachers in order to enhance basic education students' HOT.

## 1.11 Limitations of the Study

The development of HOT teaching model is intended as an example in proposing how basic students' cognitive skills could be improved in science learning through using effective teaching models. However, through the process of developing the model some limitations and issues should be taken into account.

First, with the theoretical basis of higher order thinking, there are many higher cognitive skills beyond reflective thinking (RT) and science process skills (SPS), such as critical thinking, creative thinking and problem solving. However, investigating all these types of cognitive thinking is too difficult. Thus, in determining elements of the model, the present study is limited to selection of reflective thinking (RT) and science process skills (SPS) which has not been explored deeply in past studies.

Second, in terms of methodology, only three phases of developmental research are involved in the study, since the focus of the study is developing a model. In the needs analysis phase, the study relied on the 7th grade students' level on HOT and the teaching strategies used by their teacher in science learning in determining the needs to develop the model. In the developmental phase, the study adopted semi-structured interview along with Fuzzy Delphi Method to determine the elements of the model (stages and sub-stages) using experts' opinions. Moreover, the model is evaluated in phase three by science teachers in the Iraqi-Kurdistan region using smart PLS approach. However, if the study would be conducted using different types of participants in different sites of Iraq the results may be different.

Third, the scope of this study will be limited to basic education students in the Kurdistan region; therefore, the study is contextually specific. The unique condition that the study is applied will constrain the extension of generalizable research findings, because the educational system in Kurdistan is different from that in other parts of Iraq; thus the research findings might not be applicable to all Iraqi students, but it can be generalized to all basic education students in the Kurdistan region.

## 1.12 Summary

This chapter begins with the justification of the importance of improving students' HOT in science learning with focus on reflective thinking and science process skills. In doing so, the researcher chose basic education students as a focus of the study, which capitalized on how using effective teaching model could improve students' cognitive skills in science learning. The attempt to develop a teaching model for enhancing basic education students in science learning constitutes the purpose of the study. The rationale section is justified the development of the model. Based on this justification, research objectives and questions are constructed, which systematically guided the development of the model. Moreover, these sections are followed by a discussion of theoretical framework which consists of a set of theories and models that helps to frame the elements of the model, as well as to describe how the model should be viewed as a guide in implementing the model in science class among basic education students. The next chapter gives a review of literature relevant to the study.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Introduction

This study aimed at developing HOT teaching model for basic education student in science learning. This chapter presents a review of literature relevant to the concept of higher order thinking and theories of cognitive development. Based on the concept of HOT in this study, the review of literature is discussed in three main sections. The first section explains in detail about reflective thinking skills (RTS) and the importance of enhancing these cognitive skills among basic education students in science learning. The second section introduces the concept of science process skills (SPS), the categories of SPS and why they are important in teaching science. The third section explains HOT, and the process of enhancing students' HOT in science learning through using an effective teaching model. The theories that served to scaffold the development of the model are discussed in two parts: The first part elaborates the theories that describe the process of developing higher order thinking through discovery learning. The second part frames the development of the HOT teaching model that serves as a vital representation on how the model can be implemented by science teachers in supporting basic education students in science learning through improving their HOT. Besides, the last section describes the theories, the models underlying the development of the HOT teaching model and the overall conceptual framework of the study which is presented at the end of this chapter.

### 2.2 Thinking in Science Education

Science encompasses knowledge and understanding of the biological and physical aspects of the world and the processes through which such knowledge and understanding are developed. Through science education, students construct, modify and develop a broad range of scientific concepts and ideas. Working scientifically involves them in observation, questioning, discussion, prediction, analysis, exploration, investigation, and experimentation, while the knowledge and skills they acquire may be applied in designing and making tasks (Kim, 2005). Thus, science education equips students to live in a world that is increasingly scientific and technological. Science education fosters respect for the evidence of scientific enquiry, while the collaborative nature of its activities can also help students to acquire social and co-operative skills. Investigations and problem-solving tasks nurture inventive and creative capacities in students. Science education plays a key role in promoting a sensitivity to, and a personal sense of responsibility for local and wider environments (Zippay, 2010).

Thinking, as defined by Dewey, is the operation in which present facts suggest other facts in such a way to induce belief in the latter upon the ground or warrant of the former (Burns, 2012). One of the emphasized goals in each education system is to increase and improve the learner's higher order thinking skills (HOTS) and this takes place by integrating these concepts in the curriculum. Research on cognitive skills has indicated that facilitating students' higher thinking skills in the learning process helps them enhance awareness of their own thinking, organization of thinking processes, enable flexible and effective use of knowledge and cognitive learning strategies. In addition, it will foster students' learning performance and cognitive growth (Donald, 2002; Perkins, Jay, & Tishman, 1993). Moreover, research has identified various types of thinking that aid students in the process of constructing scientific knowledge and force them to think at a higher level, such as critical thinking, creative thinking, reasoning, decision making, scientific thinking, science processes skills, problem solving, metacognition and reflective thinking, as the important capabilities that should be cultivated in both instructional, learning situations and everyday life (Harlen, 1999). However, the present research focused on two of these important higher order thinking skills; reflective thinking and science process skills and employing these two higher order thinking skills in the science classroom would aid students in their science learning, which have rarely been investigated in detail in previous research on science education.

## 2.3 Reflective Thinking

### 2.3.1 Definition of Concept

Reflective thinking (RT) is considered as thinking patterns that depend on substantive principles and causation in facing problems that explain phenomena and events (Zachariades, Christou, & Pitta-Pantazi, 2013). Reflective thinking has been explored by many scholars of diverse traditions and perspectives in education (e.g., Dewey, 1933), experiential learning theorists (Boud, 1985; Kolb, 1984; Russback, 2010), researchers of professional education and development (Burns, 2012; Josten, 2011; Kim, 2005; Russback, 2010; Schön, 1984; Zippay, 2010) and educational psychologists in metacognition and learning strategies (Phan, 2007, 2009; Vaiyavutjamai et al., 2012). These diverse approaches to the study of reflective thinking have led to various definitions and roles of reflective thinking in the literature.

According to Dewey (1933) reflective thinking is an active, persistent, and careful consideration of a belief or supposed form of knowledge, the grounds that support that knowledge, and the further conclusions to which that knowledge leads. Learners are aware of and control their learning by actively participating in reflective thinking, assessing what they know, what they need to know, and how they bridge that gap during learning situations. Dewey recognized reflection as a process for creating knowledge, in which individuals make meaning through the reflective process to move from an experience to develop a greater understanding through relationships with the environment (Ali, 2007; Xie, 2008). Paul (1987) considered RT as a pattern of scientific thinking which directs the mental processes to the specific targets; that means the reflective thinking is a mental activity to solve the problems.

Critical thinking (CT) and Reflective thinking (RT) are often used synonymously (King & Kitchener, 1994). Critical thinking is used to describe the use of those cognitive skills or strategies that increase the probability of a desirable outcome. Critical thinking is sometimes called directed thinking because it focuses on a desired outcome. On the other hand, RT is a part of the critical thinking process referring specifically to the processes of analyzing and making judgments about what has happened, so critical thinking (CT) involves a wide range of thinking skills leading toward desirable outcomes, while RT focuses on the process of making judgments about what has happened. However, reflective thinking is most important in prompting learning during complex problem-solving situations because it provides students with an opportunity to step back and think about how they actually solve problems and how a particular set of problem solving strategies are appropriated for achieving their goal (Yuen Lie Lim, 2011). Therefore, many researchers categorize reflective thinking as a higher cognitive skill, or higher order thinking (HOT) (Baker et al., 2007; Geertsen, 2003; Lia, 2011; Russback, 2010).

To specify the meaning of RT, Ali (2007) defined reflective thinking as an inquiry mental activity that learners used when they faced scientific problems by analyzing and drawing a necessary plan to understand it until they reach the desired result and finally the learners will evaluate the result according to the previous plans. Hence, based on the discussion so far, it is evident that scientists and theorists agreed on:

- Reflective thinking is a mental activity and mental process.
- Reflective thinking requires insights into the problem and analyzing it.
- The necessity to propose specific solution for complex situation.
- The evaluation of the results according to previous plans.

### 2.3.2 Reflective Thinking Skills (RTS)

Reflective thinking skill (RTS) is defined as a group of abilities and mental processes that are necessary to interpret the events and problems and modified opinions and issuance of the substantive judgments (Ali, 2007). In the same context, Song, Grabowski, Koszalka, and Harkness (2006) defined reflective thinking skills as the outcome of a developmental progression resulting from interactions between the individual's conceptual skills and an environment that promotes or inhibits these skills. Researchers differ in classifying RTS. However, Harthy (2011) identified five skills for reflective thinking as follows:

First, Meditation and observation: This is the ability to view aspects of the problem and to identify the components, whether through the problem or by giving a picture or graph that shows its components so that the existing relations are detected visually.

Second, Detect fallacies: The ability in identifying gaps in the problem by limiting the incorrect relationships or illogical relationship or identifying some of the missteps in the completion of educational tasks.

Third, Conclusions: The ability to reach a certain logical relationship by seeing the content of the problem in order to reach an appropriate outcome.

Fourth, convincing explanations: The ability to give a logical meaning of the results; this meaning may be based on previous information or the nature and characteristics of the problem.

Fifth, Propose Solutions: The ability to put all previous steps for solving the posed problem and those steps are based due to expected mental evolution for the posed problem. According to Ali (2007) there must be certain mental processes depending on the ability, tendency and experience when the individuals faced a complex problem, so they must choose between their experiences, habits and knowledge that fit the situation, in which the learner must recollect these experiences in a new pattern of responses applicable to the problem. Thus the mental processes that involve in reflective thinking (RT) could be described as follows:

- The tendency and attention toward the goal → Attitude
- Recognize relationship → Explanation
- Test and remember appropriate expertise → Test
- Discrimination, the relations between the components of experiences → Clarity
- The configuration of new mental patterns → Innovation
- Evaluating the solution as a practical application → Critique

Various scientists and theorists have presented models with different levels, phases and skills of reflective thinking

John Dewey (1993) described reflective thinking using phases such as claim, problem, hypothesis, reasoning and testing (Tuncer & Ozeren, 2012). Besides, Van Manes (1977) presented a model of reflective thinking as a hierarchy of four levels of reflection, technical reflection, practical reflection and critical reflection ( Vaiyavutjamai et al., 2012). Moreover, Mezirow's model for reflective thinking in practice categorized reflective thinking into four distinct phases: habitual action, understanding, reflection and critical reflection (Phan, 2007; Yuen Lie Lim, 2011). Finally, Rodger (2002) developed a reflective cycle model with the skills describing, interpreting, analysis and experimentation (Jansen & Spitzer, 2009; Paul, 1987). In this study reflective thinking skills (RTS) can be defined as an inquiry mental activity that students use when they face scientific problem by analyzing and drawing a necessary plan to understand it until they reach the desired result and finally the students will make judgment about the proposed solution.

### 2.3.3 The Importance of Developing (RT)

Many researchers from diverse traditions and perspectives agreed with the importance of reflective thinking for students (Dewey, 1933), which helps them to reconstruct their own thinking (Milner, Bolotin & Nashon, 2012; Pilten, 2010; Yao, 2012). In the same construct, Tuncer and Ozeren (2012) conducted research investigating the importance of reflective thinking in science education and they found that RT activities increased student academic achievement in science classes and positively influenced their behaviors toward science. The assertions of researchers about the importance of reflective thinking in learning can be described as follows.

First, reflective thinking encourages learners to make deep understanding of a domain by articulating and monitoring what they have learned and to better use their cognitive process skills by evaluating whether cognitive process skills that they have used work or do not work ( Kim, 2005; Walters, Seidel, & Gardner, 1994).

Second, reflective thinking on learning experience can make students transform negative experience associated with their feelings or motivation (e.g., discomfort, anxiety, difficulty) that they have experienced into positive learning experiences (Çakır & Sarıkaya, 2010; Chien & Chang, 2012).

Third, students' reflective activities can lead to changes to the way (e.g., belief, value, open mind) of dealing with their learning in the future by extracting inferences or meaning from their learning experience (Ayan & Seferoğlu, 2011; Dewey, 1933; Y. Kim, 2005).

In addition, to improve students reflective thinking skills Song et al. (2006) and Vaiyavutjamai et al. (2012) advocated that three not wholly independent clusters linked to teaching elements can facilitate the development of reflective thinking in the science learning environment:

- Reflective learning environments: can assist students in constructing meaning actively and reflectively. Complex learning activities require students to learn from multiple forms of information before responding and tend to elicit active consideration of multiple inputs when students make judgments on how to proceed. The authenticity and real-life experiences associated with classroom learning activities can help students to think reflectively by providing real situations and contextualized knowledge about new information that they are learning (King & Kitchener, 1994; Manolis, Burns, Assudani, & Chinta, 2013; Song et al., 2006; Vaiyavutjamai et al., 2012; Yuen Lie Lim, 2011).
- Reflective teaching methods can assist the growth of RT among students. For example, teachers who prefer inquiry-oriented activities help students to improve their reflective thinking skills by asking thoughtful questions (Kim, 2005; Vagle, 2009; Xie & Sharma, 2011; Yuen Lie Lim, 2011).
- Reflective scaffolding tools — such as interactive journals, question prompts, summarizing results and concept maps — can promote students' reflective thinking skills (Bell, Kelton, McDonagh, Mladenovic, & Morrison, 2011; Wade & Yarbrough, 1996). These elements can be shown in Figure 2.1.

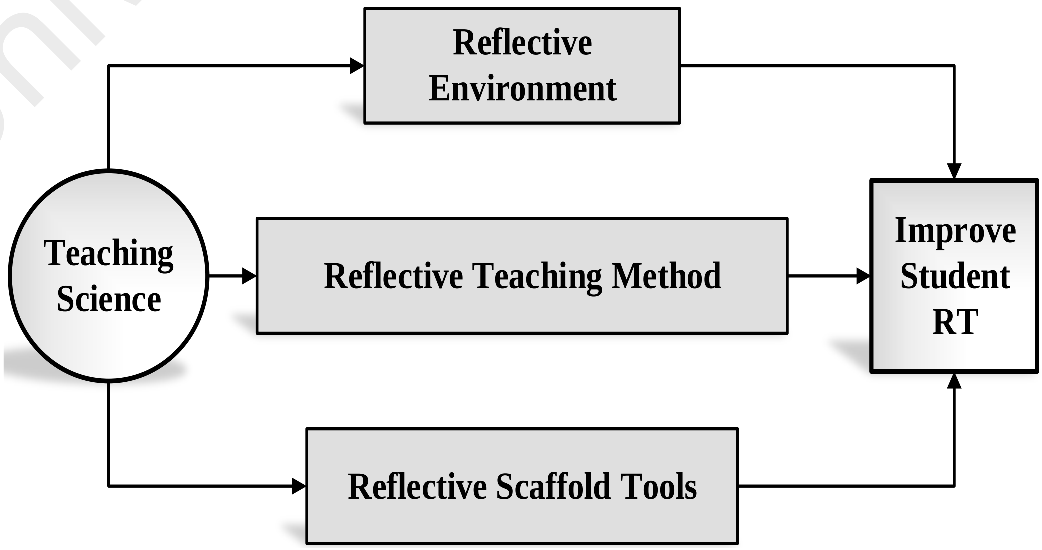



**Figure 2.1:** Teaching Elements that Improving Students' (RT)

According to previous research, teachers can promote learners' reflective thinking by relating new knowledge to prior understanding and giving them the opportunity to participate in the learning activities. In specific, using effective teaching models would aid students to think in both abstract and conceptual terms, apply specific strategies in novel tasks, and help them to understand their own thinking. Therefore, this study is aimed at developing new teaching model to improve students' reflective thinking skills in science education. The elements of the new model consist of reflective learning activities that involve students in a reflective learning environment that would further help them to be reflective thinkers and decision makers in future life situations. These elements would be selected by a panel of experts during the design and development phase of the research method.

### 2.3.4 Measuring Reflective Thinking Skills

Many researchers have developed various tools for assessing reflective thinking such as questionnaires and tests. Kember et al. (2000) developed a questionnaire based on Mezirow's model which included the levels: habitual action, understanding, reflection and critical reflection. Moreover, Ali (2007) developed a questionnaire for investigating the level of RT among higher education students which consists of 30 questions in which the scores of each student was between 0-30 for measuring the level of RT. He emphasized that students scoring less than 10 had a low level of RT, those scoring between 10 – 20 had a medium level of RT and students scoring between 20 – 30 had a high level of RT. Whereas in terms of the teacher RT, Tuncer and Ozeren (2012) developed a questionnaire for prospective teachers in terms of using RTS to solve problem. The questionnaire contained 14 items and it was scored in the form of a Likert Scale (always 5, mostly 4, sometimes 3, rarely 2, never 1) as the total scores indicated the level of RTS.

Imawi (2009) developed a test for measuring the level of RT among third grade students, which consisted of 34 items in the form of multiple choice, so the scores of each student ranged between 0 – 34. In the same constructs Harthy (2011) developed a test for investigating the level of RT among ninth grade students. This test contained 21 multiple choice questions, so the scores of each student ranged between 0 – 21. After reviewing a number of studies on reflective thinking, the researcher found that the past literature used varied tools in measuring RTS in order to achieve their research objectives. Some of researchers used questionnaires (e.g., Ali, 2007; Kember et al., 2000; Tuncer & Ozeren, 2012), while others used tests (Harthy, 2011; Imawi, 2009).

## 2.4 Science Process Skills (SPS)

### 2.4.1 Definition

Science education has a very important role in educating students who investigate, test, discuss, expand their knowledge and improve their abilities of scientific process. At the same time, the aim of science education should not only be teaching the concept, fact, law and the theories related to the science which are categorized as lower order thinking (LOT), but it also should include gathering information, interpreting it and enabling students with the ability to solve problems via scientific methods (Karar & Yenice, 2012). For more than four decades, science educators have promoted learning science as process (Aydinli et al., 2011); it has been widely accepted that science process skills (SPS) are essential for scientific inquiry as a part of cognitive and investigative skills.

Gagne pointed out that science process skills (SPS) are mental skills and educational capabilities (Oloruntegbe, 2010). In the same context Lati et al. (2012) labelled SPS as inquiry skills and abilities to think scientifically. Research in SPS abilities has taken many directions since the early 1960s with the debut of some programs such as Biological Science Curriculum Study (BSCS), Science Curriculum Improvement Study

(SCIS) and Intermediate Science Curriculum Study (ISCS) (Aydinli et al., 2011). The science process skills, besides being a necessary tool to learn and understand the science not only the scientist, should be mastered by the individual in society who should have these skills in order to be scientifically literate, and to solve daily life problems (Aktamış & Yenice, 2010). Moreover, research advocated that SPS are important skills for increasing learning performance, making students active and improving their sense of taking responsibility over their own learning by making them active. According to Burke and William (2008), SPS is an application of the methods and principles for reasoning about problem situations. Timothy (2001) stated that SPS are intellectual skills used for developing knowledge and understanding, in which these skills are a set of broadly transferable abilities, appropriate to all of the science disciplines, reflective of the true behavior of scientists when conducting experiments and solving problems. These skills enable individuals to improve their own life visions and give a scientific view as a standard of their understanding about the nature of science. However, Özgelen (2012) emphasized that the integrated process skills are strongly related to higher order thinking skills. In the same construct a great body of literature categorized science process skills as higher order thinking skills (Akinbobola & Afolabi, 2010; Lati et al., 2012; Özgelen, 2012; Thitima & Sumalee, 2012).

### 2.4.2 Classification of (SPS)

Science process skills can be defined as a set of skills that are reflective of the behavior of scientists, are appropriate to many science disciplines, and are abilities broadly transferable to other situations (Padilla, 1990). Research suggests that science process skills may be one of the most important tools for producing and arranging information about the world around us (Ostlund, 1998). Scientists were varied in classification of science process skills (SPS); the American Association for Advancement of Science (AAAS, 1996) classified these skills into basic science process skills (BSPS) and integrated science process skills (ISPS). Charlesworth and Lind (2006) categorized the SPS into basic, intermediate and advanced levels. Basic science process skills (BSPS) provide a foundation for the more complex skills and are developmentally appropriate for young learners in an elementary science classroom such as: observing, communicating, inferring, classifying, measuring and predicting (Meador, 2003). In the same context, Bently (2000) categorized these skills according to their usage and student progression phases as basic science process skills (BSPS) which consist of eight basic skills, and five integrated science process skills (ISPS). In the science and technology program (2005), these skills are classified under three different headlines as Planning and Starting, Practice, Analysis and Inference and presented as follows:

**i-** Planning and Starting: Observation, comparison and classification, inference, prediction, estimation, defining variables.

**ii-** Practice: Formulating Hypothesis, designing experiment, recognizing experiment materials and tools, setting up of experiment mechanism, controlling and changing variables, defining operationally, measuring, collecting data and information, recording data.

**iii-** Analysis and Inference: Data processing and formulating model, interpretation and inference, presentation.

Moreover, Johnston (2008) classified SPS by combining these skills with problem solving steps as follows:

**i-** Exploration: observation, inquiry, classification, formulating hypothesis.

**ii-** Planning: planning research, determination of the sources, and determination of what to measure, data collection, and communication.

**iii-** Research: actualization of understanding, determining measurement tool, controlling variables, recording data.

**iv-** Interpretation: analyzing data, interpreting data, testing hypothesis.

**v-** Communication: what did we do, what did we find, and what did we change? (Batı, Ertürk, & Kaptan, 2010).

From the preceding classification of science process skills (SPS), we observe that most of these classifications categorized SPS into basic scientific thinking and integrated scientific thinking and do not separate them from each other, but show that the skills are integrated and complement each other.

### 2.4.3 Basic Science Process Skills (BSPS)

The basic science process skills (BSPS) are the foundational activities of scientific problem solving and prerequisites to the integrated process skills ISPS (Timothy, 2001). Akinbobola and Afolabi (2010) pointed out that BSPS are vital for science learning and concept formation at the primary and junior secondary school level. BSPS consist of eight skills which can be defined as follows:

**Observing:** When students make observations, they use all their senses to gather information about objects or events in their environment. This is the most basic of all the process skills and the primary way of gathering information.

**Classifying**: Classification involves putting objects in groups according to some common characteristic or relationship. Teachers can encourage students to develop this skill by asking them to group or arrange objects by their observed properties. It is more important that students are able to justify their arrangement or grouping than to replicate a scientific grouping scheme.

**Inferring**: Making inferences involves using evidence to propose explanations of events that have occurred or things that have been observed. In other words, using past experiences or previously collected data to draw conclusions and explain events. It is important to help students distinguish between what they are observing and their inferences.

**Predicting**: In making predictions, students propose the outcome of a future event using observations and previous discoveries. Since predictions are best guesses based on available information, the more information students have, the more accurate their predictions.

**Measuring**: Includes using both standard and nonstandard measures to describe the dimensions of objects or events. This can include identifying length, width, mass, volume, temperature, and time. Measuring adds precision to students' observations, classifications and communication.

**Communicating**: It can take many forms, including using words, actions, or graphic symbols to describe an action or event. It requires students to collect information they have gathered from observations for sharing with others.

**Using Number**: It is a process skill where the learner finds the quantitative relationship among data.

**Using Space-Time Relation**: It involves describing changes in a parameter with time, in which the learner states the location and shapes of objects or describes the position and changes in position in moving objects.

Several studies highlight that basic science process skills (BSPS) can begin prior to kindergarten (Duschl, 1989; Strauss, 1972) and they argue that natural development and curiosity of children enable them to instinctively use the BSPS such as observe, classify, collect and organize data and measure.

### 2.4.4 Integrated Science Process Skills (ISPS)

According to Akinbobola and Afolabi (2010), the integrated science process skills (ISPS) are vital for science learning and concept formation at the primary and junior secondary school levels. ISPS complement basic science process skills and help students to think at a higher level. ISPS is defined by researchers (Akinbobola & Afolabi, 2010; Miles, 2010; Padilla et al., 2006; Rowicki & Reed, 2006; Shahali & Halim, 2010) as follows:

**Defining Operationally**: It simply means describing a system in terms of what we can observe, or defining all variables as they are used in the experiment by describing what must be done and what should be observed. This skill is essentially a composite of the skills of observation and communication.

**Formulating Hypothesis**: The experimenter predicts relationships that exist between two variables. Hypotheses generally imply an experimental test that may be performed to verify them.

**Interpreting Data**: This is a composite skill consisting of communicating, predicting and inferring. The learner uses data collected to accept or reject the hypothesis.

**Controlling Variables**: Identifying the fixed variables, manipulated variables, and responding variables in an investigation. The manipulated variable is changed to observe its relationship with the responding variable. At the time, the fixed variable is kept constant.

**Experimenting:** Planning and conducting activities to test a certain hypothesis. These activities include collecting, analyzing and interpreting data and making conclusions.

The overall science process skills form a hierarchy so that effective use of the integrated processes requires utilization of the basic processes. The integrated processes, with the exception of experimenting, have been defined as problem solving skills by Gagne (Shaw, 1983). The basic processes provide the data or the experiences that the problem solver needs to manipulate and integrate in order to solve a problem. The hierarchy represented by the basic processes and the integrated processes used by the Commission on Science Education suggests a difference between lower order and higher order thinking skills. A great body of research in science education focused on the effect of employing science process skills on science achievement, for example; Aydinli et al. (2011) identified that instruction in science process skills particularly in ISPS such as identifying and controlling variables, formulating hypothesis, and experimenting are beneficial to overall science achievement. Also, they are more appropriate at the secondary and tertiary school levels (Akinbobola & Afolabi, 2010). Moreover, Preece and Brotherton (1997) noted that teaching SPS at the early secondary level can have long term positive effects on science achievement. After reviewing the literature in science process skills we identified the importance of both BSPS and ISPS for basic education students in science learning. Therefore, the elements of the HOT teaching model (learning activities) would consist of both BSPS and ISPS that engage basic education students in the process of constructing knowledge in science learning.

### 2.4.5 The Importance of Developing (SPS)

Science process skills are an understanding of methods and procedures of scientific investigation; they are related to the proficiency in using various aspects of science and also are associated with cognitive and investigative skills (Gorman, 2001). Through these skills, scientists collect knowledge, put experiments together, analyze data, and formulate results. Harlen (1999) emphasized that science process skills are very important for meaningful learning, because learning continues throughout life, and individuals need to find, interpret, and judge evidence under different conditions. Therefore, it is essential for the students' future to be provided with SPS at educational institutions. If these skills are not developed sufficiently, students cannot interpret the knowledge. For example, if the related evidence is not collected, concepts will not help students to understand what takes place (Bilgin, 2006). Therefore, the basic target in science classes should be teaching students how to attain knowledge rather than passing on the convenient knowledge.

Ferreira (2004) stated that three main arguments were developed among science educator scholars for the place of science process skills (SPS) in science education.

First, it is the means for students to better understand scientific knowledge as well as to grapple with the conditions under which knowledge may change. Moreover, the best way for students to understand the products of science (or scientific knowledge) is to engage in the process by which the knowledge was generated and thinking skills enhanced. SPS are the means to achieve this end, and science learning is ultimately about gaining scientific knowledge.

Second, SPS are necessary for developing scientific literacy; they prepare individuals to evaluate how scientific claims are generated and therefore enable them to have the best knowledge to participate in public dialog involving such understanding. Kaya, Bahceci, and Altuk (2012) identified the relationship between scientific literacy and level of SPS in which a highly positive and meaningful relationship between the scores of science process skills (SPS) and scientific literacy had been registered.

Third, such skills are an integral part of scientific education as well as the central components for learning science with understanding (Harlen, 2001; Milner-Bolotin & Nashon, 2012; Pilten, 2010; Yao, 2012).

### 2.4.6 Factors Affecting Development of Science Process Skills (SPS)

Educators have found that in science education three main factors affect the development of science process skills.

The first one is curriculum. The most important element of science curriculum is the nature of science which allows students the ability to fully understand how science as a discipline functions. Miles (2010) argued that activities based in the process skills provide students an opportunity to view the true nature of science through the perspective of a scientist. While Rezba et al. devoted an entire textbook to SPS and a sub-section to show how the science process skills help teach the nature of science (Rezba et al., 2003). Moreover, Burke and Williams (2008) designed a program by infusing thinking skills into the curriculum to enhance thinking skills through science curriculum among students aged 11-12 years. Besides, they investigated how the range of thinking skills increased in performance when students work collaboratively. Monhardt and Monhardt (2006) created a context for learning science process skills through picture books. Besides, Aktamış and Yenice (2010) investigated the level of science process skills of eighth grade elementary school students and they found that SPS attainment existing in science and technology curriculum were inculcated in the students in middle level.

And the second one, teachers. In several examples from the literature (Balfakih, 2010; Chien & Chang, 2012; Duschl, 1989; Germann, 1991; Rotgans & Schmidt, 2011; Tatar, 2011) teachers pointed out the fact that in the classroom, some changes regarding their roles are required. These studies reached the following common conclusions:

1. Teachers should not see themselves as the center of all activities, as the basic source of knowledge, or as the licensed experts.
2. Teachers should not merely convey the knowledge to their students, but rather they should reinforce research and motivate students to participate in classroom activities.

3. The teacher should prepare course contents and teaching methods by taking students' individual differences into consideration.

Gorman (2001) emphasized that if teachers' knowledge of SPS is minimal then they will be ineffective in promoting acquisition of science process abilities in their students. Moreover, Miles (2010) stated that science educators must develop teachers who are competent in the knowledge and teaching of SPS to consequently ensure that students get effective and valuable skills instruction. Several studies have been conducted with pre-service teachers, to examine the relationship between science process skills proficiency and teachers' effective teaching, cognitive development and lesson planning (Hafizan et al., 2012; Kose & Bilen, 2012; Tatar, 2011).

Third, teaching methods and instructional design in science education. Students should have the opportunity to begin thinking like scientists by engaging in the process of science instead of merely ingesting the products of the scientific disciplines (Miles, 2010). The teaching of curriculum requires teachers to choose appropriate teaching methods to engage students' active participation in the learning process (Vebrianto & Osman, 2011); in the same context, Chien and Chang (2012) argued that we need to modify a varied range of educational media to improve the teaching and learning process. Besides, Lati et al. (2012) identified that the science inquiry learning process effectively enhanced students' learning achievement and integrated science process skills. Ibrahim (2006) conducted a study to investigate the effect of hands-on activity approach on science process and attitude toward science and found that the students taught by this approach showed better performance on the science process skills test (SPST) and attitude toward science scale (ATSS). In the same area, Thitima and Sumalee (2012) designed a model for enhancing scientific thinking among sixth grade students; they found a high relationship between the model and learners' scientific thinking abilities. The important factors affecting development of SPS can be summarized in Figure 2.2.

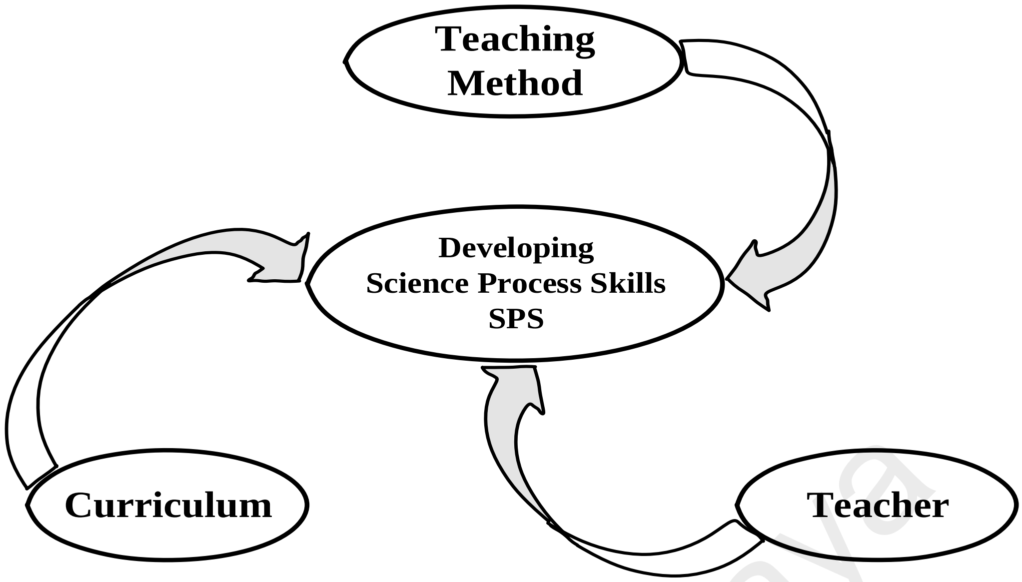



**Figure 2.2:** Factors Affecting Development of (SPS)

### 2.4.7 Test for Measuring Science Process Skills (SPS)

Researchers have used varied tests for evaluating students' science process skills (SPS). Firstly, Wise and Burns developed a test for science process skills in 1979 which contained 35 items; the average score of students from the science process skills test was from 0-35. The SPS level of students who obtained below 12 points from the test is regarded as low level; from 12-24 points' medium level and above 24 points accepted as high level (Aktamis & Yenice, 2010). This test was used by other researchers to investigate the level of SPS among students (Duran & Özdemir, 2010; Rowicki & Reed, 2006).

Feyzíoglu, Demírdag, Akyildiz, and Altun (2012) developed a test for measuring the level of SPS among 8th grade students which consisted of 36 multiple choice questions. The test included skills, such as defining variables, formulating hypothesis, operational definition, organizing data and interpreting. For the same grade Bilgin (2006) developed a test of SPS consisting of 30 items in multiple choice format which included observation, measurement, inference, prediction, operational definition, controlling variables, interpreting data and testing hypothesis. Some researchers developed a test for measuring integrated science process skills (ISPS). Aydinli et al. (2011) developed a test for investigating the level of ISPS among 8th grade students which consisted of 12 multiple choice items. In the same construct Shahali and Halim (2010) developed a test for ISPS which consisted of 30 multiple choice items to test performance on a set of ISPS associated with planning investigation. Fewer researchers have developed a test for investigating the level of basic science process skills (BSPS) among students; for example, Vebrianto and Osman (2011) developed a test investigating the effect of various constructive teaching media in science to measure BSPS among secondary students. The test consisted of 30 objective questions under four constructs: observing, predicting, communicating and inferring.

After reviewing a number of studies that used tests for measuring science process skills as a tool to achieve research purposes, we found that all of the researchers used multiple choice format for measuring the level of SPS and the number of items that have been used in the previous studies were between 25-30 items; in addition, most researchers used BSPS more than ISPS in measuring the level of SPS among students in elementary and secondary schools.

## 2.5 Higher Order Thinking (HOT)

Thinking is a general and extensive term used to describe intellectual functions. Because thinking is a mental process, it cannot be observed directly, but some action reflects thinking and this is known as cognitive skill (Özgelen, 2012). There are two types of cognitive skills; lower order thinking skills (LOTS) and higher order thinking skills (HOTS). In particular, the skills that involve acquiring knowledge and understanding knowledge are categorized under LOTS, while the skills that require students to apply and evaluate knowledge are known as HOTS (Jong et al., 1998; Nastasi & Clements, 1992; Yao, 2012). According to Barak and Dori (2009), HOT can be conceptualized as a complex mode of thinking that often generates multiple solutions, which involves applying multiple criteria, uncertainty and reflection. Newman (1990) distinguished between lower and higher order thinking. His definitions were derived from observations in classrooms and interviews with teachers and department chairs in five high schools selected because of their departmental efforts to emphasize higher order thinking in social studies classes. Newman concluded that lower order thinking demands only routine or mechanical application of previously acquired information such as listing information previously memorized and inserting numbers into previously learned formulas. In contrast, higher order thinking, according to Newman is challenging the student to interpret, analyze, or manipulate information.

Newman makes the important point that since individuals differ in the kinds of problems they find challenging, higher order thinking is relative; a task requiring higher order thinking by one individual may require only lower order thinking by someone else. Accordingly, "to determine the extent to which an individual is involved in higher order thinking, one would presumably need to know something about the person's intellectual history". In summary, there is a difference between lower and higher order thinking. While the two may be taught together in the classroom, for a given individual the need to use HOT will depend upon the nature of the task and the student's intellectual history, and how the teacher offers the problem to the students. However, it is not safe and hence not desirable to assume that teachers know or have been taught, how to teach higher order thinking skills (Yao, 2012). Therefore, it is necessary to carry out further research to describe how to teach such skills and how to incorporate the findings from that research into in-service and pre-service preparation programs (Hmelo & Ferrari, 1997).

### 2.5.1 Developing Higher Order Thinking Skills (HOTS)

A central goal of science education is to help students to develop their higher thinking skills in order to enable them to face the challenges of daily life, by enhancing students' cognitive skills such as critical, reasoning, reflective and science process skills (Davidson & Worsham, 1992; Zachariades et al., 2013). Fostering HOT among students of all ages is considered as an important educational goal. However, teachers often believe that this important goal is not intended for all students (Zohar, Degani, & Vaaknin, 2001). The common belief among teachers is that tasks requiring HOT are appropriate only for high achieving students, whereas low achieving students, who can barely master the basic facts, are unable to deal with such tasks (Zohar, 1999).

Yao (2012) asserted that one of the recommendations of the National Research Council's study (NRCS) on facilitating HOT among students is that teachers must create an environment in which students feel comfortable sharing their ideas, inventions and personal meaning. According to Miri, David, and Uri (2007), there are two steps for improving HOTS among students. First, is to create an environment for students to explore more about the complex problems by asking open-ended questions. Second, is creating opportunities for all students to think about their own thinking through group activities. However, research advocated that there is a natural progression in thinking from lower forms to higher forms with age and experience (Zohar & Dori, 2003). This means that the lower level mastery of basic facts and skills plays a critical role in supporting the development of HOT.

### 2.5.2 Socio -Demographic Factors and Development of (HOT)

Research emphasized that development of students higher order thinking skills is affected by sociodemographic characteristics of both teachers and students. A study conducted by Hamzeh (2014) on mathematics teachers teaching strategies use and its relationships with teachers' gender, experience, and scientific level. The results showed that there were no significant differences ($p \leq 0.05$) in the teaching strategies use related to teachers' gender, but there were significant differences in the teaching strategies use related to teaching experiences factor. The results also showed significant differences in the teaching strategies use related to scientific level of mathematics teachers, especially of the post graduate teachers. In addition, Tuncer &Ozeren (2012) investigated the views' of prospective teachers on problem solving and reflective thinking skills associated with their gender. Reflective thinking skill scale towards problem solving developed by Kızılkaya and Aşkar (2009) was used. Scale consisted of 14 items and 3 sub-dimensions (Questioning, Evaluating and Causation). The result of their study showed that, there was a significant difference between prospective teachers' skill levels of reflective thinking towards problem solving, in terms of gender in all dimensions of the scale. This finding contradicts the finding of Kızılkaya and Aşkar (2009) cited in Tuncer &Ozeren (2012) which indicates that there was a significant difference in terms of gender, in the total score of reflective thinking skills towards problem solving. Besides, the literature generally agreed that female teachers tend to use teaching techniques that are more interactive, such as class discussions, small-group discussions, and group projects. Such approaches are consistent with anti-hierarchal organization and other elements of feminist pedagogy. While male teachers  would be more likely to use less personal approaches such as focusing on teaching scientific concepts Miles (2010). Moreover, Bülent, Mehmet, & Nuran, (2015) investigated science teachers' science process skills in terms of variables such as gender, in service training in science process skills. The finding of their study showed that there was no significance difference between teachers' science process skills in terms of gender and experience; while, the overall findings indicated that female science teachers with 1-5 years of experience had higher scores than male science teachers who had more than five years of experiences in teaching science.

In terms of student's demographic factors, research advocated that student's level of cognitive skills also affected by sociodemographic factors such as gender, parent's occupation and monthly income. Regarding students gender, research showed that female's students have higher levels of SPS than males ( Aktamis & Yenice, 2010; Ayan & Seferoglu, 2011; Çakır & Sarıkaya, 2010; Karar & Yenice, 2012; Kaya et al., 2012). Moreover, Karar and Yenice (2012) investigated that students' cognitive skills also different according to the gender, education level and occupation of parents. Furthermore, a number of studies found positive relationship between the level of SPS and education level of parents, their jobs and school type (Ayan & Seferoglu, 2011; Çakır & Sarıkaya, 2010; Aktamis & Yenice, 2010). Moreover, Abdullah & Osman (2010) investigated primary students' scientific inventive thinking skills such as managing complexity, self-direction, curiosity, creativity, risk taking, higher order thinking and sound reasoning in science education. 500 (215 male, 285 female) of Year 5 students in Brunei were involved, the findings advocated that there were significant differences on students' inventive thinking skills with regards to their gender, as the female students performed better in their science inventive thinking skills compare to male students. Besides, the students had scored low mean on creativity and higher order thinking skills in science among male and female. In addition, research found that monthly family income also has a positive effect on the level of science process skills (Aktamis & Yenice, 2010; Ayan & Seferoglu, 2011; Çakır & Sarıkaya, 2010; Karar & Yenice, 2012; Kaya et al., 2012). Based on the above discussion, the research showed that sociodemographic characteristics have an effect on cognitive skills both on students and the teaching strategy use by teachers. Therefore, in this study the students level of HOT in terms of their gender as well as the teaching strategies use by science teachers in terms of their gender and years of experience were identified.

### 2.5.3 Bloom's Taxonomy of Cognitive Domain

The concept of higher order thinking (HOT) is derived from the Bloom taxonomy of cognitive domain in 1956 (Forehand, 2010). The cognitive domain involves knowledge and development of intellectual skills (Bloom, 1956). This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in developing intellectual abilities and skills. There are six major categories of cognitive processes, starting from the simplest to the most complex. Bloom categorized intellectual skills into six cognitive levels: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 2006; Clark, 2010; Yahya, Toukal, & Osman, 2012) as in Figure 2.3.

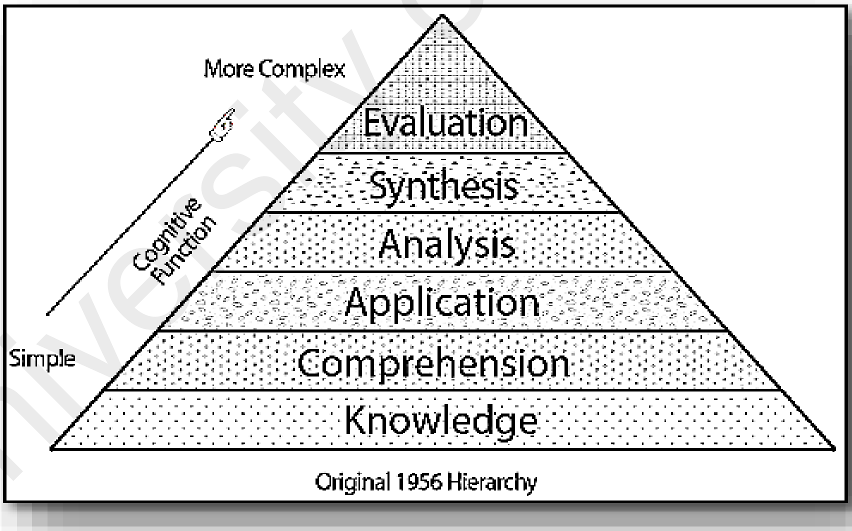



**Figure 2.3:** Bloom Taxonomy of Cognitive Development

The categories in Bloom's taxonomy for cognitive development are hierarchically ordered from concrete to abstract (Pappas et al., 2012). The hierarchical progression identifies the lower level to higher level of cognitive processing (Clark, 2010), as the first three levels of Bloom's taxonomy require recognition or recall of information such as knowledge, comprehension and application have been regarded as lower level of thinking skills. Whereas the other three levels of Bloom's taxonomy are the levels that require students to use higher cognitive skills and foster their learning performance (Forehand, 2010; Yahya et al., 2012). Specifically, information recall would be an example of a lower order cognitive pattern, or thinking skill, whereas analysis, evaluation, and synthesis would be considered higher order thinking skills. Indeed, learning experiences focused around analysis, evaluation, and synthesis, develop skills in problem solving, inferring, estimating, predicting, generalizing and creative thinking (Wilks, 1995), which are all considered as higher order thinking skills. Other examples of such skills include: question posing, decision making, and critical and systems thinking. However, based on the research into the cognitive domain among secondary school students, the first three categories of the Bloom taxonomy, knowledge, comprehension and application measure the students' lower level of thinking skills (LOTS). Whereas the others three levels of Bloom's taxonomy, namely analysis, synthesis and evaluation measure the higher levels of thinking skills or HOTS (Chang & Mao, 1999; Clark, 2010; Pappas et al., 2012; Yahya et al., 2012).

### 2.5.4 Teaching Higher Order Thinking (HOT)

Teaching is "the process of using appropriate method, teaching staff and material in order to reach in the most effective manner to the predetermined goals". Teaching is a conscious and purposeful activity (Uzun, 2002). Oriented to the predetermined goals and aimed to earn desirable behavior, teaching activities usually take place in the institutes of education. Planned, controlled and organized teaching activities that occur in schools are called instruction. Research asserted on the importance of encouraging students to use their higher order thinking skills in the classroom because they have great benefits for students. The reasoning here is similar to the rationale for pushing knowledge into our long-term memory. First, information learned and processed through higher-order thinking processes is remembered longer and more clearly than information processed through lower-order, rote memorization. For example, the difference between memorizing a formula and explaining the derivation of the formula, the difference between memorizing the definition of a new word and internalizing strategies for discerning the probable definition of the word from its context. In each case, a student who has the latter-type of understanding will carry that knowledge longer. Moreover, students with the deeper conceptual knowledge will be better able to access that information for use in new contexts. This may be the most important benefit of higher order thinking. Knowledge obtained through higher order thinking processes is more easily transferable, so that students with a deep conceptual understanding of an idea will be much more likely to be able to apply that knowledge to solve new problems. Research plays an important role in developing strategies that foster the kind of deep conceptual understanding that is transferable to various academic contexts and real life problems (Davidson & Worsham, 1992; Gokhale, 1996; Zawilinski, 2009). In order to achieve this goal teachers should use effective teaching methods that require the students to use varied thinking skills (Chapman & Aspin, 2013; Voica & Singer, 2011). Research advocated that effective strategies for developing students' HOT should have the following characteristics:

**i-** Activating the student's prior knowledge; it is important to activate the student's prior knowledge because it helps them make connections to the new information they will be learning. By tapping into what students already know, teachers can assist students with the learning process.

**ii-** Using classroom activities; these will provide students with background science information, straightforward steps, and gives them the opportunity for hands-on inquiry for students seeking science inspiration. Many of these activities can be prepared and completed in a short time, making them easy to integrate into a classroom setting.

**iii-** Grouping approach, sharing experiences in small group activities will improve students' knowledge and help them to apply the acquired knowledge into real life situations.

**iv-** Assessment forms; science teachers should use different form of assessment such as alternative assessment and evaluation approaches.

Internationally several efforts focused on using effective strategies on the development and enhancement of HOTS, in which particular strategies such as inquiry, problem solving and learning cycle have been recommended to enhance students' HOT (Miri et al., 2007; Taasoobshirazi & Farley, 2013). Brief descriptions of the most popular teaching strategies in science in general are described in the following sections.

#### 2.5.4.1 Problem Solving Model

Problem solving can be defined as flexible thinking to develop skills needed to face challenges in everyday life (McGregor, 2007). Besides, Çalışkan, Selçuk, and Erol (2010) defined problem solving as a cognitive process requiring the memory to select the appropriate activities, employ them and work systematically in order to reach the best solution for the problem.

The problem solving model (PSM) was developed by Polya in 1945 (Walker, 2004). PSM consists of five phases as the processes are linear and hierarchic. Implementation of these phases in the science class required students to use basic thinking skills gradually to achieve integrated process skills in order to reach the solution for the proposed problem. The PCM phases can be defined as:

1- Defining problem: In this phase the teacher tries to engage students in order to pay attention to the lesson by defining a problem in several ways such as asking questions, showing videos, and pictures (Parham, 2009; Taasoobshirazi & Farley, 2013; Walker, 2004).

2. Developing hypothesis: The students use an inductive process in an attempt to develop a tentative answer to oral or written questions (Batı et al., 2010; Legare et al., 2013; Walker, 2004).
3. Testing hypothesis: In this phase the students use the deductive process (Çalışkan et al., 2010) in which they would locate additional data relevant to the hypothesis being tested.
4. Deriving a conclusion: This report may be individual, small group or class activity on the basis of reasoning from the evidence that will help students to reject, accept or modify the hypothesis (Anderson, 1993).
5. Formulating generalization: in this phase, the student try to apply the new conclusion in a new situation, by conducting this solution to another problem in another subject or in their daily life (Beresford, 1999).

Many researchers emphasize the role of problem solving in developing students' reflective thinking skills (Duff 2004; Tuncer & Ozeren, 2012; Zippay, 2010), while others used the problem solving model for enhancing basic and integrated science process skills (Akinbobola & Afolabi, 2010; Aktamış & Yenice, 2010; Taasoobshirazi & Farley, 2013; Thitima & Sumalee, 2012).

Moreover, learning cycle strategy is also found to be an effective strategy for promoting HOT since one of the foundational premises of constructive learning is that learners have to construct their own knowledge individually and collectively (Dogru, Atay, & Tekkaya, 2008; Voica & Singer, 2011).This strategy is explained in the next section.

#### 2.5.4.2 Constructive Learning Model

Constructive learning model is derived from the learning cycle model developed by Kurplus with three stages; exploration, concept development, and concept evaluation to enhance thinking skills among students (Singer & Moscovici, 2008; Yager, 1991). Loucks-Horsley modified the learning cycle model into four stages based on the science technology society (STS) approach and introduced constructive learning model (Loucks-Horsley, 1990; Yager, 1991). The model consists of four stages, namely:

**Engagement**: The activities in this stage capture the students' attention, stimulate their thinking, and help them access prior knowledge. The role of the teacher is to present a situation and identify the instructional task for creating interest and curiosity among the students about new concepts.

**Exploration**: In this stage students are given time to think, plan, investigate, and organize collected information. Exploration activities are designed so that all students have common concrete experience upon which they continue building concepts, process and skills. During this stage students explore objects, events or situations to create something new.

**Explanation**: Students are now involved in analyzing their explorations, in which they are encouraged to put observations, questions, and explanations of concepts in their own words. Teacher asks for evidence and clarification of their explanation. Students listen critically to one another's explanation and to the teacher. Their understanding is clarified and modified by reflective activities.

**Elaboration**: This stage gives students the opportunity to expand and solidify their understanding of the concept to new situations. Teacher reminds students of alternative explanations and to consider existing data and evidence as they explore new situations creatively. Teacher tries to strengthen their mental models through varied examples and applications for further insight and understanding.

Shatnawi and Abedi (2006) conducted a study on the constructive learning model and they found that the teacher role in the constructive learning model stages as a facilitator, encouraging students to propose hypotheses and to analyze the validity of previously gained personal and academic knowledge. By offering suggestions for problem solving and for shaping the instructional model itself, the teacher also encourages students to reflect on the process.

#### 2.5.4.3 The 5E Learning Cycle Model

Grounded on the learning cycle, the 5E model was developed by Robert Bybee. According to Bybee (1997), the foundation of this model was influenced by the works of German philosopher Freidrich Herbart. Furthermore, in his view, this model is based on the work of John Dewey and Jean Piaget. As a very frequently used model in the constructivist learning approach, the 5E learning cycle model name comes from the number of its stages and the initials of each stage. These five stages are:

**Engagement:** The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through using short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.

**Exploration:** Exploration experiences provide students with a common base of activities within current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, design and conduct a preliminary investigation.

**Explanation:** The Explanation stage focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This stage also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this stage.

**Elaboration:** Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.

**Evaluation:** The evaluation stage encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives. Since the late 1980s this instructional model has been used for designing BSCS curriculum materials. The model describes a teaching sequence that can be used for entire programs, specific units, and individual lessons. The BSCS 5E Instructional Model plays a significant role in the curriculum development process as well as the enactment of curricular materials in science. Researchers have noted that the 5E Instructional Model encourages students to use cognitive skills such as exploration of scientific knowledge and sharing of ideas in the context of biology (Bybee, 2004; Bybee et al., 2006). However, after reviewing the strategies that have been used in the past literature to improve students' knowledge and enhance their higher order thinking skills were focused largely in using activities that encourage students to use science process skills. Whereas in this study, the learning activities of the HOT teaching model would focus on enhancing students' reflective thinking skills along with science process skills in order to further give them the opportunity to reconstruct their own thinking.

Regarding the strategies used in the context of the Iraqi Kurdistan region in science, as mentioned in chapter one, the educational system reform and revamping of the curriculum involved major changes, especially in science education. To support these major changes, several other changes were implemented or encouraged in teacher instructional methods, retention of students, and student assessment. Teachers were encouraged to revise and reform their classical teaching method, which was based on memorization, and to adopt student-centered teaching techniques, emphasizing the development of creative and analytical skills. However, research showed that the science teachers were still following the traditional teaching methods focused on memorizing science concepts, for the following reasons (Anthony et al., 2015; Vernez et al., 2014):

First, practicing teachers need more knowledge to teach the new curriculum, as the existing IKR teaching force as a whole is not adequately prepared to teach the new curriculum. Several issues are involved, ranging from a lack of needed knowledge and training, to teachers being compelled to teach outside their specializations, to difficulties in applying the student-centered learning methods required by the new policy.

Second, many practicing teachers lack the required knowledge to effectively teach the new curriculum**.** Much of the subject matter in the new curriculum is unfamiliar to practicing teachers, who are accustomed to teaching the traditional curriculum, as they were trained to teach during their years of preparation. For example, teachers lack familiarity with some of the new concepts and terms they are now required to teach. Supervisors from the Ministry put forth a similar view, observing that teachers often have a very weak command of their subjects.

Third, practicing teachers receive too little training in pedagogy and teaching methods. With the introduction of the new curriculum, the MOE has begun training teachers in five- to ten-day training sessions, mainly to familiarize them with the new textbooks. This is unlikely to be sufficient. There appears to be no deliberate alignment between the content of the new curriculum and the set of subject matter courses in the teacher colleges. Besides, science teachers that are graduated from the science faculty have not received any training in pedagogy and teaching methods before they enter a classroom. Nor are they trained in the new curriculum. Consequently, they may not be adequately prepared to teach effectively.

Therefore, the research revealed that basic education students are lacking in higher cognitive skills (Anthony et al., 2012; UNESCO, 2011; Vernez et al., 2014). According to Yao (2012) the development of students' HOTS requires strategies where learners are given opportunities to develop knowledge structures or representations that will allow them to retrieve and use the information in the future. The teachers rarely make effort to sustain students' flow of higher-level thoughts, perhaps due to teachers' incompetency or disinterest in pursuing learning outcomes other than learning content-specific goals. Attention is needed at the planning and implementation levels because recurring inconsistencies in curriculum development and enforcement will continue to keep the effective teaching of HOT in the classroom as pure rhetoric (Zohar, 2013). Therefore, this study aimed at developing a HOT teaching model for basic education students in science in the context of the Iraqi-Kurdistan region.

## 2.6 Theoretical Framework

The theoretical framework for the current study is divided into two main parts and consists of several theories and models to guide the study. The first part elaborates the theories that describe the process of developing higher order thinking through discovery learning. The second part frames the development of the HOT teaching model that serves as a vital representation on how the model can be implemented by science teachers in supporting basic education students in science learning through improving their HOT.

The first part starts with the cognitive learning theories that describe the process of learning based on the scope of this study. These theories describe how students learn cognitive skills from basic skills to more complex skills through discovery learning. Based on these theories the second part of the theoretical foundation dealt with the development of the model. The discussion consists of elaboration of the model in determining suitable stages and sub-stages for each stage that formed the model elements.

### 2.6.1 Cognitive Learning Theories

This section of the study is to describe theoretically the process of cognitive development through teaching that facilitates the development of HOT among basic education students in science learning. The cognitive theories concerned with the development of thought process influence how the students understand the scientific concepts and interact with the world, as the outcome of cognitive development is thinking. Thus, Bruner's cognitive theory has been employed as the learning theory to guide how basic education students achieve development in their HOTS through discovery learning. Jerome Bruner's cognitive development theory was created in 1966. A major theme of Bruner's theory is that learning is an active process that helps learners to build new ideas and concepts based on their prior knowledge through converting information. The process of interconnections between new experiences and the prior knowledge results in the reorganization of the cognitive structure, allowing learners to extend the information given and create new meanings for themselves.

Bruner has suggested that children progressively acquire cognitive skills, which he refers to as modes of thinking. These modes are the ways in which knowledge is kept and encoded into memory. The modes are combined and only loosely successive as they "translate" into each other (Olson, 2007). Based on these ideas, Bruner proposed discovery learning, which provides students with the opportunity to construct their own meanings rather than simply memorizing. Thus, this type of learning focuses more on enhancing students' HOT, rather than their LOT. The process of discovery learning goes through three stages. First, the inactive stage, where the teacher presents a concept involving direct operation of objects without any interior representation. Second, the iconic stage characterized by interior representation of external objects such as re-introducing the concept using some form of imagery. Third, the symbolic stage involving illustration of external objects through words, formulas, or other symbolic means (Bibergall, 1966; Künsting, Kempf, & Wirth, 2013). If the teaching process goes through these stages, the students' ability to think at a higher level will be improved, using prior knowledge to integrate the new information. This is done through categorization and problem solving, which consequently speed up the students' cognitive processes.

Past studies have revealed the impact of discovery in learning science; for example Nigam (2004) did research on the effects of direct instruction and discovery learning in early science instruction. The findings indicated that many children learned from discovery learning, and had richer scientific judgments. Therefore, these results support predictions derived from the recognised advantage of discovery approaches in teaching young children basic procedures for early scientific investigations. Moreover, Balim (2009) investigated the effects of discovery learning on students' success and inquiry learning skills, and concluded that discovery learning increased students' success and inquiry learning skills more than the traditional method of teaching.

In order to understand the process of developing science process skills (SPS), Gagne's taxonomy of learning hierarchy is adopted for this study. Gagne's theory of learning hierarchy, learning structure and learning prerequisite was developed in 1972

(Strauss, 1972). Gagne categorized three major outcomes of the learning process which are cognitive domain, affective domain and psychomotor domain (Johnson, 2008; Richey, 2000; Yen, 1987). A learning hierarchy refers to a set of component skills that must be learned before the complex skills of which they are a part can be learned (Dick, 1980). For example, students must already be able to distinguish triangles from other shapes then they will be able to identify the characteristics of triangles (Driscoll & Driscoll, 2005). Gagne assumed that the prerequisite knowledge for the concepts and principles in the hierarchy could be obtained only if the students have certain underlying capabilities; these he called intellectual skills or science processes skills (SPS) (Oloruntegbe, 2010). According to Gagne these skills are needed by students to practice and understand science. Gagne divided these skills into five hierarchy subcategories from LOTS to HOTS (Gagne, 1964; Gagnon et al., 2003). Gagne's Domains of Learning Intellectual Skills requires the learner to perform some unique cognitive activity. Gagne divided Intellectual Skills into the following subcategories, depending on the complexity of the mental processing involved. This is a hierarchy, which means that each higher-level skill requires the lower skills as a prerequisite.

First, discrimination is the ability to distinguish on the basis of one subject from another, but they still are unable to name the concept. Second, concrete concept; concept learning occurs after discrimination learning is complete. Concrete concepts are the simplest of the two concept types and consist of classes of object features, objects, and events. Some relationship is involved such as up, down, far, near, higher and lower. The performance or learning outcome achieved from mastery of concrete concepts is the ability to identify a class of objects, object qualities, or relations by pointing out one or more examples or instances of the class. Third, Defined Concepts; Concepts not only require identification, but also definition. Defined concepts require a learner to define both general and relational concepts by providing instances of a concept to show its definition. For example, if learners are able to explain the concept alliteration, they must define alliteration, and then be able to identify the components of alliteration and to provide specific examples of alliteration. Fourth, rule using is applying a rule to a given situation or condition by responding to a class of inputs with a class of actions. Relating two or more simpler concepts in the particular manner of a rule. A rule states the relationship among concepts. (Driscoll & Driscoll, 2005; Mayer, 1998; Richey, 2000). According to Gagne, students must use simple intellectual skills (e.g., classifying, inferring, using number), in a hierarchy method from simple or lower order thinking (LOT) to complex skills until they are able to use integrated process skills which are HOT (Yeany, Yap, & Padilla, 1986). Finally, problem solving skills or higher order rule which are in the higher level of Gagne's intellectual skills. Higher-order rules are the process of combining rules attained by learning into more complex rules used in problem solving. When attempting to solve a problem, a learner may put two or more rules together from different content in order to form a higher-order rule that solves the problem. A higher-order rule differs in complexity from the basic rules that compose it. Moreover, problem solving using higher-order rules occurs in writing paragraphs and using scientific principles, and applying laws to real life situations (Helfrich, 2011; Yang, Han, Liu, Tong, & Chen, 2012).

Thus, the adoption of Gagne's theory in this study could guide the variety type of SPS including basic and integrated science process skills to be included in the model; the model could be theorized according to the five stage of Gagne theory for learning hierarchy.

### 2.6.2 Theoretical Framework of the Development Model

This section discusses the theoretical framework in framing the development of the HOT teaching model for basic education students in science learning. This section elaborates further explanation on respective theories and models to guide in the selection of elements (stages and sub-stages) to develop the model. The discussion begins with the definition of model stage followed by the adoption of the theory and teaching models to guide in the selection of appropriate elements to be included for the HOT teaching model.

Model stages: according to Ali (2007), model stages are the specific steps for teaching a particular subject. It shows an interaction between teacher, learners and an environment that is carried out, in response to a task with an intended learning outcome. Since the study focuses on improving students' HOT in science learning, the model stages shows the science teacher the practical steps to teach a particular scientific concept in aiding to improve students' cognitive skills. In order to make the HOT teaching model a practical guide to be implemented in science classrooms, the sub-stages for each stage will be identified. Selecting appropriate stages as well as sub-stages for each stage is vital for successful implementation of the HOT teaching model. Thus, suitable framework need to be identified to guide the selection of model elements. The following section elaborates on Experiential learning theory and the IMSTRA teaching model to guide in the process of selecting appropriate elements to be included in the HOT teaching model.

#### 2.6.2.1 Experiential Learning Theory (ELT)

David Kolb (1984) has built experiential learning theory in reflective thinking (RT) based on roots of cognitive development theory by Dewey (1933), Piaget (1970) and Lewin's theory in social psychology 1951 (Dellaportas & Hassall, 2012; Kolb, 1984; Loo 2004). According to ELT, knowledge results from the combination of grasping and transforming experience (Baker et al., 2007). Hence learning is defined as the process whereby knowledge is created through the transformation of experience and individuals do not learn in the same manner all the time (Manolis et al., 2013). Kolb established the cyclic learning model (CLM) describing how individuals have direct experience upon which they can reflect in order to recognize the importance of experience, participation and interaction with the environment (Dellaportas & Hassall, 2012). This model has been used as a framework by many researchers (Ataöv & Ezgi Haliloğlu Kahraman, 2009; Bergsteiner, Avery, & Neumann, 2010; Demirbas & Demirkan, 2007; Garner, 2000; Holman, Pavlica, & Thorpe, 1997; Lawson & Johnson, 2002; Mainemelis, Boyatzis, & Kolb, 2002; Manolis et al., 2013).

**The process of learning in (ELT) is cyclic in nature as follows:**

**1-** Concrete Experience (Engagement): Students begin the learning process by experiencing some activity or event that has the potential to add or change the skills of the students and by initiating new experiments. The main objective of this stage is to activate the prior knowledge of the students in order to engage them in the learning process (Y. Kim, 2005; Manolis et al., 2013).

**2-** Reflective Observation (Exploration): In this stage, the students become involved in the experiment. Therefore, as they observe the new situation in Stage I, the students organized their perceptions based on prior learning. This process requires the student to reflect on experiences and to think about the present experience as either appropriate for previous patterns or not (Bergsteiner et al., 2010).

**3-** Abstract Conceptualization or thinking process (Explanation): Through this stage, the students are encouraged to connect new experiences to the past knowledge through analyzing, developing theories or hypotheses, and testing these hypotheses to explain observations (Konak, Clark, & Nasereddin, 2014).

**4-** Doing' Stage (Application): In this stage, the students plan to apply their new knowledge in a new situation by doing and using theory to make a decision and solve problems (Powell & Wells, 2002) .

Regarding the cyclic learning model (CLM) application in the science classroom, Moon (2005) pointed out that activities in CLM serve to make sense of experiences. They also improve the quality of the learning outcome, promoting a range of generic skills including SPS, RT, and problem solving skills, all of which are examples of HOT. Thus, the adoption of the experiential learning theory in this study could aid the selection of reflective thinking skills (RTS) as well as the selection of stages and sub-stages for the HOT teaching model to be guided by the CLM. This would allow the determination of sub-stages that satisfy all stages used in the model to incorporate improvements in teaching of HOT in science education.

#### 2.6.2.2 IMSTRA Model

In the context of this study, the researcher adopted the IMSTRA model for science learning to conceptualize the sub-stages of the HOT model. The IMSTRA model is a teaching and learning cycle model for science and mathematics learning focused on Immersion, Structuring, and Applying. This model is constructed based on the learning cycle model by Kurplus with three phases to enhance students' cognitive skills (Fuller, 2002; Orion, 1993; Renner, Abraham, & Birnie, 2006). The purpose of the IMSTRA model is to foster students' learning. Within the IMSTRA framework, the students are involved in a multitude of inductive and deductive pathways that help them move with ease among concrete or semi-concrete experiences, and abstract patterns. Furthermore, during this process, students are forced to use higher order thinking skills (HOTS). The IMSTRA framework can be seen in Figure 2.4. The model emphasizes the close relationship between the teacher's targets and the students' activities during the inquiries.

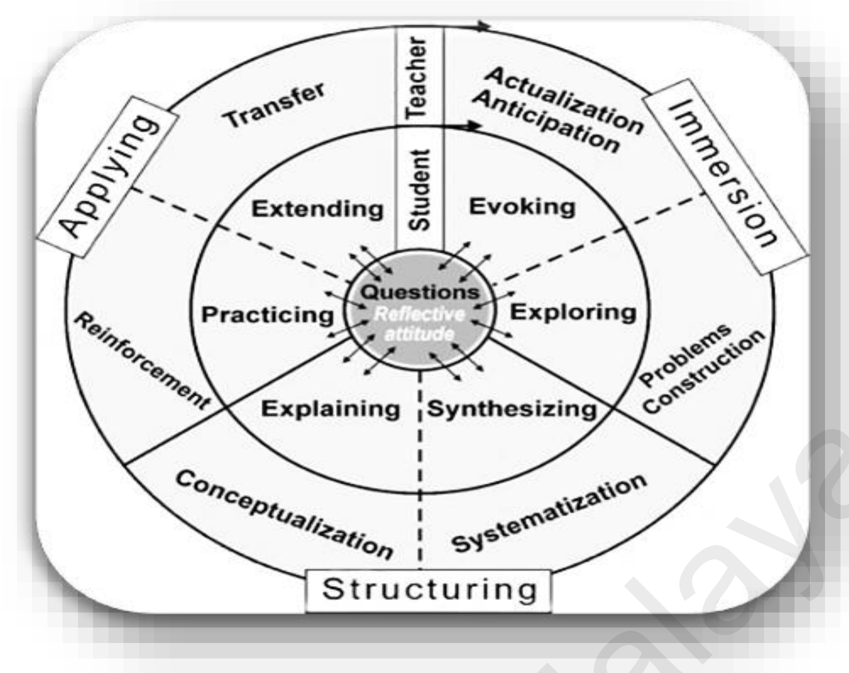



**Figure 2.4:** IMSTRA Model for the Teaching and Learning Cycle
(Singer & Moscovici, 2008)

The IMSTRA model consists of three phases in its application in the science classroom as follow:

**Immersion phase:** During this phase, students get immersed into the problem being addressed and use previous knowledge, seek more information, plan and perform experiments, and, based on all these resources and processes, identify tentative pattern(s). The students also explore their own knowledge and anticipate the knowledge development through planning personal projects. The teacher's role during this phase is to propose questions that the teacher might ask or be asked, and actions that will lead to the expected action performed by the students. There are two sub-phase for this phase, Anticipation and Problem construction. The teacher scaffolds students' research by providing necessary suggestions, encouraging students' explorations, and helping them to record data (Singer & Moscovici, 2008). As students acknowledge safety rules and remain focused on solving the problem, the teacher should abstain from leading them to his or her own solution (Singer, Ellerton, & Cai, 2013).

In terms of students' learning activities, the Immersion phase can be divided into two interconnected sub-phase: Evoking, and Exploring. During the Evoking sub-phase, students bend their previous knowledge to the problem, plan, perform, and analyze their investigations while always addressing the problem to be solved. During the Immersion phase, the students learn to select pertinent knowledge from what they know realizing that personal knowledge might prove insufficient and deciding to look for resources and to judge resources in terms of reliability of information. Students also learn to correlate between variables and experimental results, the creation and expression of a complex solution to a problem.

**Structuring phase:** During this phase, students move to another level of understanding when they interpret their concrete experiential results from the Immersion phase and adjust the pattern. They explain the claim developed during the previous phase in terms of examples and create new situations in order to challenge their own claim. In this phase, the teacher supports students by helping them synthesize observations, summarize findings, and explore inferences during the Systematization sub-phase (Singer & Moscovici, 2008). During the Conceptualization sub-phase, the teacher helps students use the new terminology, generalize conclusions, and expand their findings beyond the specific problem that they researched, into related issues. Synthesizing the sub-phase involves the students in the process of identifying and contrasting patterns, helping to extend their findings into more generalizable statements. Explaining the sub-phase requires students to connect the concrete exploration to a more abstract model that describes the results of explorations and challenges findings through concrete and hypothetical examples and counterexamples. The students define the concepts through interpreting the results of their activity and reinforce them through connection with other activities. In terms of skills, during the Structuring phase, students learn how to differentiate between opinion and fact, learn about the limitations of experiments, and about the use of appropriate language when sharing findings.

**Applying phase**: During this phase, students learn to use the abstract pattern that they developed into related and unrelated situations; they modify their pattern to be more generalizable and applicable in a wider range of situations. They apply learned concepts and patterns to new situations by trying to solve existing problems, and by creating/describing new hypothetical or realistic situations that need solving (Singer & Moscovici, 2008). These processes lead to a more generalized pattern that identifies constraining elements. The teacher during the Applying phase is concerned with assessing students' understanding of the concepts developed and with the process of inquiry and its limitations. Teachers may also explicitly prompt students to think about aspects of their everyday life that are potentially relevant for further learning. In order to incorporate appropriate activities (sub-stages) for the HOT teaching model, the researcher proposed the selection of sub-stages by the experts guided by the IMSTRA model based on all phases of use in the model.

Based on the preceding explanation of HOT theories underlying this study, we investigate that these theories emphasize more on the teacher's role in developing students' HOT in which their role should not be teaching information by rote learning, but should be as facilitators of the learning process. This means that a good teacher will design lessons that help student to use various cognitive skills. To do this the teacher must give students the information they need, but without organizing it for them in order to engage students to use higher thinking skills through discovery learning.

## 2.7 Conceptual Framework

Based on the review of literature in higher order thinking skills and teaching models in science learning, review of theory of cognitive development and the theoretical framework of the study, the following section presents the conceptual framework of the study. The conceptual framework highlights the main variables underlying the development of the HOT teaching model for basic education students in science learning. Specifically this section aimed at conceptualizing the HOT in terms of reflective thinking (RT) and science process skills (SPS) through the development of the HOT teaching model. The conceptual framework is shown in Figure 2.5, which provides an overview of the following main aspects:

First, aim and scope of the study: The main purpose of the study was to develop a HOT teaching model for enhancing HOT among basic education students in science in terms of enhancing their reflective thinking and science process skills. This contributes to the body of knowledge on how HOT can be improved through effective teaching models.

Second, theoretical basis for the development model: based on the theoretical underpinnings of cognitive development of HOT, Bruner's theory is adopted for the study. However, in describing how RT and SPS are linked and enhance students' HOT, experiential learning theory and Gagne theory for learning hierarchy have been adopted for the study. Moreover, the conceptual framework proposes how these theories along with the cyclic learning model (CLM) and IMSTRA teaching model are employed to guide the design and development of the elements of the HOT teaching model.

Third, the methodology basis: the conceptual framework also included the models and approaches in each phase of the methodology. As for phase1, the Bloom taxonomy of HOT and IMSTRA teaching models are adopted to guide in the needs analysis phase of the study. The Fuzzy Delphi method (FDM) is adopted for phase 2, where the model is developed. The survey method using partial least square (PLS) approach is adopted for model evaluation in phase 3. Finally, the overall conceptual framework aims to demonstrate how the purpose of the study is fulfilled through the connection of the variables, theories and models to develop the HOT teaching model.

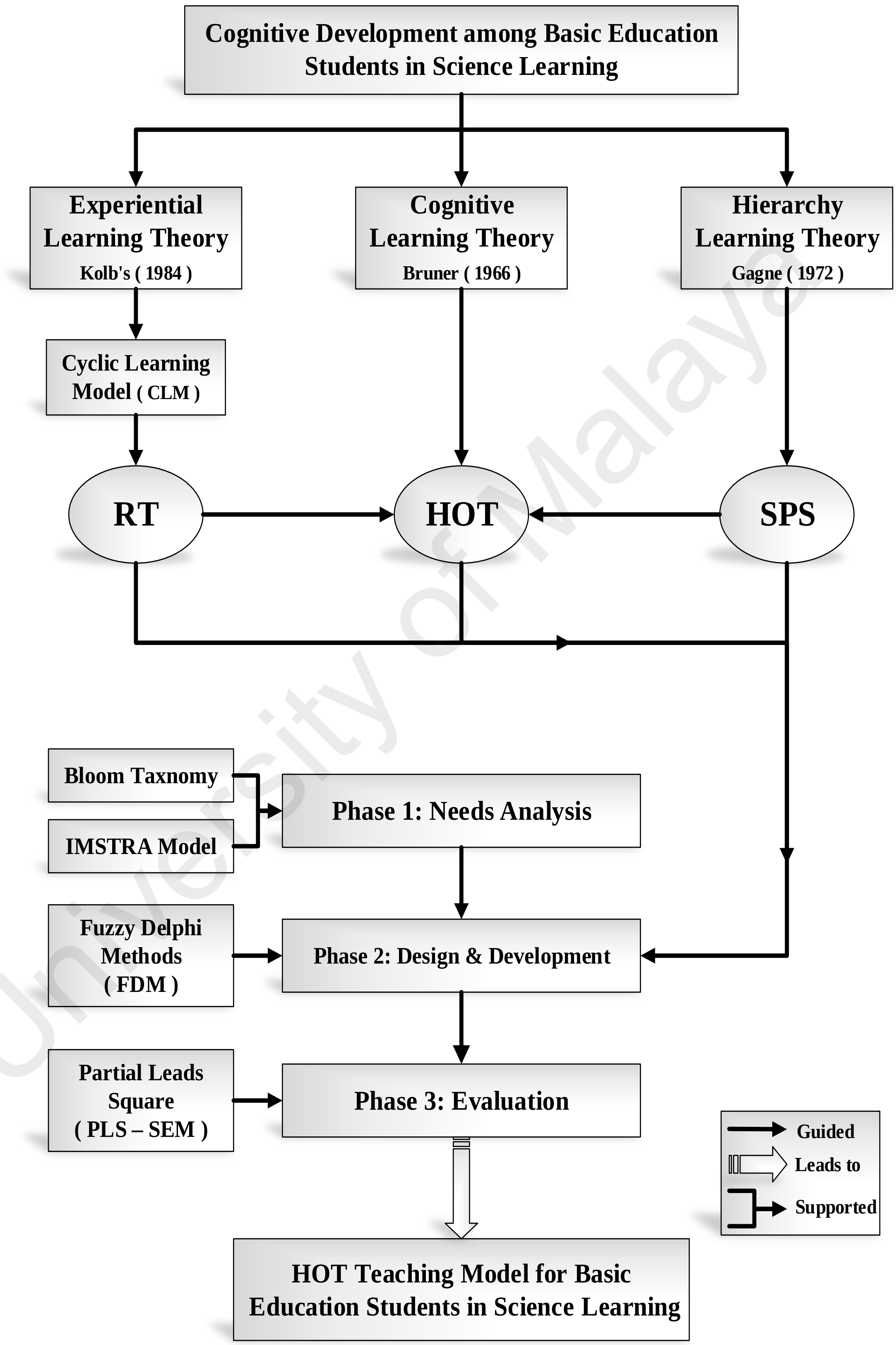



**Figure 2.5:** Conceptual Framework of the Study

## 2.8 Summary

Review of the literature on science education shows that reflective thinking and science process skills are important higher order thinking skills that should be cultivated among students. However, despite the importance of these two variables, they have not been explored more in previous research in science education. Based on the review of literature most of the studies focused on developing these skills among teachers and higher level school students, and they neglect the importance of these two cognitive skills among basic education students. Moreover, as a theoretical framework of the study, based on learning through discovery, Bruner's theory of cognitive development is adopted to describe how students could improve their cognitive skills through discovery learning. In addition, Gagne's theory for learning hierarchy is also adopted to describe the process of students' cognitive skills development. Furthermore, the theoretical framework for the HOT teaching model is also presented. In this section, experiential learning theory along with the IMSTRA model are adopted and presented to frame and describe the selection of elements for the model. Finally, the conceptual framework for the study is presented at the end of the chapter. The next chapter will provide an overview of the research methodology of this study.

# CHAPTER 3: METHODOLOGY

## 3.1 Introduction

This study was aimed at developing a HOT teaching model to enhance basic students' higher thinking skills in science learning. Using the developmental process, the central question to be answered in this study is:

What are the characteristics of the HOT teaching model that have potential to enable basic education students to acquire science process skill and reflective thinking in science learning? In order to answer this question, the design and development research approach is chosen and the research questions were formulated with a focus on the description of the general concepts of this research approach, and its application to the current study.

The subsequent section provided an explanation of aims, description of participants, data collection methods, and data analysis procedures applied in each phase. Finally, an overview of the research methods and instruments of the evaluation was presented.

## 3.2 Research Method

The study employed the design and development research approach (Richey & Klein, 2007) to develop the HOT teaching model for basic education students in science learning (Richey & Klein, 2007; Van den Akker, 1999). The design and development research approach have been used to design in past literature to develop interventions such as learning strategies, programs and products (Flink & Searns, 1993; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007; Ulrich, Eppinger, & Goyal, 2011). This justifies the use of this method in this study to satisfy the aims in the design and development of HOT teaching model.

Richey and Klein (2007) advocated that the method consists of three phases; needs analysis, design and development and evaluation of the program (intervention). Therefore, this study is conducted using these three phases. In short, phase one is the needs analysis phase which aimed at identifying the needs to develop the model. The findings of this phase formed the basis for developing the HOT teaching model for enhancing students' HOT in science. Phase two represents the main phase of the study, which is the design and development phase. In this study the Fuzzy Delphi method was used to develop the model based on experts' opinions. The final phase was evaluation of the model using science teachers' opinions. In the subsequent sections, the purpose for each phase of the methodology, selection of sample, description of instruments, data collection and data analysis for each phase are further elaborated.

### 3.2.1 Phase One: Needs Analysis

#### 3.2.1.1 Purpose

This phase aimed at identifying the needs to develop a HOT teaching model for enhancing basic education students' HOT in science in terms of identifying 7th grade students' level of HOT and strategies use by their science teachers. Overall four specific research objectives were formulated as follow:

1. To identify the students' needs in terms of identifying their higher order thinking skills level in science.
2. To determine the association between students' level of cognitive skills and their gender.
3. To identify the strategies used by science teachers to teach their students' HOTS.
4. To determine the association between sociodemographic factors such as (gender and experiences) and teaching strategies use among 7th grade science teachers.

### 3.2.1.2 Participants

According to Krohn (2008), students and teachers are the main resources of information of needs analysis. As the main aim of the study was to enhance basic education students' HOT in science learning through using effective teaching models, therefore, 7th grade basic education students and their science teachers in the Iraqi Kurdistan region represented the population of this phase. As indicated by the pervious literature the students in this period ($7^{th}$ grade) are in transition between childhood and adulthood, therefore during this period of time students experiences major changes occur in intellectual, emotional, socially and physically, they begin to shape their own thought and able to transfer it to new situation, therefore this study aimed to identify $7^{th}$ grade students need so as to help them to achieve their learning needs. As illustrated in (chapter 1), the overall three cities in the Kurdistan region are following the same educational program and share the same background characteristics. Thus, 7th grade students and 7th grade science teachers in government schools in Dohuk city are selected randomly. According to Raosoft sample size calculator software, that is available in the website http://www.raosoft.com/samplesize.html, for estimating sample size directly by entering the general population size, by sitting and limited to 5% of margin of error, with 95% confidence interval, and 50% of response distribution. Therefore, the total sample size needed for this phase is elaborated in Table 3.1.

**Table 3.1:** Participants for Needs Analysis Phase

| 7th grade students/teachers in Dohuk city for acadimic year 2013/2014 | 7th grade students | 7th grade science teachers |
|---|---|---|
| **Total** | 10341 | 389 |
| **Sample** | 371 | 194 |

According to Table 3.1 the required sample of 7th grade should be 371 students. However, this is the minimum sample required (Krejcie & Morgan, 1970), therefore the researcher chose 418 7th grade students in six basic schools (three boys schools and three girls schools) in Dohuk city. However, these schools were selected randomly and two classes for 7th grade were selected randomly from each of these schools. (69-70) students who are 13 years old (first year attending 7th grade) were selected in each basic education school in Dohuk city. Regarding selection of 7th grade science teachers. Using Raosoft sample size calculator software, the minimum number of science teachers that have to participate in this phase are 194 teachers; however, 212 science teachers who teach 7th grade teachers who have more than 10 years experiences in basic education (government schools) in Iraqi Kurdistan region in Dohuk city for academic year 2013/2014 were selected as the sample of this phase.

#### 3.2.1.3 Instrument

For the purpose of the study to develop a teaching model for enhancing students' HOT and in order to answer the two questions of the needs analysis phase, the researcher developed two instruments. In terms of determining the current level of students' HOT, the researcher developed a higher order thinking level test (HOTLT). With regard to identifying the strategies used by science teacher to teach 7th grade students HOT, the researcher also developed a teaching strategies use survey questionnaire (SUSQ). The following sections specifies on the needs analysis instruments.

**(a) Higher Order Thinking Level Test (HOTLT)**

The purpose of developing HOTLT was to determine the 7th grade students' level of cognitive development. This test was developed based on the cognitive domain of Bloom taxonomy that consisted of six levels of cognitive skills (see chapter two). According to the research (Pappas et al., 2012; Scott, 2003; Yahya et al., 2012; Zohar & Dori, 2003) the first three levels of Bloom's taxonomy, knowledge and comprehension and application measures students' lower order thinking skills LOTS, whereas the upper three levels which are analysis, synthesis and evaluation measures students' HOT.

After reviewing tests of HOT (Miri et al., 2007; Newmann, 1990; Pappas et al., 2012; Paul & Nosich, 1992; Zohar, 2004), the researcher constructed a total of 25 test items in the form of multiple choice questions, which had been used in previous studies. The distribution of HOTLT items can be seen in Table 3.2.

**Table 3.2:** The Distribution of HOTLT Items

| HOTS | Items No. | Items | Percentage |
|---|---|---|---|
| **Knowledge** | 5 | 2, 5, 8, 11, 14 | 20 % |
| **Comprehension** | 5 | 1, 4, 12, 17, 19 | 20 % |
| **Applycation** | 3 | 9, 22, 25 | 12 % |
| **Analysis** | 5 | 7, 16, 21, 6, 3 | 20 % |
| **Synthesis** | 4 | 10, 13, 20, 24 | 16 % |
| **Evaluation** | 3 | 15, 18, 23 | 12 % |
| **Total** | **25** | | **100%** |

To determine the total score for each student in HOTLT, the researcher used the scoring system for items in the form of multiple choices, in which one point is scored for the correct answer and zero score to the wrong answer or left or marked more than one answer. Thus the total score of HOTLT is between 0-25.

## Pilot Study

To identify the clarity of instructions and test items, as well as to measure the time taken to answer the all questions, the test was translated into the Kurdish language and given to a group of students representing the whole sample. The test was applied to an exploratory sample of 110 7th grade students in basic schools in the Iraqi Kurdistan region. The students were given enough time to complete the test. The average time taken was 45 minutes and it was fixed as the time limit for the last test. Moreover, in order to identify the validity of the HOTLT, the test was reviewed by nine experts in science teaching method, measurement and evaluation and educational psychology. The content validity ratio (CVR) was employed. The CVR was developed by Lawshe in 1975; Lawshe provided a table of critical values for the content validity ratio. According to Lawshe's table, the critical value in case of 9 arbitrators starts from .78 (Lawshe, 1975). Therefore, the items blew this value have been modified as in items 13, 18, 25 (See Appendix C).

For determining the reliability of the test, the data gathered from pilot study were analyzed by using SPSS version 21. Kuder Richardson 20 formula was used to determine the reliability of the test. With a score of .806, the test was found to be of high reliability (Andrich, 1982). Thus, the final test consisted of 25 items (See Appendix A).

**(b) Strategies Use Survey Questionnaire (SUSQ)**

In order to identify the strategies uses by 7th grade science teachers to teach their students HOT, the researcher developed a questionnaire based on the IMSTRA model for teaching HOT in science, specifically the first circle which is describing the teachers role in the science classroom (Singer & Moscovici, 2008) (see figure 2.4 ). For the purposes of this study the questionnaire consisted of the following sections:

**A)** Elicits demographic information about teachers with regard to information about their gender and years of experience. These information were used to determine whether there are differences in using the teaching strategies by science teachers due to their gender and years of experiences.

**B)** Included the strategies used by science teacher to teach 7th grade students' HOT. This section is divided into three sub sections according to the constructs of HOT and framed by IMSTRA model. A total of 34 items were constructed as follow:

**i-** Acquiring the knowledge: Items (1-15) represented the strategies used by science teachers to activate students' prior knowledge; students can then gather the information in order to understand the phenomena, by using basic thinking skills.

**ii-** Applying knowledge: In order to enhance students' ability to apply knowledge, teachers must encourage students to work with data or scientific material using different thinking skills to move to deep understanding of usefulness and applicability of this material to everyday life, by using integrated science process skills which are represented in Items 16-23.

**iii-** Reflection on knowledge: This requires teacher to encourage students to use higher level of thinking skills in order to analyze and make judgment about what has happened, which will increase students' reflective thinking as represented in items 24-34.

The items in each construct have been developed according to the six sub-phases of the IMSTRA model. The items for acquiring knowledge construct have been constructed based on the first phase of IMSTRA model (Immersion) which is seeks to get students attention toward the problem and encourage them to use basic thinking skills such as observation, classification and inferring. While, the items for the second construct (applying knowledge) were developed based on the third phase of TMSTRA model (Applying phase) that aims to help students to apply the acquired knowledge into real life situation. The third construct of SUSQ is reflection on knowledge which is focused on using the strategies that aid students to reflect on the required knowledge through using the activities such as journal writing and using classroom participation, as these items were framed by the second phase of the IMSTRA model (Structuring phase). However, the items under each construct were developed based on the three main elements of the effective teaching strategies that focus more on activating students' prior knowledge, activity use and forms of assessment use.

**Pilot Study**

To identify the clarity of instructions and the questionnaire items, the questionnaire was translated into Kurdish language and given to a group of science teachers representing the whole sample. The questionnaire was applied to an exploratory sample of (88)7th grade science teachers who teach basic school in the Iraqi Kurdistan region.

The validity of the SUSQ was verified by identifying the Content Validity Ratio (CVR). The researcher offered the SUSQ to a group of 11 experts. Five experts from science teaching method, four experts in measurement and evaluation and two experts in educational psychology. According to Lawshe's table, the critical value in case of 11 arbitrators starts from .59 (Lawshe, 1975). As a result items 13, 17, 18, and 22 have been modified based on experts' feedback (See Appendix C).

Furthermore, after the process of applying the questionnaire to the exploratory sample, the researcher used SPSS software to estimate the questionnaires' reliability by internal consistency coefficient "Cronbach's alpha" methods (Christmann & Van Aelst, 2006). This method is based on calculation of the correlation coefficient between the different items on the same questionnaire. (88) Usable questionnaires were used to calculate the Coefficient alpha for the proposed constructs of SUS. Table 3.3 shows Cronbach's alpha results for three proposed constructs. As shown in the table, the initial Cronbach's alpha coefficients of acquiring knowledge construct (.782), and reflection of knowledge (.715), while for applying knowledge construct (.679) was below the .70 threshold recommended by Nunnally and Bernstein (Leyro et al., 2011). In order to gain the highest possible reliability coefficient, the components were purified by dropping items with the lowest item-to-total correlation. For acquiring knowledge construct (ACQ) item 15 was deleted due to a low item-total correlation. For applying knowledge construct (APL) item 2 was dropped. Reflection of knowledge (REF) item 10 was also dropped. After excluding unreliable items, the revised items demonstrated coefficient alpha values of each construct and for overall questionnaire were within the acceptable range as in Table 3.3. Thus the final SUSQ consisted of 31 items (See Appendix B).

**Table 3.3:** Reliability Analysis (Coefficient Alpha) for Strategy Use Questionnaire

| Construct | No.of Items | Cronbach's Alpha | No.of Items | Revised Reliability |
|---|---|---|---|---|
| Acquiring Knowledge | 15 | .782 | 14 | .794 |
| Applying Knowledge | 9 | .679 | 8 | .718 |
| Reflection on Knowledge | 10 | .715 | 9 | .739 |
| Whole SUSQ | 34 | .893 | 31 | .899 |

#### 3.2.1.4 Data Collection

The data collection was done by self-administration of the final version of the needs analysis instruments (appendix A and B) after getting ethical approval from the Ministry of Education in Dohuk city in order to conduct a study in basic schools in Dohuk city, copies of the Permission letter were sent to the school principals. In which the data for the first research question regarding students' level of cognitive development were collected by the researcher from 418 7th grade students in six schools in the Iraqi Kurdistan region. The data from each school were collected in one day. However, in order to answer the second research question; after getting ethical approval from the Ministry of Education in Dohuk city, the researcher got the Permission letter to collect the data from 7th grade science teachers. Strategies use questionnaire was used and distributed among 212 7th grade science teachers. The participants were asked for their willingness to participant in the study once the verbal consent was obtained, they were given the essential instructions and information about how to fill-up the questionnaire. The participants were given enough time to answer all questions as the questionnaires were collected after one week of administration.

#### 3.2.1.5 Data Analysis

The data gathered from the needs analysis phase were analyzed by adopting descriptive and inferential statistics such as chi square to determine student's level of HOT and their gender. Besides, t-test and one-way ANOVA for examining any significant differences in using teaching strategies among participants with relation to their gender and years of experience by using the Statistical Package for the Social Sciences (SPSS) Version 21.The summary of the activities in phase one is given in Figure 3.1.

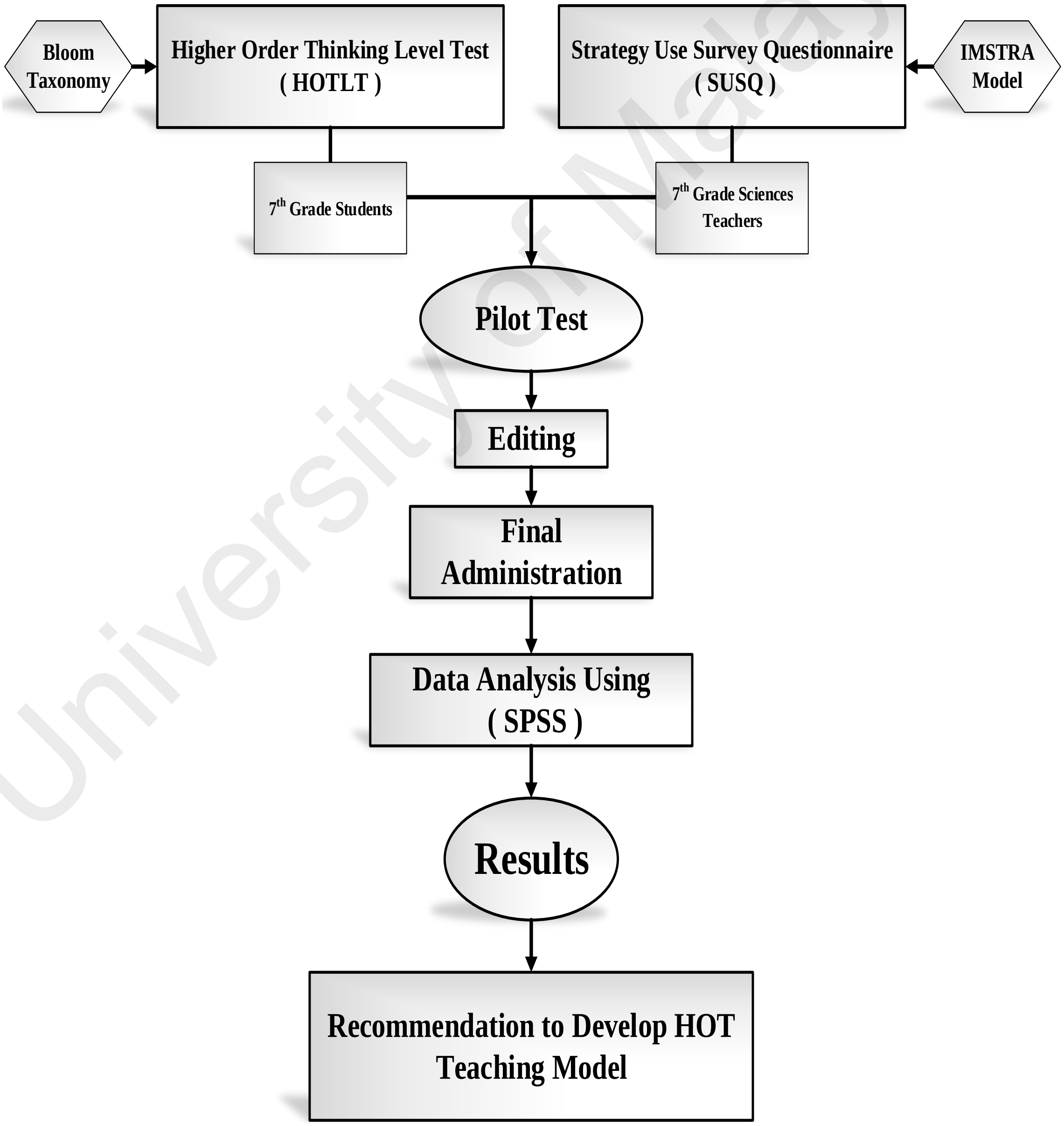



**Figure 3.1:** Summary of the Activities for Needs Analysis Phase

### 3.2.2 Phase Two: Design and Development

#### 3.2.2.1 Purpose

The second phase is where the intended HOT teaching model was developed with the idea of developing students' higher order thinking skills as a support to achieve their learning needs in science. This study aimed at developing a HOT teaching model to overcome basic students' needs in terms of developing their higher thinking skills in science education. The elements of HOT teaching model consisted of stages and the sub-stages that aimed at improving students' HOT in science learning through using various cognitive skills such as reflective thinking skills (RTS) and science process skills (SPS). These elements were selected by a panel of experts, the priorities of the elements have been identified for guiding both the teachers and students to fulfil in learning processes through discovery learning, and to produce not only a meaningful guide but also a practical one for implementing HOTS in science class to aid students to achieve their learning needs.

Thus, the elaborated objectives of this phase are to:

1- To identify the HOT teaching model stages.

2- To identify the appropriate sub-stages for each stage of the model.

3- To identify the priority of implementing model elements (stages and sub-stages) in science class.

#### 3.2.2.2 Method

In order to achieve the objectives of this phase, semi-structured interview along with the Fuzzy Delphi Method (FDM) have been adopted for this study, the description of this method is in the next section.

**Fuzzy Delphi Method:** The Fuzzy method is an analytical method based on the Delphi method that draws on the ideas of the Fuzzy theory. The Delphi method is a decision making approach that obtains the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback (Goldfisher, 1992). The Delphi method has many advantage in developing models. Basically, the logical consensus of the panel of experts is obtained on issues concerned, because the experts were given sufficient opportunity to consider their views (Okoli & Pawlowski, 2004). It is an effective method to collect various views to solve complex issues; it is rather beneficial to make a group decision, than an individual one. If the panel of experts are selected from different geographical locations, then, it is useful to receive the different opinion from a group of experts who may be separated from one another (Murry & Hammons, 1995). It is suitable to obtain consensus from a panel of experts without bringing them together, or meeting face to face (Skulmoski, Hartman, & Krahn, 2007); also it seems an inexpensive method of research, being free of social pressure, personality influence and individual dominance. There are also obvious benefits in being able to sign up a panel of experts without geographical, financial or time constraints, preserving anonymity of participants and removing any possibility of certain individuals dominating development of a consensus (Blow & Sprenkle, 2001; Gupta & Clarke, 1996; Rowe & Wright, 1999; Skulmoski, Hartman, & Krahn, 2007).

However, because the Delphi Method requires multiple repetitions when asking experts for their opinion, this must continue until the experts arrive at a consensus. As a result, it generally has the following weaknesses (Kuo & Chen, 2008; Okoli & Pawlowski, 2004):

(1) Repeatedly surveying experts and collecting their opinions is very time consuming.

(2) Experts must be surveyed and the collected results analyzed multiple times, increasing costs.

(3) Expert cooperation is required before a consensus is reached, needlessly increasing the difficulty of coordination and communication.

(4) Consensus of experts' opinions occurs during a certain part of the analytical process. The fuzziness of this part is however not taken into consideration. This makes it easy to misinterpret the expert's opinion.

(5) The analytical process has problems with some opinions being systematically weakened or suppressed.

To solve the problem of fuzziness in expert consensus in group decision making, researchers from around the world came up with new methods. The application of the Fuzzy Theory to the Delphi Method was proposed by Murray, Pipino, and van Gigch (1985). The Fuzzy Delphi Method (FDM) is an effective tool to gather data generated from opinion that usually involves imprecision and uncertainty. It is a methodology by which subjective data can be transformed into quasi-objective quantitative data and to facilitate decision-making of controversial issues (Chang, Huang, & Lin, 2000). Fuzzy theory applies fuzzy logic by using computer to make a decision. Fuzzy logic relies on two elements namely fuzzy set and fuzzy roles to model the world in making decisions. Fuzzy sets allow us to make measurement situation that are not precise, in which a set is a collection of related items that belong to that set with different degree (Klir & Yuan, 1995). Fuzzy role on the other hand, use rules to model the world; the rule applies human concepts instead of strict measurement to make decisions (Murray et al., 1985). Words are used instead of numbers to describe items. Fuzzy sets are terms to be used in fuzzy rules. Therefore, if the Fuzzy Theory could be applied to the Delphi Method, not only the merit that the result obtained could be similar to that obtained by traditional Delphi Method but, also the repeating time for survey could be reduced, hence lowering costs ( Chang et al., 2000; Ordoobadi, 2008). In particular, the individual features of each expert could be reflected and the professional knowledge of each expert would be applied more reasonably and suitably. FDM has been used for developing a product in different research area such as architecture, business and marketing (Benitez, Martín, & Román, 2007; Li, Davies, Edwards, Kinman, & Duan, 2002; Mourhir, Rachidi, & Karim, 2014). Moreover, the Fuzzy Delphi Method can combined with other methods in research studies such as Nominal Group Technique or NGT (Mullen, 2003), Fuzzy Logic (Li et al., 2002), Fuzzy Hierarchy (Cheng, Chen, & Chuang, 2008; Hsu, Lee, & Kreng, 2010) and others. In this study, the semi-structured interview was used to generate the initial elements for the development model that will be the initial point for experts in the Fuzzy Delphi Method to start with through the process of developing the model.

#### 3.2.2.3 Participants in Phase Two

The participants of this phase are a panel of experts; correct selection of experts is vital for the success of the study, since the model was developed based on the experts' views. The success of the Delphi method depends principally on careful selection of the panel of experts. According to Wang, and Ho (2010), the experts should be selected based on the following criteria:

1. Knowledge and experience with subject: in this study, the experts in science education, science curriculum, science supervisor in the Ministry of Education, basic school science teachers with more than fifteen years' experience were chosen purposefully to participate in this phase.
2. Capacity and willingness to participate
3. Ability to contribute their opinions to the needs of the study and keen to revise their initial judgement to reach agreement among experts.

The number of panellists in a Fuzzy Delphi Method varies substantially; while there is no ideal size, it is recommended that 10-50 participants are appropriate. But, the number of experts is not as important as the selections criteria (Damigos & Anyfantis, 2011). Moreover, for product development, the previous research recommended 15 to 20 experts (Kuo & Chen, 2008). Beside, as the study sought to develop a teaching model for basic education in science, overall 20 experts have been selected based on the above criteria for developing the model using FDM. The experts were selected based on their experiences in science teaching methods (biology, earth science, physics, and chemistry) as these main subjects are combined in one book named as “Science for All” which is taught in all basic grades in basic education in the Iraqi Kurdistan region. Background of the participants is stated as follows:

1. Biology: three experts in biology teaching methods were selected based on their experience (one professor, one aassociate professor and one senior lecturer) who have more than 15 years’ experiences in biology teaching methods.
2. Earth sciences: two experts in Earth Sciences teaching methods were selected based on their experience (one professor and one senior lecturer) of having more than 15 years experiences in Earth sciences education.
3. Physics education: three experts in physics teaching methods were selected based on their experience (two professors and one senior lecturer) who have more than 20 years’ experiences in physics teaching methods.
4. Chemistry: three experts were selected based on their experience in chemistry teaching methods (two aassociate professors and one senior lecturer) who have more than 15 years’ experiences in chemistry teaching methods.

Moreover, three Senior lecturers in curriculum and instructional development and Educational Psychology who have more than 18 years’ experiences were selected in order to choose the elements for the model in accordance to the curriculum used and the appropriateness of these elements to students’ age. Beside, two 7th grade science teachers were selected who have more than 25 years of experience in teaching science. Table 3.4. Summarizes the number of experts for developing the model.

**Table 3.4:** Participants for the Fuzzy Delphi Method (FDM)

| Designation | Field of Expertise | Years of Experience | No. of Experts |
|---|---|---|---|
| **Professor** | Science Education | >20 | 5 |
| **Associate Professor** | Science Education | 20- 25 | 4 |
| **Senior Lecturer** | Science Education | 15-20 | 5 |
| **Senior Lecturer** | Curriculum and Instructional Development | 15-20 | 3 |
| **Senior Lecturer** | Educational Psychology | 18 | 1 |
| **Bachelor** | Science Teacher | >25 | 2 |

#### 3.2.2.4 Instrument

Two instruments were used in this phase. First, a draft of pre-listed elements (RTS and SPS) generated from literature review such as Harthy (2011), Zohar (2003) and based on the combination of both cyclic learning model derived from Kolb theory and IMSTRA model to be included in the model was used in the first step of phase two during the interview section (See Appendix D). This list served as a starting point for experts' ideas and discussion; experts were allowed to add other skills that they found suitable for inclusion in the final survey for the model.

The second instrument in this phase was Fuzzy Delphi survey questionnaire. The questionnaire consisted of 29 questions divided into two parts: part one was about experts' views and their decision making about the stages of the HOT teaching model. The second part was about the experts' views and their decision making about the sub-stages of the developmental model. In order to improve the questionnaire items, a pilot study with 10 lecturers was carried out at Dohuk University. These 10 lecturers did not take part in the actual Fuzzy Delphi survey. Reliability test was conducted on the survey questionnaire for all items by using the Cronbach alpha coefficient; the alpha value of .865 obtained indicates high reliability. Furthermore, the questionnaire was validated by five (5) experts, three (3) were curriculum and instructional technology experts and two (2) were teaching science experts.

#### 3.2.2.5 Data Collection

The main aim of this phase was to develop a HOT teaching model for basic education students in science using experts' opinions. As the study used the Fuzzy Delphi Method for the developing process, the procedure for this phase is described in two major steps:

**1) Constructing Initial Elements for the Developmental Model**

In this study the researcher employed a semi-structured interview in order to identify the pre-listed elements (stages and the sub-stages) to be included in the fuzzy Delphi questionnaire. A semi-structured interview is flexible, allowing new questions to be brought up during the interview. This type of interview gives the respondent the time and scope to talk about opinions on a specific subject. The interview focus is decided by the researcher; the aim is to explore areas the research is keen on investigating in order to comprehend the respondents' point of view rather than make generalization about behavior. Questions are a raised whenever the interviewer feels it is appropriate to ask them. The process for conducting experts review was as follows:

1. Based on the previous criteria for this phase eight experts were selected.
2. Constructing a pre-listed element for the developmental model, in which this list offers a description of the scope of the outcome of the study and it guides the experts with a starting point of idea to begin with.
3. Conducting semi-structured interview. The researcher tried to use the appropriate language familiar to the participants whenever possible to allow them to review pre listed elements. Moreover, these elements have been familiarized and clarified to allow

experts to make appropriate judgment on whether to include or not and to present additional skills that are deemed to fit the model.

**2) Conducting Fuzzy Delphi Model (FDM)**

The FDM is conducted by using the following procedure:

**Step 1-** Selection of experts: A total 20 experts were selected for the process of FDM as elaborated in the previous section.

**Step 2-** Determining the linguistic scale: The linguistic scale is a Likert scale with addition of fuzzy numbers (Hsieh, Lu, & Tzeng, 2004). It is used mainly to address the issue of fuzziness among experts, three fuzzy values are given for every response as shown in the following Figure 3.2.

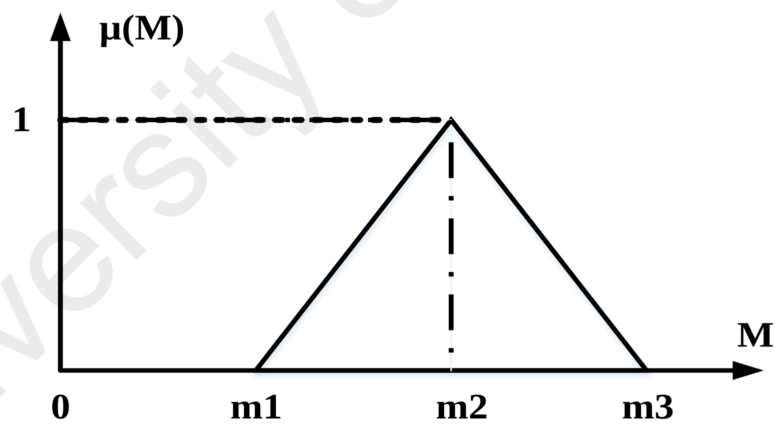



**Figure 3.2:** Triangular Fuzzy Number

Where m1 is the minimum value; m2 is the medium value; m3 is the maximum value.

In other words m1, m2, and m3 are fuzzy numbers, the range of fuzzy number is between 0 -1, so for every response there will be three values as in Table 3.5.

**Table 3.5:** Sample of Linguistic Scale

| Seven Linguistic Scale | Fuzzy Number | | |
|---|---|---|---|
| | **m1** | **m2** | **m3** |
| **Strongly Agree** | 0.90 | 1.00 | 1.00 |
| **Agree** | 0.70 | 0.90 | 1.00 |
| **Moderately Agree** | 0.50 | 0.70 | 0.90 |
| **Slightly Agree** | 0.30 | 0.50 | 0.70 |
| **Slightly Disagree** | 0.10 | 0.30 | 0.50 |
| **Disagree** | 0.00 | 0.10 | 0.30 |
| **Strongly Disagree** | 0.00 | 0.00 | 0.10 |

**Step 3-** Average fuzzy number: By identifying the average responses for every fuzzy number (Benitez et al., 2007) according to the formula:

$$\boldsymbol{M} = \frac{\sum_{i=1}^{n} \boldsymbol{mi}}{\boldsymbol{n}} \qquad 3\text{-}1$$

**Step 4-** Identifying threshold value "*d*": The threshold value is important to determine the consensus level among experts (Thomaidis, Nikitakos, & Dounias, 2006) which can be calculated by identifying the differences between the three average values for all experts on a certain item (M1, M2, M3) and the three fuzzy number for each experts on this item (m1, m2, m3) as in the following equation:

$$\boldsymbol{d}(\bar{\boldsymbol{M}}, \bar{\boldsymbol{m}}) = \sqrt{\frac{\mathbf{1}}{\mathbf{3}}[(\boldsymbol{M1} - \boldsymbol{m_1})^2 + (\boldsymbol{M2} - \boldsymbol{m_2})^2 + (\boldsymbol{M3} - \boldsymbol{m_3})^2]} \qquad 3\text{-}2$$

According to Chang, Hsu, and Chang (2011) the experts are considered to have achieved a consensuses if the threshold value is less than or equal to 0.2 and the overall group consensus should be more than 75%; otherwise the survey should be repeated until consensus achieved.

**Step 5-**Identifying alpha-cut level: in order to select the elements for the developmental model, most of the literature used alpha-cut level equal to 0.5, because the range of the fuzzy number is between 0 to 1 (Mourhir et al., 2014). Thus, based on the previous literature (Abdelgawad & Fayek, 2010; Mourhir et al., 2014) the alpha-cut (0.5) was used as a cut level to select the elements for the HOT teaching model, in which the elements above 0.5 were selected and the elements below 0.5 were rejected.

**Step 6-**Fuzzy evaluation: once the alpha-cut has been identified, the aggregate fuzzy evaluation is determined by adding all fuzzy numbers for all experts (mean of, m1, m2, m3).

**Step 7-**Defuzzification process: to justify the experts' consensus about stages and sub-stages (elements) of the model, defuzzification of the information is needed. Defuzzification is a technique to convert fuzzy number into crisp real number (Thomaidis et al., 2006). The defuzzification value (DV) for each questionnaire items is calculated using the following equation:

$$DV = 1/3 * (m1 + m2 + m3) \tag{3-3}$$

Where m1, m2 and m3 are the mean values for fuzzy number for each expert. The Defuzzification value was used to identify the agreement level among experts on the selected items for the model (Ordoobadi, 2008). The range of accepted value as reaching the consensus among experts in this study was between 10 -19. DV of 10 is the minimum agreement which corresponds to "Slightly agree" to 19 which is maximum value ("Strongly agree"). The range of the Defuzzification values for this study is elaborated in Table 3.6.

**Table 3.6:** Experts' Agreement Based on the Defuzzification Value

| Consensus Agreement | Defuzzification Value |
|---|---|
| **Strongly Agree** | 19 |
| **Agree** | 17.3 |
| **Moderately Agree** | 14 |
| **Slightly Agree** | 10 |
| **Slightly Disagree** | 6 |
| **Disagree** | 2.6 |
| **Strongly Disagree** | 0.66 |

**Step 7-** Ranking the stages and sub-stages (elements) of the model: the ranking process was used to identify the priority of the elements in its implementation in science class based on the defuzzification value. in which the element having the highest defuzzification value is ranked highest in priority to be considered as output for the model (Fortemps & Roubens, 1996). The summary of the process of phase two is given in Figure 3.3.

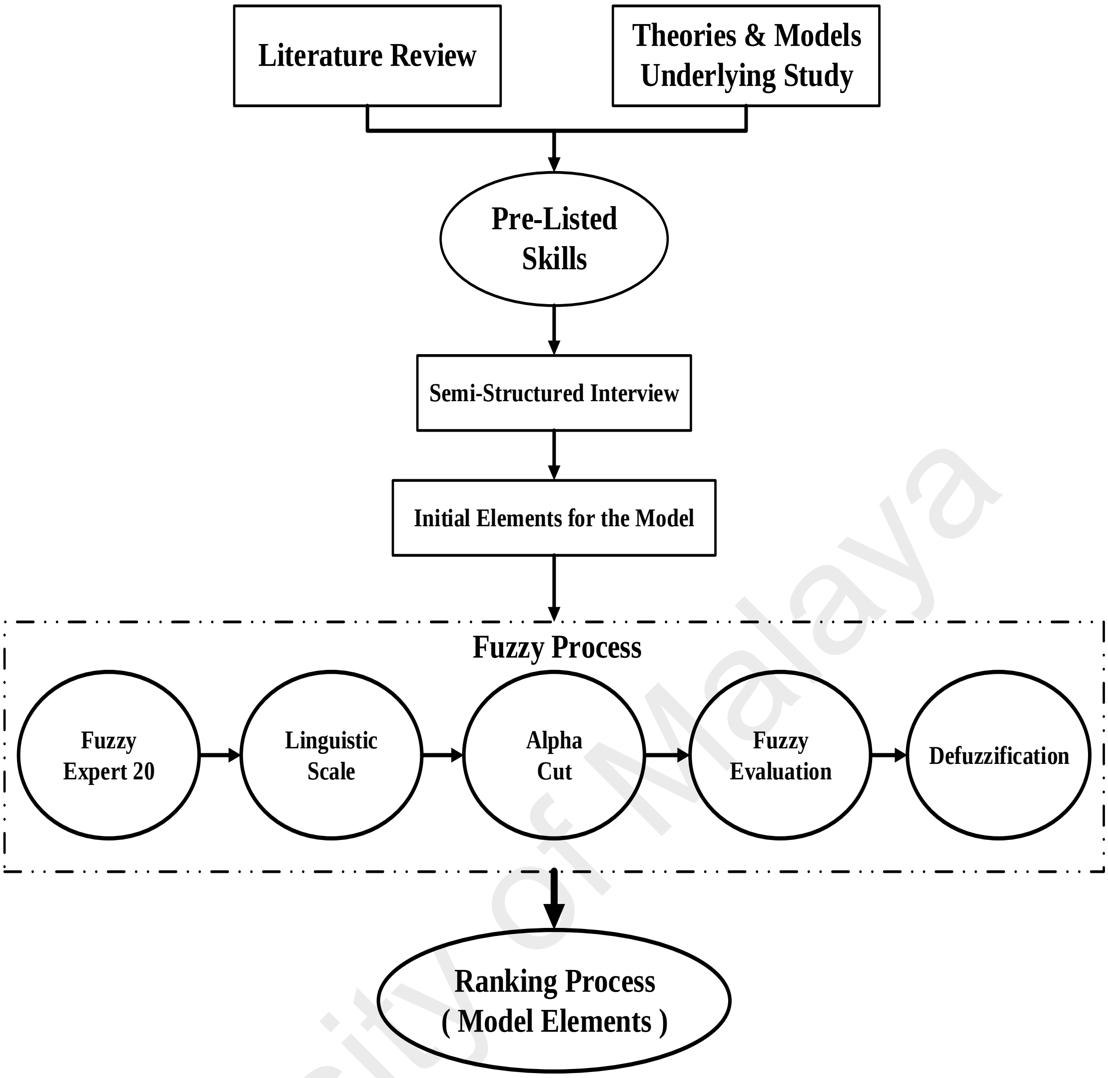



**Figure 3.3:** Summary of the Process of Design and Development Phase

### 3.2.3 Phase Three: Model Evaluation

#### 3.2.3.1 Purpose

The purpose of this phase was to evaluate the development model, to validate whether HOT teaching model is suitable to be implemented in the science classroom as a teaching model to enhance students' HOT in science learning. As the model is a teaching model, thus it is better to be evaluated by science teachers. The specific objectives of this phase are as follow:

1- To identify the importance of model stages and sub-stages in enhancing students' HOT.

2- To determine the usability of overall HOT teaching model in its implementation in science class.

Further elaboration on instrument, participants of this phase and the process of data analysis is presented in the following sections.

#### 3.2.3.2 Data Collection

In order to evaluate the model, the survey evaluation questionnaire was developed based on the model developed in phase two. Specifically, the questionnaire consisted of two parts. 1) Teachers' personal details; and 2) teachers' views of the model. This part consisted of two sections. Section A elicits participants' views of the stages and sub stages of the model and section B served to elicit science teachers' views of the overall model. 67 questions were constructed in the form of 5-point Likert scale from strongly agree to strongly disagree.

Since, the questionnaire was developed by the researcher based on the constructs of the HOT teaching model, it is necessary to check the content validity through pre-testing before going to pilot study. In this case, the content validity is essential to ensure the correctness of items' categorization and appropriateness of wording used to formed questions, to avoid any mistake or error before distributing the questionnaire for pilot study. Therefore, the questionnaire was reviewed by a panel of experts in science education (7 senior lectures). Based on their evaluation, comments and feedback, some items were revised and modified (see appendix H).

**Pilot Study**

The next step following pre-testing was the pilot test of the questionnaire. Since Pilot test precedes actual data collection, it has several advantages. It eventually recognizes the deficiencies of questionnaire design and makes certain that different measures present the acceptable degree of reliability. Furthermore, the pilot test is essential to ensure that the structure of the questionnaire is clear enough to be understood by the respondents. Therefore, 122 science teachers were chosen randomly for pilot study; however these teachers are not included in the actual survey sample. The main aim of piloting the questionnaire was to identify the reliability and its construct validity. Roberts, Priest, and Traynor (2006) recommended testing the reliability of the data from a pilot study prior to actual data collection. The data from pilot study were inserted into (SPSS) software (version 21). To test the reliability of the constructs, Cronbach's alpha was used to indicate the extent to which the proposed items can measure or represent a particular construct. Moreover, factor analysis was used to identify the validity of the questionnaire. In particular, exploratory factor analysis was used to test the construct validity. Exploratory factor analysis (EFA) is often considered to be more appropriate in the early stages of scale development (Gorsuch, 1988). According to Thompson (2004) exploratory factor analysis comprises two major stages: (a) assessment of suitability of data for factor analysis and factor extraction. Therefore, prior to performing the factor analysis, some assumptions should be included in the preliminary analysis performed to check for suitability of the data set for conducting EFA such as Bartlett's Test of Sphericity be significant ($p$ <.05) and Kaiser-Meyer- Olkin (KMO) (Fabrigar & Wegener, 2011). The requirement of this process is described in Table 3.7.

**Table 3.7:** Requirements for Factor Analysis

| Condition | Requirement | Reference |
|---|---|---|
| **Outliers** | No Outliers accepted | (Joseph F Hair, 2010) |
| **Kaiser-Meyer-Olkin (KMO) Index** | ≥ 0.6 | (Ferguson & Cox, 1993) |
| **Bartlett's Test of Sphericity** | Be Significant ($p$ < .05) | (Hubbard & Allen, 1987) |

For checking the normality of the data set, the skewness and kurtosis values were used. According to Poulsen, Ziviani, Cuskelly, and Smith (2007) skewness refers to the symmetry of a distribution. The Kaiser-Myer-Olkin (KMO) is a measure of sampling adequacy. KMO was used to investigate the data in order to decide whether a factor analysis should be undertaken. Moreover, Bartlett's test of Sphericity assesses the overall significance of the correlation matrix. The best result in this test is when the value of the test statistics for Sphericity is large and the significance level is small (Williams, Brown, & Onsman, 2012). However, J Pallant (2010) pointed out that data is factorable when the Bartlett's test of Sphericity is significant ($p < .05$).

After running the exploratory factor analysis, the final survey questionnaire (Appendix I) was used for collecting data for evaluating the development model

#### 3.2.3.3 Data Analysis Technique

To analyze the survey data, suitable techniques and software were chosen. SPSS Version 21 was used to prepare the data for analysis and to evaluate multivariate assumption (e.g., normality, linearity). In addition the exploratory factor analysis (EFA) was used for pilot study to identify the construct validity of the questionnaire. While for evaluation the survey data Smart PLS (version 2.0) was used to identify confirmatory factor analysis (CFA) to confirm the data from pilot test. Moreover, the HOT teaching model was evaluated by assessing the influence of using stages sub-stages in improving students' HOT (measurement model) as well as assessing the usability of the model in implementing in science class (structural model).

**Structural Equation Modelling (SEM)**

Structural Equation Modelling (SEM) is an advanced statistical analysis method used to understand and analyze complex relationships between variables in various disciplines including education. SEM is a method to measure latent, unobserved concepts with multiple observed indicators however, it has been used to evaluate more complex and sophisticated multivariate data analysis methods ( Hair et al., 2013). Partial least square structural equation modelling (PLS-SEM) and Covariance-based structural equation modelling CB-SEM are examples of primary exploratory and primary confirmatory statistical methods respectively. Furthermore, these methods include unobservable variables that measured indirectly by utilizing indicators to them and at the same time, they assist in dealing with measurement errors in observable variables ( Hair, Ringle, & Sarstedt, 2011). There are two statistical methods for SEM: Covariance-Based Structural Equation Modelling (CB-SEM) and Partial Least Square Structural Equation Modelling (PLS-SEM). Table 3.8 exhibits the rules of thumb that could be employed in determining whether to use (CB-SEM) or (PLS-SEM). The rules of thumb are outlined with respect to the four forms of decision considerations.

**Table 3.8:** Rules of Thumb for Selecting CB-SEM or PLS-SEM

| Criteria | PLS-SEM | CB-SEM |
|---|---|---|
| 1. Data Characteristics and Algorithm | • Sample size is small and/or non-normal data distribution | • Large data sets and/or normal data |
| 2. Measurement Model Specification | • If formative constructs are part of the structural model | • If error terms require additional specification, such as Covariation |
| 3. Structural Model | • If the structural model is complex (many constructs and many indicators) | • If the model is non-recursive |
| 4. Model Evaluation | • If you need to use latent variable scores in subsequent analysis | • Requires a global goodness-of-fit criterion<br>• Need to test for measurement model invariance, |

*( Hair et al., 2011)*

Based on the aims and scope of this study and according to Table 3.8, PLS seemed to be more suitable to be utilized in this study for several reasons: firstly, it has been advocated by many researchers as an appropriate method for testing the developmental model (Bentler & Huang, 2014; Henseler et al., 2014; Lowry & Gaskin, 2014; Monteiro, Wilson, & Beyer, 2013), more specifically it has been used in the past literature for evaluating the model developed using fuzzy Delphi method and AHP such as Chiang (2013) and Yingyu & Chunpin (2009) as in the case of this study. Secondly, (PLS-SEM) is recommended to studies utilising second-order formative constructs as in the case of this study (Wetzels, Odekerken-Schröder, & Van Oppen, 2009). As the HOT teaching model consisted of both stages and sub-stages that aims to enhance students' HOT; therefore, stages were considered as the second-order formative construct (refer to chapter6). Thirdly, (PLS-SEM) can deal with small sample sizes, as well as big sample sizes, and non-normal data distribution (Goodhue, Lewis, & Thompson, 2012). However, Hair et al. (2011, p. 144) pointed out that with large data sets, CB-SEM and PLS-SEM results are similar. Lastly, latent construct scores will be used to analyze second order constructs, as in this study the sub-stages score were used to analyze the stages of the model.

Based on the preceding discussion, the study employed PLS approach to evaluate the HOT teaching model. As the model consisted of both stages and sub-stages, in PLS the path between stages and HOT model is called structural model, more specifically the importance of using these stages in enhancing students' HOT the relation between sub-stages and stages of the model is called the measurement model. The assumption of analyzing structural and measurement model are explained in detail in the following sections.

**Specifying the Structural Model**

In a study employing PLS path modelling, an important first step is to prepare a diagram that illustrates the main variable relationship that will be examined. As in the case of this study, the model developed in phase 2 based on the experts' views was evaluated. Thus, the relationship between the stages of HOT teaching model represented the structural model. There are two types of structural models; first-order component models and higher-order component models. Research provides some rationales toward recommending the use of hierarchical latent variable models (second order) more than the use of models composed completely of lower-order dimensions (Becker, Klein, & Wetzels, 2012; Vandenberg, Richardson, & Eastman, 1999). Therefore, the supporters of the utilization of higher-order constructs have stated that the constructs allow for more theoretical parsimony and decreased model complexity. Additionally, hierarchical models facilitate the matching level of abstraction for predictor and criterion variables in conceptual models (Wetzels et al., 2009). Therefore, this study employed higher-order component models for describing the structural model. The steps for testing the structural model were as follows:

**Step1**: Identifying the variance explained ($R^2$ value); which is the amount of variance in students' HOT explained by model stages. More specifically the importance of the selected stages in developing students' HOT. According to Hair et al. (2011), $R^2$ values of 0.75, 0.50, or 0.25 for dependent constructs are considered strong, moderate, and weak, respectively.

**Step2**: The next step was to examine the path coefficient between constructs, for example the path between stage one and HOT model 'the importance in using stagee one in enhancing students' HOT'; this path is computed using significance *t*-statistics. The path coefficient is significant if $p$ value is less than .05 meaning that the independent variables have a positive and significant influence on the dependent variable (Westfall, 1993) which is identified in this study using AMOS 17 software. For example if the $p$ value between stage one and HOT is less than .05 it means that stage one has a positive and significant influence in students' HOT.

**Step3**: $\boldsymbol{f^2}$ **Effect Sizes;** The effect size of $\mathrm{f}^2$ is the assessment of $R^2$ in a case when a particular independent construct is removed from the model. Thus, it evaluates the impact size of the removed independent construct on the dependent construct (Hair , Ringle, & Sarstedt, 2013). The effect size $\mathrm{f}^2$ can be calculated as:

$$\boldsymbol{f^2 = \frac{R^2 included - R^2 excluded}{1 - R^2 included}} \qquad 3\text{-}4$$

The value of $\mathrm{f}^2$ can be contrasted to 0.02, 0.15, and 0.35 to report small, medium, and large effects, respectively ( Hair et al., 2013).

**Step 4:** The Predictive relevance $Q^2$ and $q^2$ Effect Sizes;$Q^2$ value is a measure of predictive relevance based on the blindfolding technique. The Blindfolding procedure can be regarded as a resampling process that specify and delete data points of the indicators in a systematic way to predict the measurement model of the reflective dependent constructs ( Hair et al., 2013).

**Specifying the Measurement Model**

The measurement model refers to the relationship between measures and their related constructs (Jarvis, MacKenzie, & Podsakoff, 2003), for example, the relationship between sub-stages of HOT teaching model and its measures (items). There are two types of constructs in the measurement model; reflective construct and formative construct. The limited concern about the measurement model has directed many researchers to treat all constructs in the same way, whether a particular construct is formative or reflective the misidentification of the formative and reflective constructs may lead to type I and type II errors which may have negative impact on theory advancement, due to the generation of inappropriate outcomes (Coltman, Devinney, Midgley, & Venaik, 2008). Furthermore, Jarvis et al. (2003) listed the main four decision rules to identify whether the construct is formative and reflective, as shown in the following Table 3.9.

**Table 3.9:** Decision Rules to Identify Construct as Formative or Reflective

| Rules | Formative Model | Reflective Model |
|---|---|---|
| 1. Direction of causality from construct to measure implied by the conceptual definition<br>Are the indicators (items) (a) defining characteristics or (b) manifestations of the construct?<br>Would changes in the indicators/items cause changes in the construct or not?<br>Would changes in the construct cause changes in the indicators? | • Direction of causality is from items to construct<br>• Indicators are defining characteristics of the construct<br>• Changes in the indicators should cause changes in the construct<br>• Changes in the construct do not cause changes in the indicators | • Direction of causality is from construct to items<br>• Indicators are manifestations of the construct<br>• Changes in the indicator should not cause changes in the construct<br>• Changes in the construct do cause changes in the indicators |
| 2. Interchangeability of the indicators/items<br>Should the indicators have the same or similar content?<br>Do the indicators share a common theme? Would dropping one of the indicators alter the conceptual domain of the construct? | • Indicators need not be interchangeable<br>• Indicators need not have the same or similar content/ indicators need not share a common theme<br>• Dropping an indicator may alter the conceptual domain of the construct | • Indicators should be interchangeable<br>• Indicators should have the same or similar content/ indicators should share a common theme<br>• Dropping an indicator should not alter the conceptual domain of the construct |
| 3. Covariation among the indicators. Should a change in one of the indicators be associated with changes in the other indicators? | • Not necessary for indicators to covary with each other<br>• Not necessarily | • Indicators are expected to covary with each other<br>• Yes |
| 4. Nomological net of the construct indicators<br>Are the indicators/items expected to have the same antecedents and consequences? | • Nomological net for the indicators may differ<br>• Indicators are not required to have the same antecedents and consequences | • Nomological net for the indicators should not differ<br>• Indicators are required to have the same antecedents and consequences |

*(Jarvis et al., 2003)*

Based on the roles specified in Table 3.9, the researcher categorized whether the construct is reflective or formative. However, the aim of assessing the measurement model was to identify the validity and reliability of the model. Besides, the assessment of the reflective construct is different from the assessment of the formative construct. The following section describes assessment of both reflective and formative measurement constructs.

First, reflective measurement construct: To investigate the reliability of reflective constructs, Cronbach's alpha and composite reliability measures can be extracted by (PLS-SEM). The measurements with Cronbach's alpha and composite reliability above .70 are considered reliable (Hair, 2010). Compared to Cronbach's alpha, composite reliability is regarded as a more rigorous assessment of reliability (Chin, 2010). As for validity, there are two types of validity: convergent validity and discriminant validity. Convergent validity investigates "the degree to which two measures of the same concept are correlated" (Hair & Anderson, 2010). Convergent validity can be evaluated by the average variance extracted (AVE) values, which refers to the degree the construct identifies the variance of its indicators. Discriminant validity can be evaluated by comparing the square root of (AVE) values for each construct with the correlation values between the construct and other constructs (Thiruvenkada, Hari, & Panchanatham, 2014).

Second, formative measurement construct: Hair, Hult, Ringle, and Sarstedt (2013) proposed three steps to empirically assess formative measurements: assessing convergent validity of formative measurement; assessing collinearity issues; and assessing the significance and relevance of formative measures. Figure 3.4 shows the systematic process of the evaluation the model.

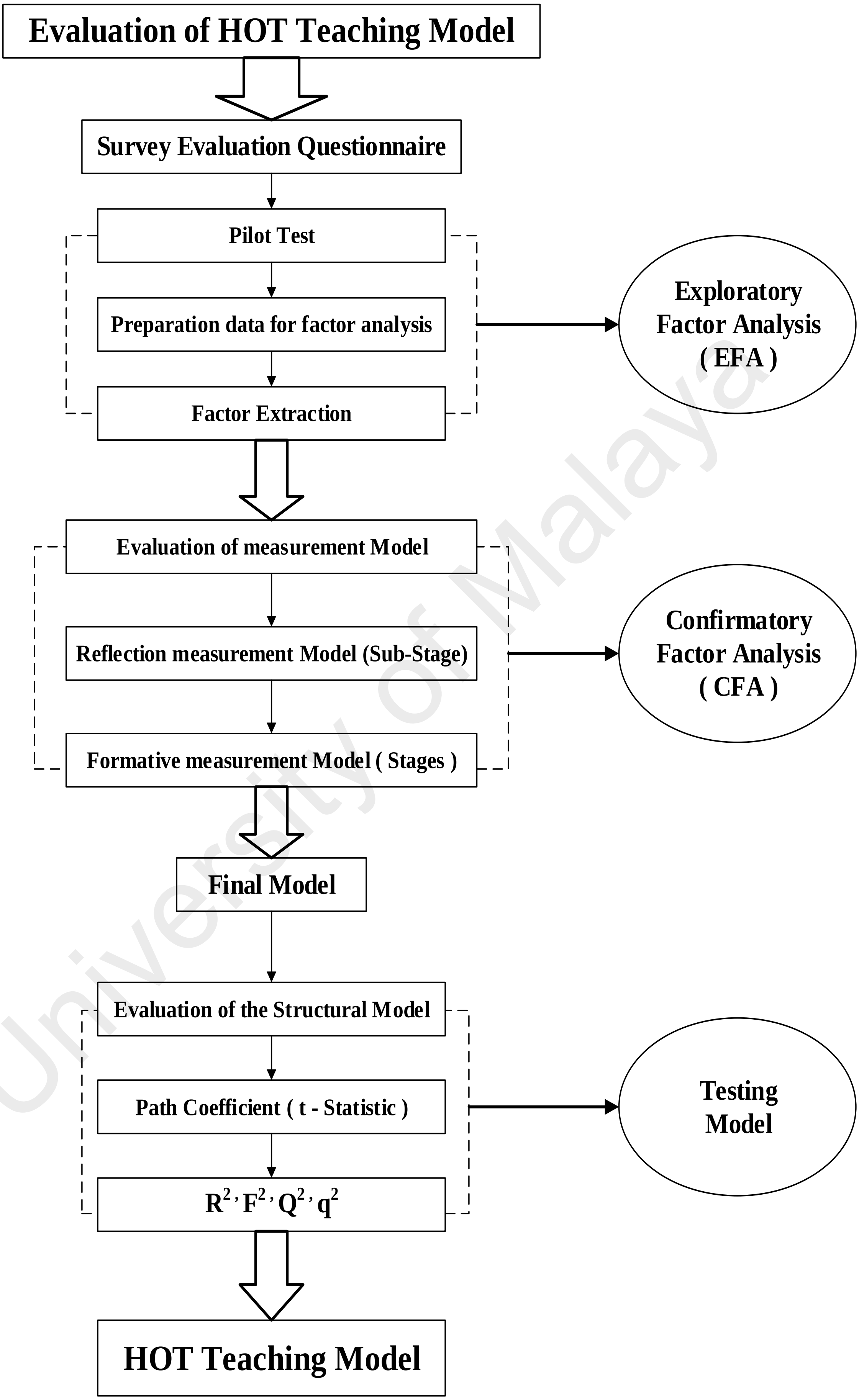



**Figure 3.4:** Systematic Process of Evaluation the Model

#### 3.2.3.4 Participants

The participants of this phase were science teachers in the Dohuk city in the Iraqi-Kurdistan region. However, the required sample size depends on some aspects, such as the data analysis methods. It is said that “PLS-SEM has higher levels of statistical power with complex model structures or smaller sample size” ( Hair et al., 2013). However, (PLS-SEM) accept the use of 10 times rule by Barclay, Higgins, and Thompson (1995) who recommended the sample size to be of 10 times either the factor that contains the biggest number of formative indicators or 10 times the biggest number of structural paths linked to a specific construct in the structural model ( Hair et al., 2013). While this rule indicates the minimum sample size required, the researcher should assign the sample size according to model foundation and data characteristics (Hair et al., 2011). Considering the 10 times rule, the study model has 5 formative indicators that form HOT constructs (stages), (5 X 10 = 50 cases), therefore 50 is the minimum required sample size.

Hair and Anderson (2010) stated that bigger sample sizes usually generate higher power for the statistical analysis with respect to the level of alpha. Furthermore, Pallant (2010) stated that the power of any test is influenced by three factors: sample size, effect size, and alpha level (e.g., 5% or 1%). Stevens (2012) stated that when the sample size is sufficient, power will not be considered as an issue. On the other hand, Pallant (2010) stated that the sample size should be more than 150 cases with a ratio of five cases for each indicator. Therefore, as the survey evaluation questionnaire consisted of 67 items, according to the 5:1 ratio (67 x 5 = 335 cases) then 335 is the minimum acceptable sample size for this study. In the current study, 355 basic science teachers were selected randomly, which is considered sufficient by the power calculations.

### 3.2.4 Overview of Data Collection and Data Analysis

The design of the present study is developmental research, which consisted of three phases, needs analysis, design and development and evaluation. Hence, the data from the needs analysis phase were collected by conducting a survey. Whereas, the data from phase two were collected by using the Fuzzy Delphi Method and the proposed model was evaluated in phase three by using partial least square. Table 3.10 summarizes the research activities in the three phases.

**Table 3.10:** Summary of the Research Activities in Three Phases

| Research Phases | Objectives | Data Collection | Instruments | Data Analysis |
|---|---|---|---|---|
| **Phase One** | To identify the needs to develop a HOT teaching model for basic education students in science learning. | Survey | • Higher order thinking level test HOTLT.<br>• Strategy use survey questionnaire SUSQ. | Quantitative data analysis SPSS |
| **Phase Two** | To develop a HOT teaching model for basic education students in science learning. | Fuzzy Delphi Method FDM | • Fuzzy Delphi questionnaire | Quantitative data analysis EXCEL |
| **Phase Three** | To evaluate the HOT teaching model for basic education students in science learning. | Survey | • Survey evaluation questionnaire | Quantitative data analysis. (PLS-SEM) approach |

## 3.3 Summary

Following the main phases of development research, namely, needs analysis, design and development phase and evaluation phase, this chapter has described the combined design and research activities conducted through the development process. In order to achieve the purposes of needs analysis phase, higher order thinking level test (HOTLT) and strategy use survey questionnaire (SUSQ) have been developed to investigate the level of HOT among 7th grade students and the strategies used by their teachers to teach HOT in the Iraqi-Kurdistan region. The two instruments have been piloted; validity and reliability were taken into account. The second phase is the development of the HOT teaching model. This phase was carried out using semi-structured interviews along with the Fuzzy Delphi Method (FDM), which is a powerful decision making approach. A Fuzzy Delphi questionnaire in the form of a seven-point linguistic scale was used to select appropriate elements of the model (stages and sub-stages). Furthermore the model was evaluated in phase three using survey method and the data were analyzed using partial least approach (PLS-SEM) approach. The evaluation aimed to assess the measurement model and structural model.

# CHAPTER 4: FINDINGS OF PHASE ONE

## 4.1 Introduction

The overall findings of the study are presented in three chapters 4, 5,and 6 consistent with the method used in this study which is design and developmental research approach that consist of three phases, needs analysis, design and development and evaluation. Besides, the findings of each phase are presented according to research questions and aims of each phase. Therefore, this chapter presents an analysis of the data for the preliminary part of the study, namely needs analysis. The answers to two main research questions are sought to provide information about 7th grade students' current level in HOT and strategies used by science teacher to teach their students HOT in science learning.

## 4.2 Students' Level of (HOT) in Science Learning

This section discusses the data obtained in order to answer the first research question and the sub question.

1- What is the current level of higher order thinking (HOTS) among 7th grade students in science?

1.1 Is there any association between students' level of cognitive skills and their gender?

In order to answer these research questions, the higher order thinking level test (HOTL) was developed based on the cognitive domain of Bloom's taxonomy and used to collect the data. The final version of HOTL test consisted of 25 questions in the form of multiple choice questions, distributed into six constructs; knowledge, comprehension, application, analysis, synthesis and evaluation (See Appendix A), the details of test can be referred to in chapter three. The test was delivered to 418 7th grade students in six schools (three girls and three boys) in the Iraqi Kurdistan region; some 69 incomplete responses were excluded from analysis. Therefore, 349 completed test sheets were received (83.4% response rate). Data normality was assessed through identifying the value of the skewness and kurtosis. According to Hair et al. (2010) the distribution of the data is considered normal if the empirical *z*-value lies between ±2.58 at (0.01 significance level); or ±1.96, at (0.05 significance level). On the other hand, the recommended range of skewness and kurtosis values is between ±1. As displayed in Table 4.1 the values for skewness and kurtosis lie within the range ±1. However, in order to assess students' levels of cognitive skills based on the six constructs of Bloom's taxonomy for cognitive domain SPSS version 21 was utilized, by using descriptive statistics, the researcher identified mean, median and standard deviation for each construct as follows:

**Table 4.1:** Students' Results on Cognitive Domain Constructs

| Construct | Knowledge | Comprehension | Application | Analysis | Synthesis | Evaluation |
|---|---|---|---|---|---|---|
| **Mean** | 2.01 | 1.98 | 1.27 | 1.15 | 1.11 | 1.32 |
| **Std. Deviation** | 1.188 | 1.141 | .929 | .732 | .880 | 0.82 |
| **Range** | 5 | 4 | 4 | 4 | 4 | 4 |
| **Skewness** | .159 | -.037 | .463 | -.106 | .465 | 0.17 |
| **Kurtosis** | -.410 | -.652 | -.109 | -.846 | .373 | 0.098 |
| **Median** | 2.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 |

The students' results for higher order thinking level test based on the Bloom taxonomy indicated that the scores for all the constructs were very low; the highest mean was for knowledge construct with a score of 2.01 out of the maximum 5, followed by comprehension (1.98) and application (1.27), while the average mean score for evaluation was only 1.32 out of 4. The lowest mean (1.11) synthesis was recorded for construct.

According to previous research on HOT, the first three constructs (knowledge, comprehension and application) are referring to lower level of thinking skills (LOTL), while the last three constructs (analysis, synthesis and evaluation) are referring to higher order thinking level (HOTL) (Forehand, 2010; Yahya et al., 2012). Therefore, in order to identify students' level of cognitive skills, the researcher computed the items for the first three constructs, 13 items as a lower order thinking level LOTL and the last three constructs (12) items as a higher order level HOTL, by using descriptive statistics, the researcher identified the students' results as in Table 4.2.

**Table 4.2:** Results of Student's Level in Cognitive Skills in Science

| Level | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| **LOT** | 349 | 1.00 | 11.00 | 5.25 | 2.076 |
| **HOT** | 349 | 0.00 | 7.00 | 3.58 | 1.636 |

Regarding the students' level of thinking skills as in Table 4.2, the results indicated that the majority of the 7th grade students were in the lower level of thinking skills with a score of 5.25 out of 13 with minimum 1 and maximum 11 points. While the score of higher order thinking level was 3.58 out of 12 with a minimum point of zero and a maximum 7 points. As the 7th grade students were selected form three girls' and three boys' schools, so it is rather necessary to identify whether there is relationship between the students' level of higher order thinking skills and their gender. To answer this question, chi-square test was used as in Table 4.3.

**Table 4.3:** Association between Students' Level of Thinking Skills and Gender

| Gender | Level of thinking skills | | Total (%) |
|---|---|---|---|
| | Lower (%) | Higher (%) | |
| Female | 142 (75.9) | 45 (24.1) | 187 |
| Male | 136 (84.0) | 26 (16.0) | 162 |
| **Total** | **278 (79.7)** | **71 (20.3)** | **349** |

*Chi-square test.* $\chi^2$ *=3.441, df. = 1, p= .064.*

Based on Table 4.3 data from 349 participants indicated that 278 (79.7%) of the students were in lower level of thinking skills, while only 71 (20.3%) of the students were in the higher level of thinking skills. Regarding the gender, the number of the female were 187 students with 142 (75.9%) in LOTL and 45 (24.1%) in HOT. Some 162 male students were included in this study, the majority of the male students 278 (79.7%) were in the lower level of thinking skills. However, the findings in Table 4.3 indicated that there is no significance difference between levels of thinking skills and students' gender (*p*-value > .05).

### 4.2.1 Conclusion

It has been well verified that higher order thinking skills are essential for effective learning and form the central goal of science education. In 2009 the educational system in the Kurdistan region was reformed to meet the challenges of the 21st century, whereby the new basic education science curriculum has focused largely on prompting students' Higher Order Thinking. Therefore, the needs analysis phase aimed at assessing 7th grade students' level of cognitive development as well as to identify if there is any association between students' level of cognitive skills and their gender. However, the findings of this study indicated that most of the 7th grade students were in the lower level of thinking, especially in synthesis and evaluation constructs, which are the skills that improve students' creativity in science. In addition, the results of the chi square test showed that there was no significance difference between students level of thinking skills with regard to their gender ($p > .05$). Based on the results of students' level of cognitive skills, the needs analysis has provided evidence that almost all students needs to improve their (cognitive skills) lower order thinking as well as higher order thinking, in which the lower order thinking is basic to improve students' higher order thinking. It pointed to the need for the acquisitions of higher skills such as analysis and evaluation and hence these should be targeted for inclusion in the development model.

However, the previous research in cognitive skills advocated that the lower level of thinking was caused by many factors, one of the most important being the strategies used by science teachers (Barak & Dori, 2009). Thus, the following section reports findings on the investigation into the strategy used by science teacher to teach their students HOTS.

## 4.3 Science Teachers' Teaching Strategies Use

This section presents the findings of needs analysis in terms of 7th grade science teachers' teaching strategies use according to the second research questions.

What strategies do 7th grade science teachers use to teach their students HOT in science?

Moreover, in order to identify the association between strategies use by 7$^{th}$ grade science teachers and their sociodemographic factors such as gender and experiences two specific research questions were formulated

2.1 Is there any association between 7th science teachers teaching strategies use and their gender?

2.2 Is there any association between 7th science teachers teaching strategies use and their years of experiences?

In order to answer these research questions, the Strategies use survey questionnaire (SUSQ) was used to collect the data. The questionnaire consisted of 36 questions divided into two parts: the first section served to elicit demographic information about teachers with regard to information about their gender and years of experience. The second part served to identify the strategy used by 7th grade science teachers in science. This part consisted of (31) questions in the form of 5-piont Likert scale (never = 1, rarely = 2, sometimes = 3, often = 4, always = 5). Items 1-14 of the questionnaire measured the strategies used for acquiring the knowledge aimed at improving students' lower order thinking skills. Items (16-22) of the study questionnaire seeks out to measures the strategies used by science teacher for applying knowledge. Reflection on knowledge strategies are represented in items (24-31), in which employing these strategies aid students in improving their higher cognitive skills in science learning. More details about this questionnaire can be found in chapter three.

The questionnaire was conducted with 212 7th grade science teachers in Dohuk city in the Iraqi Kurdistan region and the survey received a high response rate of 81.1% with 172 completed responses. The background of participants is illustrated in the next section.

**Background of Participants**

The demographic characteristics of the participants are presented in Table 4.4. The sample finally consisted of 57 males and 115 females. Moreover, all the participant have 10 years of experience and above as indicated in Table 4.4.

**Table 4.4:** Distribution of the Sample According to Gender and Expertise

| **Variable** | | **Frequency** | **Percent (%)** |
|---|---|---|---|
| **Gender** | Male | 57 | 33.1 |
| | Female | 115 | 66.9 |
| **Years of Experience** | Above 25 | 24 | 14.0 |
| | 20-25 | 36 | 20.9 |
| | 15-20 | 52 | 30.2 |
| | 10-15 | 60 | 34.9 |
| | Total | 172 | 100 |

In order to identify the most popular strategy among 7th grade science teacher and which construct they focus on teaching science, the researcher computed the items for each construct as in Table 4.5.

**Table 4.5:** Results of Strategies Used by Science Teachers

| Construct | Item | Mean | Std. Deviation | Range |
|---|---|---|---|---|
| **Acquiring Knowledge** | I organize students to observe scientific phenomena. | 3.39 | 0.95 | 3 |
| | I try to increase students' interest toward scientific problems. | 3.88 | 1.02 | 4 |
| | I focus on learning students basic concepts. | 4.17 | 0.919 | 3 |
| | I organize students in which students compare objects using standardized units of measure. | 3.15 | 1.134 | 4 |
| | I ask students to explain concepts to one another. | 2.99 | 1.337 | 4 |
| | I devise exercise in which students have to conduct investigation. | 3.31 | 2.699 | 4 |
| | I encourage students to generate their own questions. | 2.85 | 1.339 | 4 |
| | I give students scientific problems in which they are encouraged to construct hypotheses. | 2.61 | 1.095 | 4 |
| | I perform tasks requiring methods or ideas already introduced to students. | 3.15 | 1.206 | 4 |
| | I encourage students to answer questions that require inference. | 2.97 | 1.16 | 4 |
| | I involve the whole class in finding the solution to a problem. | 3.08 | 1.40 | 4 |
| | I observe students and ask questions as they work in small groups. | 2.74 | 1.151 | 4 |
| | I conduct a pre assessment to determine what students already know. | 2.05 | 1.412 | 4 |
| | I allow students time to work on homework in class. | 2.90 | 1.24 | 4 |
| | **Total** | **44.24** | **7.13** | **37** |
| **Applying Knowledge** | I manage a class of students engaged in investigation strategies. | 2.90 | 1.24 | 4 |
| | I encourage students to identify variables that affect scientific phenomena. | 2.42 | 1.005 | 4 |
| | I devise exercises in which students have to construct table of data. | 2.39 | 1.39 | 4 |
| | I devise exercises in which students have to describe relationship between variables on a graph. | 2.68 | 1.124 | 4 |
| | I give students scientific problems in which they are encouraged to construct a hypothesis. | 2.35 | 1.077 | 4 |
| | I give students hypotheses and request them to design investigation to test the given hypotheses. | 2.03 | 1.051 | 4 |
| | I teach students how to make charts for solving problems to break information into smaller pieces. | 2.39 | 0.956 | 3 |

**Table 4.5:** Results of Strategies Used by Science Teachers

| | | | | |
|---|---|---|---|---|
| | I encourage students to do hands- on laboratory science activity. | 2.79 | 1.08 | 4 |
| | **Total** | **20.22** | **5.22** | **17** |
| **Reflection on Knowledge** | I devise exercises in which students identify the variables under investigation. | 3.06 | 1.185 | 4 |
| | I encourage students to explain the reasoning behind their ideas. | 2.01 | 1.148 | 4 |
| | I ask students to consider alternative explanation. | 3.13 | 1.32 | 4 |
| | I observe students and ask question as they work individually. | 2.24 | 1.232 | 4 |
| | I review student's note books. | 3.21 | 1.510 | 4 |
| | I ask students questions during large group discussion. | 2.78 | 1.116 | 4 |
| | I give students opportunities to make oral and written presentations in class. | 2.71 | 1.26 | 4 |
| | I use cooperative learning groups approach. | 2.17 | 1.175 | 4 |
| | When I assess students, I give tests requiring open-ended responses. | 2.74 | 1.061 | 3 |
| | **Total** | **24.45** | **5.63** | **20** |

The teacher's responses to the strategies use questionnaire indicated that 7th grade science teachers focus more on teaching students basic concepts by using strategies for acquiring knowledge with (M= 44.24 ±.13). More specifically, science teachers always focus on learning students basic concepts in science which refers to item 3 with (M= 4.17, SD=0.919), while science teachers sometimes gives the students scientific problems which refers to item 8 with (X = 2.61, *SD* = 1.09). However, the second strategies use construct that science teachers focused on was reflection on knowledge (M= 24.45 ±5.63). Based on the teachers responses to items 22-31 on reflection on knowledge construct, the results indicated that the most popular strategies among science teachers was a review of a student's notebook which refers to item 27 (*M* = 3.21, *SD* = 1.51), however the least used strategy for enhancing students reflection on knowledge is the cooperative learning approach for item 30 (*M* = 2.17, *SD* = 1.17). Applying the knowledge strategies was the least strategies used by science teacher (M=20.22 ±5.22), that refer to the strategies that science teacher uses to help the student to apply the acquired knowledge into a real life situation. According to teachers' responses to items 15-22 of applying knowledge construct, the results indicated that, the teacher focus more on book exercises activities which refers to item 22 (X = 2.79, *SD* = 1.08). While the teacher, rarely use science laboratory activity in science classroom as in item 19 (X = 2.35, *SD* = 1.07). Moreover, to investigate the strategies used by science teacher according to their gender independent samples t-test was used as in Table 4.6.

**Table 4.6:** Results of t-test for Strategy Use Constructs

| Variable | Gender | N | Mean | Std. Deviation | t | p Value |
|---|---|---|---|---|---|---|
| **Acquiring Knowledge** | Male | 57 | 46.50 | 4.72 | 3.000 | .003 |
| | Female | 115 | 43.12 | 7.83 | | |
| **Applying Knowledge** | Male | 57 | 21.36 | 4.54 | 2.035 | .043 |
| | Female | 115 | 19.66 | 5.46 | | |
| **Reflection on Knowledge** | Male | 57 | 23.05 | 4.39 | 2.665 | .008 |
| | Female | 115 | 26.66 | 6.02 | | |

Table 4.6 shows that there is a significant difference between the male and female on strategies use for teaching science in 7th grade in the Iraqi-Kurdistan region due to ($p < 0.05$). As for the acquiring knowledge construct the mean score for male (46.50) participants was significantly higher than female participants (43.12) with ($p = 0.003$). While for applying knowledge ($t = 2.035$, $p < 0.05$) as well as for reflection on knowledge strategies ($t = 2.665$, $p < 0.05$) with the mean for male science teachers significantly higher than female science teachers for applying knowledge construct which was conversely with the reflection knowledge construct.

However, to explore the differences between science teachers' score in the strategy use questionnaire based on their years of experiences, one-way ANOVA analysis was used. The assumption of ANOVA was fulfilled such as the homogeneity between study variables (p value>0.05). Table 4.7 shows the mean and stander deviation for each construct based on participants years of experiences.

**Table 4.7:** Teaching Strategy among Science Teachers with Different Years of Experiences

| Variable | Years of Exp. | N | Mean ±*SD* |
|---|---|---|---|
| **Acquiring Knowledge** | Above 25 | 24 | 47.79 ±5.18 |
| | 20-25 | 36 | 44.88 ±4.83 |
| | 15-20 | 52 | 45.03 ±7.91 |
| | 10-15 | 60 | 41.75 ±7.52 |
| | **Total** | **172** | **44.24 ±7.13** |
| **Applying Knowledge** | Above 25 | 24 | 21.91 ±3.85 |
| | 20-25 | 36 | 19.66 ±4.36 |
| | 15-20 | 52 | 22.01 ±5.39 |
| | 10-15 | 60 | 18.33 ±5.39 |
| | **Total** | **172** | **20.22 ±5.22** |
| **Reflection on Knowledge** | Above 25 | 24 | 24.70 ±5.10 |
| | 20-25 | 36 | 25.94 ±2.94 |
| | 15-20 | 52 | 26.44 ±5.03 |
| | 10-15 | 60 | 21.73 ±6.51 |
| | **Total** | **172** | **24.45 ±5.63** |

From Table 4.7, teachers with experience more than 25 years got the highest mean for adopting the strategies for acquiring knowledge. Besides, majority of the science teachers with (15-20) years of experiences use strategies for applying knowledge and reflection knowledge constructs. In order to verify the significant differences between the means of the teachers regarding using the teaching strategies, the ANOVA analysis was used. Table 4.8 shows the results of this analysis.

**Table 4.8:** ANOVA Analysis for Science Teacher Strategy According to their Years of Experiences

| Variable | | Sum of Squares | df | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|---|
| **Acquiring Knowledge** | Between Groups | 723.05 | 3 | 241.01 | 5.07 | .002 |
| | Within Groups | 7972.68 | 168 | 47.45 | | |
| | **Total** | **8695.74** | **171** | | | |
| **Applying Knowledge** | Between Groups | 462.01 | 3 | 154.00 | 6.14 | .001 |
| | Within Groups | 4210.14 | 168 | 25.06 | | |
| | **Total** | **4672.15** | **171** | | | |
| **Reflection on Knowledge** | Between Groups | 731.22 | 3 | 243.74 | 8.70 | .000 |
| | Within Groups | 4705.40 | 168 | 28.00 | | |
| | **Total** | **5436.62** | **171** | | | |

Results in Table 4.8 indicated that the (F) value for the acquiring knowledge, applying knowledge and reflection knowledge constructs were (5.07, 6.14, 8.70) respectively with ($p<0.05$) indicated that there is a significant differences among science teachers strategy use with different years of experiences. In order to further explore this differences Tukey post hoc test was used as the equality of variance was assumed. Table 4.9 shows the results of Tukey test.

**Table 4.9:** Results of Tukey HSD[a,b] test

| Variables | | N | Subset for Alpha = .05 | |
|---|---|---|---|---|
| | | | 1 | 2 |
| **Acquiring Knowledge** | above 25 | 24 | | 47.7917 |
| | 20-25 | 36 | 44.8889 | 44.8889 |
| | 15-20 | 52 | 45.0385 | 45.0385 |
| | 10-15 | 60 | 41.7500 | |
| | **Sig.** | | **.164** | **.260** |
| **Applying Knowledge** | above 25 | 24 | | 21.9167 |
| | 20-25 | 36 | 19.6667 | 19.6667 |
| | 15-20 | 52 | | 22.0192 |
| | 10-15 | 60 | 18.3333 | |
| | **Sig.** | | **.164** | **.260** |
| **Reflection on Knowledge** | above 25 | 24 | 24.7083 | 24.7083 |
| | 20-25 | 36 | | 25.9444 |
| | 15-20 | 52 | | 26.4423 |
| | 10-15 | 60 | | 21.7333 |
| | **Sig.** | | **.072** | **.484** |

Results in table 4.9 revealed that the science teachers with 25 years of experience and more were found in subset 2. However, the strategies used for acquiring knowledge construct among science teachers with various years of experience was not significant ($p>0.05$). In addition, the results showed that science teachers with (15-20) years of experiences were more employing strategies for applying knowledge and reflection knowledge constructs.

### 4.3.1 Conclusion

The data collected on 7th grade science teacher strategies use indicated that the most popular strategies among 7th grade science teachers is the strategies for acquiring knowledge which focus more in memorizing basic concepts in science, while the least strategies use by science teacher is the strategies for applying knowledge such as problem solving and hand -on activity by using science laboratory, which are the strategies that improve students' higher cognitive skills. Moreover, the findings indicated that most of the experienced science teachers focus on strategies for improving students basic thinking skills than younger science teachers.

## 4.4 Summary and Discussion of the Needs Analysis Findings

This section examined research questions on 7th grade student's level of higher order thinking and strategies used by 7th grade science teacher to teach their students higher order thinking linked to their gender and years of experiences. First, in terms of 7th grade students' cognitive skills, the result revealed that, the majority of the 7th grade students were in lower level of thinking skills LOT with male students more than female. These findings indicated that there is a pressing need to improve student' HOT in science learning, so as to facilitate the transition of their knowledge and skills into responsible action regardless of their particular role in the society.

Second. The data collected on 7th grade science teacher strategies use showed that a variety of HOT teaching strategies were lacking among the teachers and that low processing strategies, such as focusing on learning student's memorizing basic concepts were dominant among 7th grade students which improve students' knowledge and comprehension levels especially among experienced science teachers. While strategies that encourage students to use higher cognitive skills such as exploration, reflection and sharing of idea which have been suggested in the literature such as problem solving, collaborative learning and inquiry strategies were less used by both male and female science teachers.

## 4.5 Summary

This chapter has presented the results of the needs analysis that aims to identify the students' need in terms of their higher level of cognitive skills, as well as the strategies use by science teacher to improve their higher cognitive skills. The results of the needs analysis used to determine the important elements to be included in HOT teaching model that would support the science teacher with a practical guide for improving students' HOT. The following chapters, five and chapter six presents the finding of phase two Design and Development which focuses more on developing the (elements) of the HOT teaching model, and phase three the evaluation of the HOT teaching model.

# CHAPTER 5: FINDINGS OF PHASE TWO

## 5.1 Introduction

Design and development is the second phase of the study, which is the most important phase where the model was developed. In order to improve students' higher order thinking, the result of the needs analysis indicated that there is a need to improve teachers' strategies through employing the learning activities that encourage active participation of the students. As a solution, the study focuses on developing a HOT teaching model for enhancing students' higher cognitive skills in science learning. This section constitutes the results of experts' views on the elements of the model (stages and sub-stages), through two steps by using semi-structured interview along with the Fuzzy Delphi Method.

## 5.2 Constructing Initial Elements for the Model

The semi-structured interview was used to construct the initial elements (stages and the sub-stages) for the model. The interview was carried out with eight experts (as described in chapter three). Generally, all experts proposed and consensually agreed on the pre-listed elements for the model that included learning activities that encourage students to use RTS and SPS. Nevertheless, several issues were raised by the experts relating to the selection of the stages and sub-stages of the model.

Model stages: all the experts agreed and gave positive comments with the proposed stages for HOT teaching model. Moreover, they realized that the selected stages are suitable, in accordance with and linked to the content of science for 7th grade.

Science process skills SPS: the second area that experts voiced concerns about was the selection of SPS. According to all eight experts, the selected science process skills are essential to enhance students' HOT and appropriated to their age, while two experts commented on the sequences of the selected skills.

"In order to enhance students' HOT, the most important thing is the implementation of these skills, in which the science teacher should starts with improving students' basic skills to more complex skills" (EXP7).

"If possible, you may have to elaborate on that part (i.e., Rearrange these skills in a hierarchical form simple to more complex" (EXP4). Taking into account the experts views, the science process skills in each stage were then rearranged from basic skills to more complex skills.

Reflective thinking skills RTS: while most of the experts agreed that the selected RTS are suitable to students age and important to enhance students HOTS in science learning. EXP3 and EXP4 voiced their concerns on students' feedback.

"The skills are logically selected and sequenced but it's important for students to get feedback about what they were learned which is very important in reflective thinking" (EXP3).

"The selected skills are suitable for enhancing students' RT as well as their higher level of cognitive skills but not enough; you know, there are other skills which can be added although the students will try to think reflectively of their own thinking, such as getting feedback of what they have learned" (EXP4).

Accordingly, the feedback was also selected and added to list of RTS and the appropriate sub-skills were further identified which would help students to think reflectively about what they have learned in science education. Based on experts' views the pre-listed elements for the model (Learning Activities) have been modified (See Appendix D).

## 5.3 Design and Development the Model: Fuzzy Delphi Method FDM

Based on the Fuzzy survey questionnaire (See Appendix E), the experts' responses in seven-point linguistic scale were obtained (See Appendix F). In order to determine the consensus level among experts for each item, the threshold value was calculated for all questionnaire items as shown in Table 5.1.

**Table 5.1:** Threshold Value for Survey Items

| R | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **R1** | 0.043 | 0.164 | 0.188 | 0.076 | 0.185 | 0.137 | **0.203** | 0.145 | 0.034 | 0.14 | 0.067 | 0.104 | 0.032 | 0.034 | 0.147 |
| **R2** | 0.151 | 0.058 | 0.078 | **0.217** | 0.072 | 0.136 | **0.202** | 0.047 | 0.034 | **0.342** | 0.067 | **0.288** | 0.103 | 0.135 | 0.146 |
| **R3** | 0.043 | 0.163 | 0.107 | **0.217** | 0.184 | 0.156 | 0.092 | 0.148 | 0.062 | 0.192 | 0.103 | 0.135 | 0.043 | 0.096 | 0.19 |
| **R4** | 0.151 | **0.318** | 0.187 | **0.265** | **0.298** | 0.136 | **0.28** | 0.148 | **0.342** | 0.139 | 0.067 | 0.103 | 0.19 | 0.033 | 0.146 |
| **R5** | **0.332** | 0.058 | **0.294** | 0.076 | 0.184 | **0.346** | **0.202** | **0.333** | 0.034 | 0.153 | 0.062 | 0.192 | 0.032 | 0.157 | 0.147 |
| **R6** | 0.151 | 0.163 | 0.078 | **0.217** | 0.072 | 0.035 | 0.092 | 0.148 | 0.142 | **0.342** | 0.067 | 0.192 | 0.103 | 0.033 | 0.146 |
| **R7** | 0.141 | 0.13 | 0.187 | **0.265** | **0.298** | 0.136 | **0.202** | 0.145 | 0.142 | 0.139 | **0.416** | 0.103 | 0.103 | 0.135 | 0.146 |
| **R8** | 0.151 | 0.058 | 0.187 | 0.076 | 0.184 | **0.346** | 0.09 | 0.148 | 0.15 | 0.139 | 0.067 | 0.192 | 0.032 | **0.544** | **0.336** |
| **R9** | 0.043 | 0.13 | 0.107 | **0.217** | 0.109 | 0.035 | **0.28** | 0.148 | 0.142 | 0.153 | 0.067 | **0.288** | 0.103 | 0.033 | 0.043 |
| **R10** | 0.141 | 0.163 | 0.107 | **0.265** | 0.109 | 0.035 | **0.202** | 0.148 | 0.15 | 0.139 | 0.062 | 0.192 | 0.032 | 0.135 | 0.147 |
| **R11** | 0.151 | 0.13 | 0.187 | 0.076 | 0.184 | 0.136 | **0.28** | **0.333** | 0.15 | 0.041 | 0.067 | **0.288** | 0.103 | 0.033 | 0.146 |
| **R12** | 0.141 | 0.163 | **0.294** | **0.217** | **0.298** | 0.035 | **0.202** | 0.047 | 0.142 | 0.139 | 0.067 | **0.288** | **0.381** | 0.033 | 0.043 |
| **R13** | 0.043 | 0.163 | 0.078 | 0.076 | 0.072 | 0.136 | 0.09 | 0.148 | 0.15 | **0.342** | 0.062 | 0.192 | 0.032 | 0.135 | 0.146 |
| **R14** | 0.151 | **0.318** | 0.187 | **0.217** | **0.298** | 0.156 | 0.092 | 0.148 | 0.142 | 0.139 | 0.067 | 0.192 | 0.103 | 0.157 | 0.147 |
| **R15** | 0.151 | 0.058 | **0.294** | 0.076 | 0.072 | 0.136 | 0.092 | 0.145 | 0.15 | 0.041 | 0.062 | 0.192 | 0.19 | 0.135 | 0.146 |
| **R16** | 0.141 | 0.163 | 0.078 | **0.217** | 0.109 | 0.156 | **0.202** | 0.148 | 0.142 | 0.139 | 0.067 | **0.288** | 0.032 | 0.033 | 0.043 |
| **R17** | **0.332** | 0.163 | 0.187 | 0.076 | 0.072 | 0.035 | **0.28** | 0.047 | 0.034 | 0.041 | 0.062 | 0.103 | 0.103 | **0.348** | **0.533** |
| **R18** | 0.141 | **0.318** | 0.187 | 0.076 | 0.184 | 0.136 | **0.28** | 0.148 | 0.15 | 0.153 | 0.067 | 0.192 | 0.032 | 0.135 | 0.146 |
| **R19** | 0.151 | **0.318** | **0.294** | 0.076 | 0.109 | 0.156 | 0.09 | **0.333** | 0.142 | 0.139 | 0.062 | 0.103 | 0.103 | 0.135 | 0.146 |
| **R20** | 0.075 | 0.168 | 0.056 | 0.065 | 0.128 | 0.139 | 0.16 | 0.119 | 0.182 | 0.156 | **0.297** | 0.182 | 0.0835 | 0.035 | 0.075 |

**Table 5.1** Continued:

| R | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **R1** | 0.043 | 0.164 | 0.188 | 0.076 | 0.185 | 0.137 | **0.203** | 0.145 | 0.034 | 0.14 | 0.067 | 0.104 | 0.032 | 0.034 | 0.147 |
| **R2** | 0.151 | 0.058 | 0.078 | **0.217** | 0.072 | 0.136 | **0.202** | 0.047 | 0.034 | **0.342** | 0.067 | **0.288** | 0.103 | 0.135 | 0.146 |
| **R3** | 0.043 | 0.163 | 0.107 | **0.217** | 0.184 | 0.156 | 0.092 | 0.148 | 0.062 | 0.192 | 0.103 | 0.135 | 0.043 | 0.096 | 0.19 |
| **R4** | 0.151 | **0.318** | 0.187 | **0.265** | **0.298** | 0.136 | **0.28** | 0.148 | **0.342** | 0.139 | 0.067 | 0.103 | 0.19 | 0.033 | 0.146 |
| **R5** | **0.332** | 0.058 | **0.294** | 0.076 | 0.184 | **0.346** | **0.202** | **0.333** | 0.034 | 0.153 | 0.062 | 0.192 | 0.032 | 0.157 | 0.147 |
| **R6** | 0.151 | 0.163 | 0.078 | **0.217** | 0.072 | 0.035 | 0.092 | 0.148 | 0.142 | **0.342** | 0.067 | 0.192 | 0.103 | 0.033 | 0.146 |
| **R7** | 0.141 | 0.13 | 0.187 | **0.265** | **0.298** | 0.136 | **0.202** | 0.145 | 0.142 | 0.139 | **0.416** | 0.103 | 0.103 | 0.135 | 0.146 |
| **R8** | 0.151 | 0.058 | 0.187 | 0.076 | 0.184 | **0.346** | 0.09 | 0.148 | 0.15 | 0.139 | 0.067 | 0.192 | 0.032 | **0.544** | **0.336** |
| **R9** | 0.043 | 0.13 | 0.107 | **0.217** | 0.109 | 0.035 | **0.28** | 0.148 | 0.142 | 0.153 | 0.067 | **0.288** | 0.103 | 0.033 | 0.043 |
| **R10** | 0.141 | 0.163 | 0.107 | **0.265** | 0.109 | 0.035 | **0.202** | 0.148 | 0.15 | 0.139 | 0.062 | 0.192 | 0.032 | 0.135 | 0.147 |
| **R11** | 0.151 | 0.13 | 0.187 | 0.076 | 0.184 | 0.136 | **0.28** | **0.333** | 0.15 | 0.041 | 0.067 | **0.288** | 0.103 | 0.033 | 0.146 |
| **R12** | 0.141 | 0.163 | **0.294** | **0.217** | **0.298** | 0.035 | **0.202** | 0.047 | 0.142 | 0.139 | 0.067 | **0.288** | **0.381** | 0.033 | 0.043 |
| **R13** | 0.043 | 0.163 | 0.078 | 0.076 | 0.072 | 0.136 | 0.09 | 0.148 | 0.15 | **0.342** | 0.062 | 0.192 | 0.032 | 0.135 | 0.146 |
| **R14** | 0.151 | **0.318** | 0.187 | **0.217** | **0.298** | 0.156 | 0.092 | 0.148 | 0.142 | 0.139 | 0.067 | 0.192 | 0.103 | 0.157 | 0.147 |
| **R15** | 0.151 | 0.058 | **0.294** | 0.076 | 0.072 | 0.136 | 0.092 | 0.145 | 0.15 | 0.041 | 0.062 | 0.192 | 0.19 | 0.135 | 0.146 |
| **R16** | 0.141 | 0.163 | 0.078 | **0.217** | 0.109 | 0.156 | **0.202** | 0.148 | 0.142 | 0.139 | 0.067 | **0.288** | 0.032 | 0.033 | 0.043 |
| **R17** | **0.332** | 0.163 | 0.187 | 0.076 | 0.072 | 0.035 | **0.28** | 0.047 | 0.034 | 0.041 | 0.062 | 0.103 | 0.103 | **0.348** | **0.533** |
| **R18** | 0.141 | **0.318** | 0.187 | 0.076 | 0.184 | 0.136 | **0.28** | 0.148 | 0.15 | 0.153 | 0.067 | 0.192 | 0.032 | 0.135 | 0.146 |
| **R19** | 0.151 | **0.318** | **0.294** | 0.076 | 0.109 | 0.156 | 0.09 | **0.333** | 0.142 | 0.139 | 0.062 | 0.103 | 0.103 | 0.135 | 0.146 |
| **R20** | 0.075 | 0.168 | 0.056 | 0.065 | 0.128 | 0.139 | 0.16 | 0.119 | 0.182 | 0.156 | **0.297** | 0.182 | 0.0835 | 0.035 | 0.075 |

As shown in Table 5.1. The threshold values in bold are the items that exceed the threshold value 0.2. This indicated that, the individual expert opinions are not in consensus with the other experts' views for the particular questionnaire item.
The overall threshold value is calculated using the following formula:

$$\{(\Sigma \boldsymbol{Experts} \times \Sigma \boldsymbol{Items}) - (\boldsymbol{Total\ Responses} > \mathbf{0.2} \,/\, \{(\Sigma \boldsymbol{Experts} \times \Sigma \boldsymbol{Items})\} \times \mathbf{100}\%$$

Based on the formula the overall threshold value is equal to 86.20%. This means that the threshold had exceeded 75% which indicated that the experts had reached the required consensus about the elements (learning Activities) that should be included in the developmental model (Lin & Chuang, 2012). Since consensus has been achieved, there was no need to repeat the survey; the next step was to seek the findings for experts' views on the development of the model in terms of their agreement on the following aspects:

A) Selection of HOT teaching model stages.

B) Selection of sub-stages for each HOT teaching model stages.

Aspect (A) represents the model stages that constitute the main parts of the structural model. While aspect (B) represents the sub-stages that show the learning activities that engage students in the process of constructing knowledge. In order to develop a clear and valid guide for implementation the HOT teaching model in science education, which can be identified by the following research questions:

1) What are the experts' views on the stages and sub-stages that should be included in the development of the HOT teaching model?
2) Based on the experts' agreement consensus, how should the HOT teaching model stages and sub-stages be arranged in the implementation of the model?

### 5.3.1 Selection of Stages of HOT Teaching Model.

This section presents results regarding the specific stages (Teaching Steps) for the HOT teaching model according to the following specific research question:

What are the experts' views on the stages that should be included in the development of the HOT teaching model?

Selecting the model stages is the most important part of the model, which describe the structural model, therefore in order to select the stages (Elements) for the developmental model, the alpha-cut level was identified based on the experts' responses to question 1 in FDM Questionnaire (See Appendix E) as in Table 5.2.

**Table 5.2:** Alpha-Cut Value of the Proposed Stages in the HOT Teaching Model

| Item | Engagement | | | Investigation | | | Conclusion | | | Reflection | | | Explanation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Average Response** | 0.69 | 0.85 | 0.945 | 0.68 | 0.835 | 0.925 | 0.65 | 0.81 | 0.91 | 0.61 | 0.775 | 0.905 | 0.65 | 0.815 | 0.92 |
| **Alpha-Cut Value** | **0.828** | | | **0.813** | | | **0.79** | | | **0.763** | | | **0.795** | | |

As elaborated in Chapter three, the accepted value for alpha-cut is equal to 0.5. As seen in Table 5.2 the overall items have reached the acceptance level, the maximum value of alpha cut (0.82) was for item engagement and the minimum value (0.763) was for reflection. Thus, based on experts' responses the five stages have been selected for the HOT teaching model.

In order to identify the experts' consensus agreement about the overall five selected stages, the defuzzification value has been calculated as in Table 5.3.

**Table 5.3:** Experts' Views on the Proposed Stages in the HOT Teaching Model

| Item | Engagement | | | Investigation | | | Conclusion | | | Reflection | | | Explanation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuzzy Evaluation | 13.8 | 17 | 18.9 | 13.6 | 16.7 | 18.5 | 13 | 16.2 | 18.2 | 12.2 | 15.5 | 18.1 | 13 | 16.3 | 18.4 |
| Defuzzification | 16.56 | | | 16.26 | | | 15.8 | | | 15.266 | | | 15.9 | | |

As discussed in chapter 3, the agreement consensus of experts' collective view was between 19 for strongly agree to 10 for slightly agree (refer to Table 3.6). Thus, according to Table 5.3, the range of defuzzification value is between"15.26 to 16.56" which means that the experts achieved moderate consensus on the five proposed stages. The engagement stage received the highest agreement from the experts with a defuzzification value of 16.56, while the reflection stage received the lowest agreement with a defuzzification value of 15.26. The overall findings in this aspect indicated that the participants slightly agreed that the proposed stages are important for teaching science and should be included in the HOT teaching model.

### 5.3.2 Selection of Sub-Stages for HOT Teaching Model

This section discussed results regarding the specific stages (Teaching Steps) for the HOT teaching model according to the following specific research question:

What are the experts' views on the sub-stages that should be included in the development of the HOT teaching model?

The sub-stages of the HOT teaching model are the learning activities that support students' use of both reflective thinking skills and science process skills through applying each stage of the developmental model. These sub-stages were identified based on the experts' responses on FDM questionnaire for items 2, 3, 4, 5 and 6.

1) **Selection of Sub-Stages for the Engagement Stage**

As for item 2 the participants were given the following questionnaire item to respond: Do you agree with these sub-stages under the engagement stage? In order to select the sub-stages under the engagement stage, the alpha-cut level has been calculated as in Table 5.4.

**Table 5.4:** Alpha-Cut Value of the Sub-Stages for the Engagement Stage

| Stage | Sub-Stages | Average Response | | | Alpha-Cut |
|---|---|---|---|---|---|
| **A Engagement** | A1: Asking Critical Question | 0.71 | 0.865 | 0.95 | 0.841 |
| | A2: Estimation | 0.63 | 0.795 | 0.905 | 0.776 |
| | A3: Formulating Precisely Problem | 0.7 | 0.85 | 0.935 | 0.828 |
| | A4: Making Comparison | 0.7 | 0.86 | 0.955 | 0.838 |
| | A5: Identifying Relationships | 0.71 | 0.86 | 0.94 | 0.836 |

The alpha-cut value for the sub-stages under the engagement stage are shown in Table 5.4, which exceed the critical value for alpha-cut 0.5; this means all sub-stages were selected as the important activities that help students to engage in the science class, that would further help them to think properly about the problem and how it can be solved. After selecting the sub-stages for the engagement stage, it is very important to identify the experts' agreement on these sub-stages by identifying the defuzzification value as in Table 5.5.

**Table 5.5:** Experts Views on the Sub-Stages for the Engagement Stage

| Stage | Sub-Stages | Fuzzy Evaluation | | | Defuzzification |
|---|---|---|---|---|---|
| **A Engagement** | A1: Asking Critical Questions | 14.2 | 17.3 | 19 | 16.833 |
| | A2: Estimation | 12.6 | 15.9 | 18.1 | 15.533 |
| | A3:Formulating Precisely Problem | 14 | 17 | 18.7 | 16.566 |
| | A4: Making Comparison | 14 | 17.2 | 19.1 | 16.766 |
| | A5:Identifying Relationships | 14.2 | 17.2 | 18.8 | 16.733 |

As in Table 5.5 the findings indicated that the item (A1) asking critical questions received the highest consensus agreement from the participant with a defuzzification value of 16.83, while the lowest defuzzification value was for item (A2) Estimation. However, the sub-stages for the engagement stage only received the range of agreement. Thus conclusively, the experts consensually agreed with the proposed learning activities for engagement stage of the HOT teaching model.

**2) Selection of Sub-Stages for the Investigation Stage**

The alpha-cut level values for the sub-stages under the Investigation stage are shown in the following Table 5.6.

**Table 5.6:** Alpha-Cut Value of the Sub-Stages for the Investigation Stage

| Stage | Sub-Stages | Average Response | | | Alpha-Cut |
|---|---|---|---|---|---|
| **B Investigation** | B3: Writing Procedure | 0.65 | 0.8 | 0.9 | 0.876 |
| | B2: Plaining | 0.65 | 0.8 | 0.9 | 0.783 |
| | B4: Controlling Variable | 0.71 | 0.87 | 0.95 | 0.843 |
| | B1: Formulating Hypothesis | 0.8 | 0.94 | 0.985 | 0.908 |
| | B5: Measuring | 0.7 | 0.855 | 0.94 | 0.831 |

Referring to the survey questionnaire (item 3), the findings indicated that the overall five sub-stages for the Investigation stage were selected based on their alpha-cut values more than 0.5. In order to identify the agreement consensus among the experts, the defuzzification value has been calculated as in Table 5.7.

**Table 5.7:** Experts' Views on the Sub-Stages for the Investigation Stage

| Stage | Sub-Stages | Fuzzy Evaluation | | | Defuzzification |
|---|---|---|---|---|---|
| **B Investigation** | B3: Writing Procedure | 0.65 | 0.8 | 0.9 | 17.366 |
| | B2: Planning | 13 | 16 | 18 | 15.666 |
| | B4: Controlling Variable | 14.2 | 17.4 | 19 | 16.866 |
| | B1: Formulating Hypothesis | 16 | 18.8 | 19.7 | 18.166 |
| | B5: Measuring | 14 | 17.1 | 18.8 | 16.633 |

Based on Table 5.7, the findings illustrated the participants' consensus agreement on the sub-stages for the Investigation stage with a highest defuzzification value (for item B1) 18.16 and the lowest defuzzification value (for item B2) 15.66, which is the range from moderately agree to agree as the defuzzification values were above 14 (based on Table 3.6).



**3) Selection of Sub-Stages for the Explanation Stage**

The overall sub-stages of the Explanation stage have been selected as the activities that encouraged students to use their higher cognitive skills on science due to the value of alpha-cut. As seen in Table 5.8, all the sub-stages received more than 0.5 meaning that these sub-stages are very important and selected by the panel of experts as the learning activities that would help students to explain what they have investigated in the previous Stage.

**Table 5.8:** Alpha-Cut Value of the Sub-Stages for the Explanation Stage

| Stage | Sub-Stages | Average Response | | | Alpha-Cut |
|---|---|---|---|---|---|
| **E Explanation** | C4: Critiquing | 0.79 | 0.935 | 0.985 | 0.903 |
| | C1: Organizing Data | 0.76 | 0.91 | 0.975 | 0.881 |
| | C2: Checking | 0.75 | 0.905 | 0.975 | 0.876 |
| | C5: Identifying Assumption | 0.61 | 0.785 | 0.91 | 0.768 |
| | C3: Comparing Result | 0.72 | 0.87 | 0.945 | 0.845 |

In order to elicit the experts' views whether they agreed with the selected sub-stages for Explanation stage, the defuzzification values have been identified as in Table 5.9.

**Table 5.9:** Experts Views on Sub-Stages for the Explanation Stage

| Stage | Sub-Stages | Fuzzy Evaluation | | | Defuzzification |
|---|---|---|---|---|---|
| **E Explanation** | E4: Critiquing | 15.5 | 18.2 | 19 | 17.566 |
| | E1: Organizing Data | 15.2 | 18.2 | 19.5 | 17.633 |
| | E2: Checking | 15 | 18.1 | 19.5 | 17.533 |
| | E5: Identifying Assumption | 12.2 | 15.7 | 18.2 | 15.366 |
| | E3: Comparing Result | 14.4 | 17.4 | 18.9 | 16.9 |

Table 5.9, shows the finding of the experts' collective views on the sub-stages for the Explanation stage. The defuzzification values for all sub-stages indicated that the experts consensually moderately agreed as in the case of item (E5: Identifying assumption) and (E3: Comparing result) with the DV (15.366) and (16.9) respectively. While the panel of experts agreed on the overall other sub-stages for the explanation stage such as (E4: Critiquing, E1: Organizing data. and E2: Checking) due to the DV of more than 17.33.

**4) Selection of Sub-Stages for the Conclusion Stage**

The five sub-stages proposed for the Conclusion stage were selected by the experts' as they received the alpha-cut values more than 0.5.

**Table 5.10:** Alpha-Cut Value of the Sub-Stages for the Conclusion Stage

| Stage | Sub-Stages | Average Response | | | Alpha-Cut |
|---|---|---|---|---|---|
| **C Conclusion** | C1: Expanding | 0.77 | 0.91 | 0.97 | 0.883 |
| | C2: Generating Idea | 0.81 | 0.945 | 0.99 | 0.915 |
| | C3: Defining the Concept | 0.75 | 0.9 | 0.975 | 0.875 |
| | C4: Summarize Results in Graph | 0.77 | 0.915 | 0.98 | 0.888 |
| | C5: Producing | 0.73 | 0.88 | 0.955 | 0.855 |

After identifying the defuzzification values for the sub-stages of the Conclusion stage, the findings showed that, the experts' moderately agreed on Producing sub-stage with defuzzification value of (17.1). While all the experts consensually agreed to the other four sub-stages of the Conclusion stage according to the defuzzification value more than 17.3 (see Table 5.11).

**Table 5.11:** Experts' Views on the Sub-Stages for the Conclusion Stage

| Stage | Sub-Stages | Fuzzy Evaluation | | | Defuzzification |
|---|---|---|---|---|---|
| **C Conclusion** | C1: Expanding | 15.4 | 18.2 | 19.4 | 17.666 |
| | C2:Generating Idea | 16.2 | 18.9 | 19.8 | 18.3 |
| | C3: Defining the Concept | 15 | 18 | 19.5 | 17.5 |
| | C4: Summarize Results in Graph | 15.4 | 18.3 | 19.6 | 17.766 |
| | C5: Producing | 14.6 | 17.6 | 19.1 | 17.1 |

**5) Selection of Sub-Stages for Reflection Stage**

In terms of experts' views on the selection of the sub-stages for the Reflection stage, the results in Table 5.12 shows that the reflection sub-stages were selected by the panel of experts as the activities that would help students to look back about what they have done in the previous stages.

**Table 5.12:** Alpha-Cut Value of the Sub-Stages for the Reflection Stage

| Stage | Sub-Stages | Average Response | | | Alpha-Cut |
|---|---|---|---|---|---|
| **D Reflection** | D1:Identifying Experimental Error | 0.75 | 0.9 | 0.975 | 0.875 |
| | D2: Making Judgment | 0.83 | 0.955 | 0.99 | 0.925 |
| | D3:Suggesting another Procedure to Solve the Problem | 0.72 | 0.885 | 0.975 | 0.86 |
| | D4: Evaluation of Argument | 0.76 | 0.905 | 0.965 | 0.876 |

Table 5.13 shows the finding of experts' collective views on the sub-stages for the Reflection stage. Similar to other stages, the defuzzification values for the all four sub-stages were above the minimum value of 10 indicating experts' consensus on the sub-

stages for the Reflection stage. The highest DV was for making judgement (18.5) as the essential reflective thinking skills that has to be cultivated among students. Following by evaluation of argument, identifying experimental error and suggesting another procedure to solve the problem.

**Table 5.13:** Experts' Views on the Sub-Stages for the Reflection Stage

| Stage | Sub-Stages | Fuzzy Evaluation | | | Defuzzification |
|---|---|---|---|---|---|
| **D Reflection** | D1: Identifying Experimental Error | 15 | 18 | 19.5 | 17.5 |
| | D2: Making Judgment | 16.6 | 19.1 | 19.8 | 18.5 |
| | D3: Suggesting another Procedure to Solve the Problem | 14.4 | 17.7 | 19.5 | 17.2 |
| | D4: Evaluation of Argument | 15.2 | 18.1 | 19.3 | 17.533 |

### 5.3.3 Features of the HOT Teaching Model

Regarding the second research question for phase two (design and development phase) of the study, that is:

Based on the experts' agreement consensus, how should the HOT teaching model stages and sub-stages be arranged in the implementation of the model?

In order to determine the priorities of elements (stages and sub-stages), for the HOT teaching model, ranking of the elements was used, based on the defuzzification values for both, model stages and the sub-stages for each model stage. The overall findings are concluded in Table 5.14 and 5.15. The ranking number (1) was taken as the highest rank consistent with the highest defuzzification values registered to the particular item.

**Table 5.14:** Ranking of the Stages for HOT Teaching Model

| Stage | Fuzzy Evaluation | | | Defuzzification | Ranking |
|---|---|---|---|---|---|
| **Engagement** | 13.8 | 17 | 18.9 | 16.566 | 1 |
| **Investigation** | 13.6 | 16.7 | 18.5 | 16.266 | 2 |
| **Conclusion** | 13 | 16.2 | 18.2 | 15.8 | 4 |
| **Reflection** | 12.2 | 15.5 | 18.1 | 15.266 | 5 |
| **Explanation** | 13 | 16.3 | 18.4 | 15.9 | 3 |

**Table 5.15:** Ranking of Sub-Stages for the HOT Teaching Model

| Stage | Sub-Stages | Fuzzy Evaluation | | | Defuzzification | Ranking |
|---|---|---|---|---|---|---|
| **A Engagement** | | | | | | |
| | A1: Asking critical question | 14.2 | 17.3 | 19 | 16.833 | 1 |
| | A2:Estimation | 12.6 | 15.9 | 18.1 | 15.533 | 5 |
| | A3: Formulating precisely problem | 14 | 17 | 18.7 | 16.566 | 4 |
| | A4: Making comparison | 14 | 17.2 | 19.1 | 16.766 | 2 |
| | A5: Identifying relationships | 14.2 | 17.2 | 18.8 | 16.733 | 3 |
| **B Investigation** | | | | | | |
| | B3: Writing Procedure | 0.65 | 0.8 | 0.9 | 17.366 | 2 |
| | B2: Planning | 13 | 16 | 18 | 15.666 | 5 |
| | B4: Controlling Variable | 14.2 | 17.4 | 19 | 16.866 | 3 |
| | B1: Formulating Hypothesis | 16 | 18.8 | 19.7 | 18.166 | 1 |
| | B5: Measuring | 14 | 17.1 | 18.8 | 16.633 | 4 |
| **E Explanation** | | | | | | |
| | E4: Critiquing | 15.5 | 18.2 | 19 | 17.566 | 2 |
| | E1: Organizing Data | 15.2 | 18.2 | 19.5 | 17.633 | 1 |
| | E2: Checking | 15 | 18.1 | 19.5 | 17.533 | 3 |
| | E5: Identifying Assumption | 12.2 | 15.7 | 18.2 | 15.366 | 5 |
| | E3: Comparing Result | 14.4 | 17.4 | 18.9 | 16.9 | 4 |
| **C Conclusion** | | | | | | |
| | C1: Expanding | 15.4 | 18.2 | 19.4 | 17.666 | 3 |
| | C2: Generating Idea | 16.2 | 18.9 | 19.8 | 18.3 | 1 |
| | C3: Defining the Concept | 15 | 18 | 19.5 | 17.5 | 4 |
| | C4: Summarize Results in Graph | 15.4 | 18.3 | 19.6 | 17.766 | 2 |
| | C5: Producing | 14.6 | 17.6 | 19.1 | 17.1 | 5 |
| **D Reflection** | | | | | | |
| | D1: Identifying Experimental Error | 15 | 18 | 19.5 | 17.5 | 3 |
| | D2: Making Judgment | 16.6 | 19.1 | 19.8 | 18.5 | 1 |
| | D3: Suggesting Another Procedure to Solve the Problem | 14.4 | 17.7 | 19.5 | 17.2 | 4 |
| | D4: Evaluation of Argument | 15.2 | 18.1 | 19.3 | 17.533 | 2 |

The priority of the HOT teaching model stages and sub-stages are elaborated as follows:

#### 5.3.3.1 Stage One: Engagement

The experts consensually agreed that the engagement stage has to be the first stage of the HOT teaching model. Engaging students in science is still essential for the following reasons:

**i.** When students engage in the construction of knowledge, an element of uncertainty is introduced into the instructional process and the outcomes are not always predictable. In other words, the teacher is not certain what the students will produce. In helping students become producers of knowledge, the teacher's main instructional task is to create activities or environments that allow more opportunities for them to engage in higher- order thinking.

**ii.** Students should primarily engage in lower order thinking for a good share of lessons, so there will be at least one significant question or activity in which some students performs some higher order thinking skills.

**iii.** The engagement invited students to brainstorm and present possible problems related to real life through specific questions; these questions may raise students' motivation, shift their attention toward the topic and highlight the importance of this topic for learners (Hofstein & Lunetta, 2004).

**Ranking of Sub-Stages for the Engagement Stage**

The overall five sub-stages have been selected by the experts as the activities that help students to engage in science as well as to improve their HOTS. The ranking of these sub-stages were as follow:

1- Asking critical questions: this sub- stage received the first ranking of sub-stages that engage students in science. Students who have questions are really thinking and learning, however students come up with excellent questions when they observe scientific phenomena. Thus, the science teacher should help students to think deeply by asking critical questions. Different type of questions can be driven by the science teacher for different tasks to help them to use basic skills, such as questions of logic, force students to consider how they can put all of their thoughts together, questions for purpose that help students to define their task and question for information that force them to look at their sources of information as well as at the quality of that information (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005).

2- Making comparisons: the second sub- stage that should be improved by the science teacher is making comparisons. Using observation and asking questions would help students to make a comparison between two objects, identifying the characteristic of each object according to specific properties.

3- Identifying relationships: this sub- stage received the third rank between overall five sub-stages for the engagement stage. This sub- stage serves to complete making comparisons; by identifying specific property for each object, students will be able to identify relationship between these objects.

4- Formulating precisely problem: the experts agreed that using previous activities, students will be able to formulate a problem based on what they have seen and thought about the subject. The science teacher should help students to make a problem simpler, easier and clear, that would help them to engage more and encourage them to find a solution.

5- Estimation: this sub-stage would help students to think at a higher level. Using brainstorming, students can estimate how the proposed problem should be solved and what are the steps that they should follow to solve the proposed problem. Estimation sub-stage allow students the ability to reason through math answers.

#### 5.3.3.2 Stage Two: Investigation

Referring to Table 5.14, investigation has been ranked as the second stage for the HOT teaching model. By the end of the engagement stage, students will be able to identify and formulate the problem; hence the way to solve the problem is called investigation. In this stage, students have to think of the best way to solve the problem, develop a plan to address the problem, then apply it to solve the problem.

Baird, Fensham, Gunstone, and White (1991) agree with the importance of discussion before and after investigation. Learning through investigation needs to be seen as a recursive process rather than a constrained procedure. This recursive process is promoted in science investigation as the best support for student learning. In order to carry out science investigation, the science teacher should teach students both the understanding of science concept (substantive knowledge) and skills (understanding of science procedure). The sub-stages that would help the students to investigate the problem are as follows:

**Ranking of the Sub-Stages for the Investigation stage**

1- Formulating hypothesis: The first and the most important sub-stage for investigation which the experts agreed with was formulating hypothesis. The prediction or an educated guess about what might happen in an experiment and the possible outcome is called hypothesis. The hypothesis can be tested through experimentation or observation and it could be disproved or supported by the collected evidence. By encouraging students to generate multiple hypotheses, we teach them that there are several possible outcomes to any experiment and it also a way to help students avoid the feeling that they are wrong, if the experiment does not turn out as expected (Tamir, 1989). Thus, formulating hypotheses will help students maintain their objectivity and improve their integrated science process skills.

2- Writing procedure: The second sub-stage that the experts agreed with its importance for the Investigation stage was writing procedure. The procedure is a set of very specific instruction about how the students are going to investigate the solution for the proposed problem (Hand, Prain, & Yore, 2001). Therefore, after generating the hypothesis and selecting materials, students are ready to design an experiment to test their hypothesis. This is a time for the science teacher to encourage students and pay attention to all the details and help them to write specific steps to do the experiment and solve the problem.

3- Controlling variable: This integrated science process serves to complete the writing procedure sub- sub-stage, in which before doing experiment the science teacher should help students to identify the fixed variables, such as manipulated variables and responding variables in an investigation. The teacher should help students to identify the variables that will affect the experiment and find the appropriate way to control it.

4- Measuring: Employing this learning activity in science class is vital for students in science learning, because it requires them to use math skills that are higher cognitive skills.

5- Planning: The experts consensually agreed that this sub-stage improve students' integrated science process skills, through the process of investigating the problem, which will shorten the way to solve the proposed problem.

#### 5.3.3.3 Stage Three: Explanation

This stage of the HOT teaching model focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities for them to verbalize their conceptual understanding and explanations of concepts in their own words. Connecting students' prior knowledge (stage one) to new discoveries and understandings in (stage two) would encourage students to explain the scientific concepts. There are a number of important reasons for engaging elementary students in scientific explanation. Constructing and critiquing evidence-based explanations engages students in authentic scientific practices and discourse, which can contribute to the development of their problem-solving, reasoning, and communication skills. These abilities are consistent with those characterized as twenty-first century skills necessary for a wide range of current and future occupations. Constructing scientific explanations can also contribute to students' meaningful learning of science concepts and how science is done. As illustrated in the literature on science education, inquiry science is not only about collecting data and sharing results. By participating in the language of science, through talking and writing, students make sense of ideas and explain phenomena as they negotiate coherence among claims and evidence. This meaning-making process is essential to science learning and is supported through the construction of scientific explanations. The ranking of the sub-stages for the explaining stage showed that experts consensually agreed that organizing data, checking, comparing results, critiquing and identifying assumption. These integrated science process skills would help students to interact in a positive, supportive manner in the process of explaining the concept.

**Ranking of the Sub-Stages for Explanation**

1- Organizing data: Describing and understanding the results of an experiment are critical aspects of science. According to the experts view, the Explanation stage starts with helping students to organize the collected data based on the evidence that they have observed during the Investigation stage.

2- Critiquing: Reviewing or discussing the data critically is an important learning activity for improving HOTS in science learning. Through using their prior knowledge, students will be able to critique the data that have been collected.

3- Checking: The third sub-stage of the Explanation stage is checking. Through checking the results, students will separate the irrelevant data from the relevant one. Using tables and interpreting graphs will aid students in checking their results.

4- Comparing result: These science process skills will help students to share their ideas, build communication skills and identify their mistakes.

5- Identifying assumption. By the end of this stage, the students should be able to investigate the assumption, to verify whether the hypotheses that they have assumed are correct or not. The teacher allows students the opportunities to verbalize and clarify the concept; introduces concepts and terms and summarizes the results of the exploration stage.

#### 5.3.3.4 Stage Four: Conclusion

After conducting an experiment and analyzing the results, students should come to some conclusion as to what their results told them about the answer to their question. Therefore, this fourth stage of the model, Conclusion, serves to complete stage three (explanation). It aimed at extending students' conceptual understanding, allowing further chances for them to clarify their discovered understandings, and reach conclusions through new experiences. However, a conclusion should reflect what students have learned by doing the experiment. To aid students in reaching conclusions, the experts selected five sub-stages that including reflective thinking (RT) and science process skills (SPS). The ranking of these sub-stages are given next:

**Ranking of the Sub-Stages for the Conclusion Stage**

1- Generating idea: The experts agreed that this learning activity is the most important sub-stage to aid students to conclude their finding through the process of creating, developing, and communicating ideas which are abstract, concrete, or visual. The idea could be generated alone or by a group of students (Duschl & Osborne, 2002).

2- Summarize results in graph: Understanding the results of an experiment and summarizing it in a graph are critical aspects of science learning. There are three parts to this sub- stage: making a data table, making graphs, and analyzing data with simple statistical tests. However, it is important for students to practice making tables and graphs by hand. Once students learn how to make organized data tables and graphs, they should use this knowledge to present the results of the concept.

3- Expanding: Expanding the concept between subjects is the third sub-stage for the Conclusion stage; this learning activity is essential for students to practice the transfer of learning. Transfer of learning can range from transfer of one concept to another (e.g., Newton's law of gravitation and Coulomb's law of electrostatics). Also the transformation of learning can occur through one school subject to another (e.g., math skills applied in scientific investigations); one year to another (e.g., significant figures, graphing, chemistry concepts in physics); and school to non-school activities (e.g., using a graph to calculate whether it is cost effective to join a video club or pay a higher rate on rentals) (Engeström, 2014). Through this process students will see the connection between subjects, how each subject can complete the other one and how they are connected to real life.

4- Defining the concepts: This integrated science process skill serves to complete the previous sub-stages under the Conclusion stage. After doing the previous activities, students will be able to verbalize the concepts using their own words. The science teacher guides students toward coherent and consistent generalizations, helps them with distinct scientific vocabulary, and provides questions that help students use this vocabulary to precede the concept's terminology.

5- Producing: The final sub-stage for the Conclusion stage was producing. This higher order thinking skill will support students to go through all previous stages, as much as they understand the concept, it will be easier for them to produce a simple application model, or give a new example of the concept.

#### 5.3.3.5 Stage Five: Reflection

The final stage of the HOT teaching model in the science classroom was Reflection. The importance of this stage is to aid students to get feedback on what has been done in the previous steps, by taking time to think again about the initial problem, the path taken to solve it, and the actual conclusions. According to the experts' views, four sub-stages were selected to assist students in reflecting about the experiences: evaluating the argument, making judgment, identifying experimental error, and suggesting another procedure to solve the problem. Moreover, activities such as journal writing, using subject connection, presentation, and asking students to create their own examples of the concepts can assist students to achieve the objectives of this stage.

**Ranking of the Sub-Stages for Reflection Stage**

1- Making judgment: This reflective thinking skill is an important for students to define their opinion that is based on careful thought and will make them be decision makers in their real life situation.

2- Evaluation of argument: The critical evaluation of ideas, arguments, and points of view is important for developing students' reflective thinking. It is only through this critical evaluation that students can distinguish among competing claims for truth and determine which arguments and points of views they can trust, and those of which they should be sceptical (Dwyer, Hogan, & Stewart, 2010). This will improve students' ability to comprehend the arguments of others and produce their own learning of how to analyze and critically evaluate arguments, and it will aid students to develop a sound framework to test their own arguments and advance their own points of view.

3- Identifying experimental error: The third sub-stage that the experts consensually agreed on its importance in reflective thinking is identifying experimental error. Through this activity students will think again on the previous steps and the way they have solved the problem. Accounting for errors in an experiment, determine the validity and reliability of that experiment, in turn, will make them either support the experimental results by accepting the hypothesis or make them discard the experimental results, by rejecting the hypothesis.

4- Suggesting another procedure to solve the problem: This sub-stage improves students' reflective thinking, which is a higher level of thinking. The Science teacher should encourage students to suggest another way to solve the posed problem; through this sub-stage, the teacher can assess their students' understanding of the concepts and the solving problem process.

## 5.4 Summary of Findings of Phase Two

The overall result of this phase was selecting and ranking the elements of the HOT teaching model for basic education students in science learning. The model was developed using the experts' views by adopting the Fuzzy Delphi Method, which is an established decision-making approach that relies on experts' opinions to make decisions. In this study FDM was applied to select the elements of the model (stages and sub-stages) as well as to identify the priority of the selected elements in its implementation in science class. The prototype I of the HOT teaching model can be shown in Figure 5.1

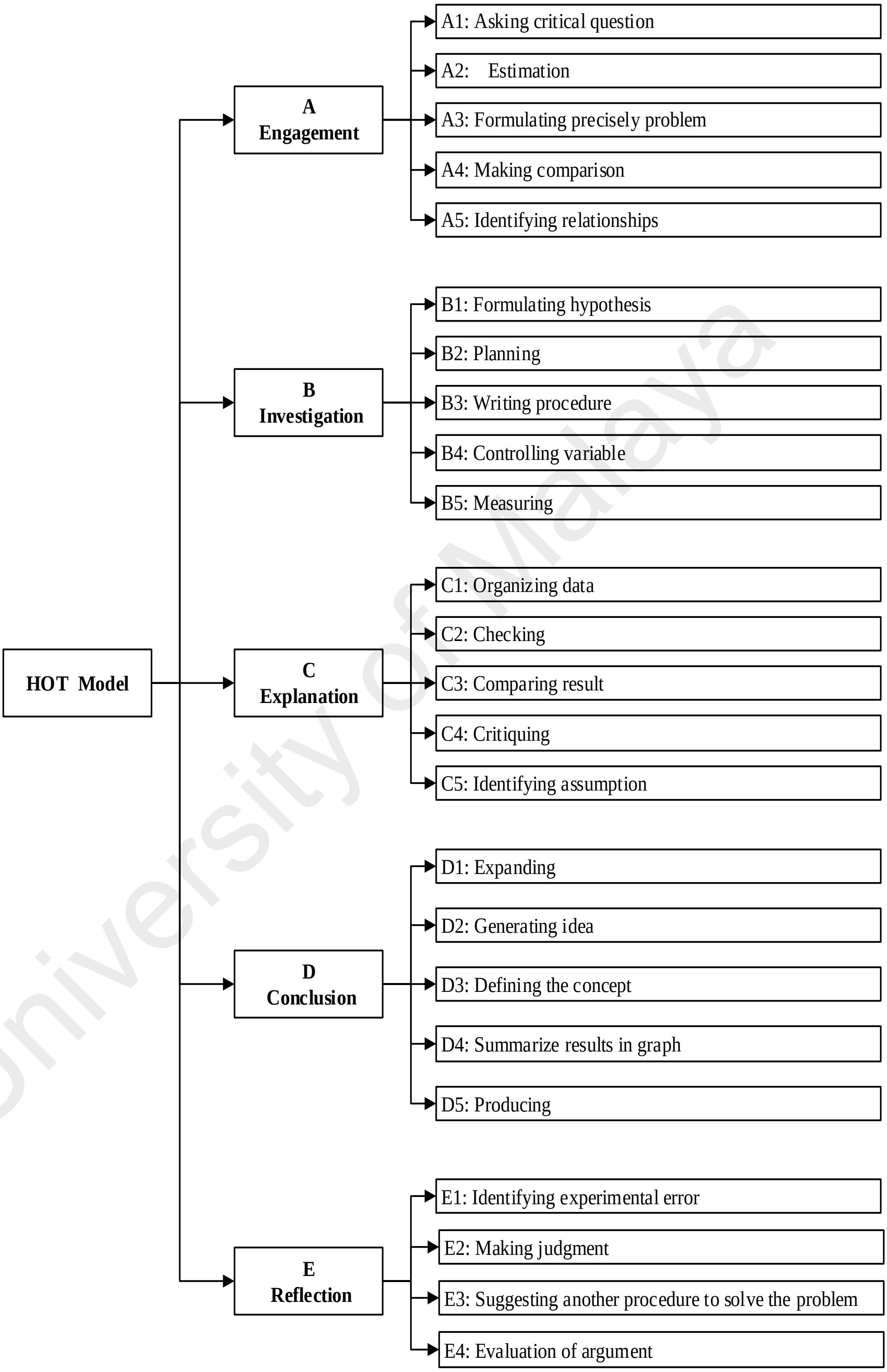





**Figure 5.1:** Fuzzy Delphi Method (FDM) HOT Teaching Model for Basic Education Students' in Science

As shown in Figure 5.1, the results indicate that the HOT teaching model consisted of five stages, Engagement, Investigation, Explanation, Conclusion, and Reflection. Furthermore, 24 sub-stages (reflective thinking and science process skills) have been selected by the panel of experts to be improved during the implementation of these stages.

## 5.5 Summary

The result of this phase is the prototype 1 HOT teaching model for basic education students in science as in Figure 5.1. The HOT model was developed using experts' views through employing the Fuzzy Delphi Method which is a decision making approach used widely in the business and economic sector to develop new models and programs. The HOT model aimed at enhancing students' higher order thinking skills in science learning through utilizing the activities that encourage students to use reflective thinking skills and science process skills in science education. The model consists of five stages (Engagement, Investigation, Explanation, Conclusion and Reflection). Besides, 24 sub-stages were selected by a panel of (20) experts as the learning to be adopted through employing the model stages in the science class. This prototype 1 model is further evaluated by science teachers' opinions through using partial least square approach in phase three. The findings are detailed in Chapter six.

# CHAPTER 6: FINDINGS OF PHASE THREE

## 6.1 Introduction

The aim of this phase was to evaluate the prototype 1 HOT teaching model developed in phase two. The evaluation phase is essential to determine the validity of the model as well as to identify the usability of the model for implementation in the science classroom. Partial least square (PLS) was used to test the HOT teaching model. The survey was carried out with 355 science teachers. The presentation of findings is divided into two parts. The first part presents the findings of the pilot study, while the second part reveals the science teachers' views about the model according to the following aspects.

A. Evaluation of the stages and sub-stages of HOT teaching model (measurement model).

B. Evaluation the usability of the HOT teaching model in its implementation in science classroom (structural model).

## 6.2 Instrument

The first version of the evaluation survey questionnaire (See Appendix H) consisted of 67 items divided into two parts: part 1 serves to elicit teachers' views of the model elements (stages and sub-stages) in the form of a 5-point Likert scale from "strongly agree" to "strongly disagree". Part 2 serves to identify experts' views on the overall impact of the model in influencing students' HOT.

The survey questionnaire consisted of six constructs (five stages of the HOT model and the usability of the model): Engagement stage ENG, consisted of 13 items representing the importance of the selected sub-stages for engagement stage in enhancing students' HOT. Investigation stage INV, 13 items; 11 items for Explanation stage EXP, 11 items for Conclusion stage CON and 11 items for Reflection stage REF constructs.

These constructs are the five stages of the HOT teaching model (see Figure 5.1). While the last construct represented the usability of the model (HOT construct) that comprised 8 items.

### 6.2.1 Piloting Questionnaire

The best way to purify the questionnaire items is by piloting it, collecting data and testing the reliability and validity. The questionnaire was piloted among 122 science teachers who were not included in the target sample. Pilot test is aimed at identifying the reliability of the questionnaire and the content validity using exploratory factor analyses. The results of the pilot study are presented in the following sections.

### 6.2.2 Reliability

The Cronbach alpha coefficient is recommended to measure the internal consistency (Reliability) of a set of items and should be the first measure calculated to assess the quality of the instrument. Table 6.1 shows Cronbach's alpha results for six proposed constructs, Engagement, Investigation, Explanation, Conclusion and Reflection and the usability of the model HOT construct. The reliability coefficients of all the constructs were above the threshold value (0.7) recommended by Gliem and Gliem (2003) and for the whole questionnaire alpha was (0.953) indicating a high reliability coefficient.

**Table 6.1:** Reliability Analysis for the Evaluation Survey Questionnaire Constructs

| Constructs | Items | Cronbach Alpha |
|---|---|---|
| **Engagement** | ENG1- ENG13 | .700 |
| **Investigation** | INV1- INV13 | .776 |
| **Explanation** | EXP1- EXP11 | .712 |
| **Conclusion** | CON1- CON11 | . 754 |
| **Reflection** | REF1- REF11 | .897 |
| **HOT** | HOT1- HOT8 | .879 |
| **All Questionnaire** | **67 items** | **.953** |

### 6.2.3 Exploratory Factor Analysis (Validity)

Exploratory Factor Analysis (EFA) was used to confirm the different constructs underlying the data set; in addition, it measured the constructs' validity (Hair & Black, 2010). A total of 67 items that were developed (See Appendix H) were subjected to EFA using SPSS version 21. Like any statistical method, EFA requires a number of assumptions. These assumptions should be met to ensure trustworthy results. One basic assumption is that the variables should be quantitative at the interval level. Using a 5-point Likert scale in the survey questionnaire fulfilled this requirement (Hair, 2010). The second important assumption is the sample adequacy, which is clarified in the next section.

**Test of Sphericity and Measure of Sampling Adequacy**

The Kaiser-Meyer-Olkin (KMO) is a measure of sampling adequacy. The KMO is recognized as one of the best measures of determining the suitability of a set of data for subsequent factor analysis and to investigate the data in order to decide whether factor analysis should be undertaken. The KMO varies from 0 to 1.0 and small values of KMO suggest that a factor analysis should not be undertaken. The recommended value for KMO is 0.60 or higher to proceed with factor analysis (Tabachnick & Fidell, 2007). The Bartlett's test of Sphericity assesses the overall significance of the correlation matrix. The best result in this test is when the value of the test statistics for Sphericity is large and the significance level is small (Williams et al., 2012). Table 6.2 presents the results of the Bartlett's test of Sphericity and the KMO measure of sampling adequacy.

**Table 6.2:** KMO and Bartlett's test

| Characteristic | | Value |
|---|---|---|
| **Kaiser-Meyer-Olkin Measure of Sampling Adequacy** | | **.654** |
| **Bartlett's Test of Sphericity** | Approx. Chi-Square | 7715.672 |
| | df | 1225 |
| | **Sig.** | **.000** |

According to Tabachnick and Fidell (2007), data is factorable when the Bartlett's test of Sphericity is significant (p-value < .05) and the KMO measure of sampling adequacy is at least 0.60. As shown in the Table 6.2, the score of the KMO of evaluation survey questionnaire is higher than the cut-off value of 0.60. The questionnaire constructs achieved a significant p-value < .001. The results of Bartlett's test of Sphericity suggested that the items of the construct are sufficiently correlated, indicating that the data are suitable for factor analysis.

**Factor Extraction and Factor Loading**

The main purpose of factor rotation is to obtain a simple structure of factors. Hair and Black (2010) suggest that a factor loading higher than 0.50 is considered statistically significant at an alpha level of .05. Thus, the item loading, which is more than 0.50, was considered to be significant in this research.

As the prototype 1 HOT teaching model consisted of five stages of the model (Engagement, Investigation, Explanation, Conclusion and Reflection), the survey evaluation questionnaire comprises 67 items distributed into six constructs; five constructs measure the importance of the five stages of the HOT teaching model in enhancing students' higher order thinking skills in science learning. While the last construct measures the usability of the overall model to be implemented in science class to achieve its objectives (see Appendix H). After running the factor analysis, the first construct of the model (Engagement stage) extracted four factors with 12 items. First factor, Asking critical question (ASK) included 3 items, in which one item (ENG13) was dropped due to the cross loading of more than 0.3 as in Table 6.3. The second factor, making comparison (MAC) included 3 items; the third factor is a combination of the two sub-stages; identifying relationship and Formulating problem which was renamed formulating problem (PROB) that included 3 items; fourth, Estimation included two items.

**Table 6.3:** Factors Loading for Engagement Stage

| Item | Factor 1 Asking Critical Questions (ASK) | Factor 2 Making Comparison (MAC) | Factor 3 Formulating Problem (PROB) | Factor 4 Estimation (EST) |
|---|---|---|---|---|
| **ENG1** | | .816 | | |
| **ENG2** | | | .781 | |
| **ENG3** | | .817 | | |
| **ENG4** | | .566 | | |
| **ENG5** | .806 | | | |
| **ENG6** | .760 | | | |
| **ENG7** | .708 | | | |
| **ENG8** | | | .754 | |
| **ENG9** | | | .897 | |
| **ENG10** | | | | .664 |
| **ENG11** | | | | .734 |
| **ENG12** | | | .830 | |
| **ENG13** | **.77** | **.45** | | |
| **Variance Explained (%)** | 19.726 | 18.699 | 13.170 | 10.795 |
| **Cumulative Variance (%)** | 19.726 | 38.425 | 51.595 | 62.390 |

For the second construct (Investigation stage), it is found that four factors were extracted, Formulating hypothesis (FORM) with 4 items loaded highly (above 0.7). Planning (PLAN) with 4 items. The third factor combined the items for writing procedure with Controlling variable and was named as Controlling variable (CON) with 3 items. Measuring (MSUR) 2 items above 0.7.

**Table 6.4:** Factors Loading for Investigation Stage

| Item | Factor 1 Formulating Hypothesis (FORM) | Factor 2 Planning (PLAN) | Factor 3 Controlling Variable (CON) | Factor 4 Measuring (MSUR) |
|---|---|---|---|---|
| **INV1** | .774 | | | |
| **INV2** | .928 | | | |
| **INV3** | | .863 | | |
| **INV4** | .774 | | | |
| **INV5** | .930 | | | |
| **INV6** | | | | .761 |
| **INV7** | | | | .937 |
| **INV8** | | | .560 | |
| **INV9** | | | .790 | |
| **INV10** | | | .527 | |
| **INV11** | | .650 | | |
| **INV12** | | .711 | | |
| **INV13** | | .811 | | |
| **Variance Explained (%)** | 25.715 | 15.652 | 14.163 | 9.668 |
| **Cumulative Variance (%)** | 25.715 | 41.367 | 55.530 | 65.198 |

For the third construct Explanation, which is the third stage of the HOT teaching model, three factors were extracted with overall 11 items. As for the first factor five items were loaded on organizing data sub-stage (ORG) as expected. While for the second factor four items were loaded and labelled as Checking sub-stage (CHEK). The third factor labelled as Summarizing (SUM) loaded on two items (see Table 6.5).

**Table 6.5:** Factors Loading for Explanation Stage

| Item | Factor 1 Organizing data (ORG) | Factor 2 Checking (CHEK) | Factor 3 Summarizing (SUM) |
|---|---|---|---|
| **EXP1** | .775 | | |
| **EXP2** | .719 | | |
| **EXP3** | .674 | | |
| **EXP4** | .597 | | |
| **EXP5** | | .534 | |
| **EXP6** | | | .725 |
| **EXP7** | | .777 | |
| **EXP8** | | | .762 |
| **EXP9** | | .570 | |
| **EXP10** | | .570 | |
| **EXP11** | .591 | | |
| **Variance Explained (%)** | 23.194 | 17.471 | 14.274 |
| **Cumulative Variance (%)** | 23.194 | 40.665 | 54.939 |

For the fourth construct which is Conclusion stage, all the items are loaded on three factors (Table 6.6). Three items are loaded highly (above 0.9) for the first factor Expanding sub-stage (EXPN) and one item was deleted due to cross loading. Four items for Defining operationally sub-stage (DFN) and 3 items are loaded on the third factor Producing sub-stage (PROD).

**Table 6.6:** Factors Loading for Conclusion Stage

| Item | Factor 1 Expanding (EXPN) | Factor 2 Defining Operationally (DFN) | Factor 3 Producing (PROD) |
|---|---|---|---|
| **CON1** | **.56** | **.33** | |
| **CON2** | | .649 | |
| **CON3** | | .657 | |
| **CON4** | | .589 | |
| **CON5** | | | .618 |
| **CON6** | | .536 | |
| **CON7** | .977 | | |
| **CON8** | .981 | | |
| **CON9** | | | .720 |
| **CON10** | .980 | | |
| **CON11** | | | .720 |
| **Variance Explained (%)** | 35.036 | 16.081 | 15.854 |
| **Cumulative Variance (%)** | 35.036 | 51.116 | 66.970 |

Moreover, for the fifth construct (Conclusion stage); four dimensions (sub-stages) were extracted three factors. Factor one Evaluation of arguments sub-stage (EVL), which remained the same as expected with six items. Making judgment (JUDG) is the second factor extracted with 2 items that loaded highly (0.885) and (0.808) respectively upon dropping one item as in Table 6.7. While the third factor, conceptualizing (CONSP) has 2 items.

**Table 6.7:** Factors Loading for Reflection Stage

| Item | Factor 1 Evaluation of Arguments (EVL), | Factor 2 Making Judgment (JUDG) | Factor 3 Conceptualizing (CONSP) |
|---|---|---|---|
| **REF1** | .696 | | |
| **REF2** | | **.56** | **.44** |
| **REF3** | .816 | | |
| **REF4** | .872 | | |
| **REF5** | | | .922 |
| **REF6** | | .885 | |
| **REF7** | .792 | | |
| **REF8** | .868 | | |
| **REF9** | | | .943 |
| **REF10** | | .808 | |
| **REF11** | .872 | | |
| **Variance Explained (%)** | 39.389 | 21.893 | 18.710 |
| **Cumulative Variance (%)** | 39.389 | 61.282 | 79.992 |

Regarding the last construct of the survey evaluation questionnaire (usability of the overall model), the findings of the factor analysis indicated that a total of 8 items were loaded highly with Cronbach alpha values more than .7 except item 4 which loaded .58 as illustrated in Table 6.8.

**Table 6.8:** Factors Loading for HOT Construct

| HOT | Cronbach alpha |
|---|---|
| **HOT1** | .775 |
| **HOT2** | .751 |
| **HOT3** | .768 |
| **HOT4** | .588 |
| **HOT5** | .847 |
| **HOT 6** | .724 |
| **HOT 7** | .838 |
| **HOT 8** | .849 |
| **Variance Explained (%)** | 48.335 |
| **Cumulative Variance (%)** | 48.335 |

However, after running the factor analysis for the overall survey evaluation questionnaire, the results revealed that the number of factors, as well as the number of items is reduced due to the correlation between some items. Therefore, the final questionnaire (survey evaluation questionnaire) consisted of 64 items distributed into six constructs, five stages of the model and the usability of the overall model (see Appendix I)

## 6.3 Survey Results

The evaluation phase was conducted with 355 science teachers in the Iraqi Kurdistan region. The data were collected in order to identify confirmatory factor analysis (CFA) as well as to evaluate the research model. The data were prepared for analysis by coding, editing, and cleaning which are illuminated in the following sections.

### 6.3.1 Data Preparation

**Data Coding and Cleaning**

Data coding is the primary step in data preparation for empirical researches. It facilitates the insertion of the collected data in statistical programs (e.g., SPSS). As presented the survey questionnaire comprises 64 items or questions, which forms the measurement of the proposed constructs of this study (See Appendix I). Each item was given a code as a representation for data analysis. The questionnaire was administered to 355 science teachers in the Iraqi Kurdistan region. Each questionnaire was given a serial number equal to its record number in the SPSS program; this step is very important for tracing errors or mistakes. The researcher inserted the responses of all respondents in a systematic way by following the items' code that was predefined and entered into the SPSS program. However, 315 questionnaires were collected out of 355 originally distributed.

**Missing Data**

Missing data are often an issue in studies utilizing survey research. Missing data occurs when a respondent intentionally or unintentionally does not respond to one or more questions. According to Hair et al. (2013) if the missing data in one questionnaire exceeds 15%, then the questionnaire is rendered inapplicable. After screening the data files, 20 questionnaires recorded more than 15% of missing data, thus those questionnaires were removed from the data base. However, the software used in this research is Smart PLS (Ringle, Wende, & Will, 2005); this program offers two options for dealing with missing data; mean value replacement and case wise deletion. In mean value replacement, the missing data is replaced by the mean of the presented indicators under the same construct, while case wise deletion option deletes all the cases or records if it contains missing values. Hair et al. (2013) recommends using the mean value replacement option when there are less than 5% of values missing per indicator. In addition, in Smart PLS, the missing values have to be assigned to a unique number to be identified and recognized by the program. Therefore, the value -99 is assigned to represent the missing values.

Moreover, another technique was used to check the data file. We screened the pattern for all responses. Straight lining pattern is an issue in survey questionnaires. This happens when a respondent answers all the questions by using the same answer (e.g., in a 5-point Likert scale, the respondent chose 4 for all the answers). In this case the record is considered biased and must be discarded (Hair et al., 2013). When the whole data set was screened for a straight lining pattern, 11 questionnaires were found with this issue, and had to be removed from the data file. As a result, from 315 collected questionnaires, 20 were excluded due to more than 15% data missing while 11 were excluded because of Monotone Response Pattern. Thus the final number of usable questionnaires is 284, corresponding to an 80% response rate.

**Outlier**

An outlier is "an observation that is substantially different from the other observations" (Hair & Anderson, 2010). In other words, it can be seen as "an extreme response to a particular question or extreme responses to all questions" (Hair et al., 2013). If a case has a value above or below the majority of other cases, it is regarded as an outlier. Outliers can create undesired effect on the correlation coefficient (Pallant, 2010). The decision of removing or retaining the outlier depends on the outlier's strength and effect on the results. Outliers can be detected using the SPSS program. They can be detected visually by screening the histogram, normal Q-Q plot, or boxplot for each construct. Moreover, the effect of outlier can be determined by comparing the mean of each construct with the 5% trimmed mean. If the mean values and 5% trimmed mean are very different, further investigation is required for those cases. In order to assess their effects on the overall distribution, the mean values are contrasted with the 5% trimmed mean, and the results in Table 6.9 show that both mean values are similar. Given this, and the fact that the values do not differ from the remaining distribution, these cases will be retained in the data file.

**Table 6.9:** Mean, and Trimmed Mean-Outliers

| Construct | Mean | 5% Trimmed Mean | Std. Deviation |
|---|---|---|---|
| **Engagement** | 4.181 | 4.186 | 0.284 |
| **Investigation** | 4.224 | 4.223 | 0.305 |
| **Explanation** | 4.191 | 4.194 | 0.294 |
| **Conclusion** | 4.199 | 4.201 | 0.319 |
| **Reflection** | 4.277 | 4.280 | 0.418 |
| **HOT** | 4.2500 | 4.270 | 0.447 |

### 6.3.2 Assessment of Multivariate Assumptions

**Normality Assessment**

One of the crucial assumptions in multivariate analysis is normality, which is "the degree to which the distribution of the sample data corresponds to a normal distribution", and it can be seen as "the shape of the data distribution" (Hair & Anderson, 2010). Normality can be represented by two measures: kurtosis refers to the "peakedness" or "flatness" of the distribution and skewness is used to describe the balance of the distribution; if the shape is unbalanced, it will be shifted to either the left or the right side. Statistical programs such as SPSS calculate the empirical measures of both kurtosis and skewness. The ideal point (symmetrical distribution) is zero (Hair & Anderson, 2010). According to Hair and Anderson (2010), if the empirical z -value lies between ±2.58 at (0.01 significance level); or ±1.96, at (.05 significance level), the distribution of the data is considered normal. On the other hand, the recommended range of skewness and kurtosis values is between ±1.

As displayed in Table 6.10, the results show that the values for skewness and kurtosis in this study lie within the range ±1. Most of the values of skewness are negative, which indicate that the normal distribution shape is skewed to the right. In addition, the kurtosis values for investigation, reflection and HOT constructs are negative, indicating that the distribution shape for them is flatter than for the other constructs.

**Table 6.10:** Normality of the Survey Evaluation Questionnaire

| Construct | Mean | Std. Deviation | Skewness | Kurtosis |
|---|---|---|---|---|
| **Engagement** | 4.181 | 0.284 | -.028 | .075735 |
| **Investigation** | 4.224 | 0.305 | .400 | -.562 |
| **Explanation** | 4.191 | 0.294 | -.341 | .665 |
| **Conclusion** | 4.199 | 0.319 | -.840 | .571 |
| **Reflection** | 4.277 | 0.418 | 0.265 | -.525 |
| **HOT** | 4.2500 | 0.447 | -.028 | -.076 |

**Multicollinearity Assessment**

Multicollinearity refers to the relationship between the independent variables (Pallant, 2010). The presence of multicollinearity affects the quality and the results of the regression model (Pallant, 2010) by decreasing the ability to predict the dependent variable and determine the comparable roles of independent variables (Hair & Anderson, 2010).

The technique recommended for inspecting the degree multicollinearity is by checking the Tolerance index (TI) and variance of inflation factor (VIF) values of the regressed variables (Hair & Anderson, 2010; Pallant, 2010). However, if the TI value is less than 0.10, and the VIF value more than 10, it indicates that the two variables are highly correlated. Table 6.11 summarizes the TI and VIF values of all proposed independent variables under the construct and dimension level. The findings again confirm that multicollinearity is not an issue in this study.

**Table 6.11:** Multicollinearity of the Survey Evaluation Questionnaire

| Dependent Constructs | Independent Constructs | Collinearity Statistic | |
|---|---|---|---|
| | | **Tolerance** | **VIF** |
| **Engagement** | Investigation | .354 | 2.824 |
| | Explanation | .304 | 2.999 |
| | Conclusion | .384 | 2.604 |
| | Reflection | .333 | 2.999 |
| **Reflection** | Engagement | .405 | 2.469 |
| | Investigation | .375 | 2.665 |
| | Explanation | .550 | 1.817 |
| | Conclusion | .405 | 2.469 |

### 6.3.3 Specifying Measurement Model

As discussed in Chapter 3, partial least square-structural equation modelling (PLS-SEM) is suitable software to evaluate the research model for several reasons; the major one is the need to test formative constructs, as the sub-stages are the formative constructs that form the stages of the HOT teaching model. Specifying the nature of the constructs in the structural and measurement model prior to model evaluation is an important step in using PLS (Hair et al., 2013). In specifying the structural model, there are two types of structural model; first-order component models and higher-order component models as illustrated in Chapter three. As the HOT teaching model consist of both stages and sub-stage that aimed at developing students' HOT, thus it falls into Higher-order constructs which has been recommended by previous studies in order to decrease model complexity that facilitate the matching level of abstraction for predictor and criterion variables in conceptual models (Hair et al., 2014). While, in specifying the structural model there are two types of construct in the measurement model; reflective construct and formative construct. According to Jarvis et al. (2003) many researchers treat all constructs in the same way whether a particular construct is formative or reflective due to their limited concern about the measurement model. In fact, the misidentification of the formative and reflective constructs may have negative impact on the evaluation of the development model. Furthermore, Jarvis et al. (2003) listed the main four decision rules to identify formative and reflective constructs (refer to chapter 3. Table 3.6); therefore, based on these rules, the researcher made a decision about the model constructs (stages and sub-stages) and the overall construct, whether it is a reflective or formative construct as shown in the next section.

Engagement Stage: In this study the Engagement stage is defined as the procedural steps aimed at activating students' prior knowledge through the process of constructing knowledge. Five sub-stages were selected by the panel of experts (refer to chapter five) as the learning activities that would help students to become creators of knowledge, generating activities that provide opportunities for them to engage in higher order thinking skills in science learning. After running the factor analysis these sub-stages were reduced to four sub-stages, namely: Asking Critical Questions, Making Comparisons, Formulating Problem and Estimation. Based on the decision rules and construct measures analysis, as displayed in Table 6.12, the current study hypothesized that the engagement stage is a second-order formative construct comprising four dimensions (sub-stages);

Asking Critical Questions (ASK), Making Comparisons (MAC), Formulating Problem (PROB), and Estimation (EST).

**Table 6.12:** Decision Rules to Identify the Sub-Stages of the Engagement Construct as Formative or Reflective

| Criteria | Construct Analysis | Decision: Formative | Decision: Reflective |
|---|---|---|---|
| **Rule1:** Direction of causality from construct to measure implied by the conceptual definition | The sub-stages of the Engagement construct measures are considered manifestations of the construct, thus changes in the items (sub-stage) will not cause change in the construct (stage), and any change in the construct will cause changes in the items. | | √ |
| **Rule2:** Interchangeability of the indicators/items | All measurement items are interchangeable, all the items have the same content that reflect the accuracy and adequacy of the uploaded information, thus dropping any of the measures will not affect the construct. | | √ |
| **Rule3:** Covariation among the indicators | Engagement sub-stage items covary with each other, e.g., making comparisons and formulate the problem would engage students in science learning. | | √ |
| **Rule4:** Nomo logical net of the construct indicators | All the indicators (items) would have the same antecedents and consequences as all of them aimed at engaging students in science learning. | | √ |
| Final Decision | Engagement stage is a second order formative construct and the four sub-stages are first order reflective construct. | | √ |

Investigation stage: The second construct of the HOT teaching model is the Investigation stage which is defined as the way to solve the problem through performing a specific task. Therefore, activities that expose students to a variety of resources connected to the topic, give hints and cues to keep the exploration going and avoid defining terms or explaining evidence until the students have made enough trials to orient to the solution will facilitate the student's searching. In this study, these activities are concluded by experts into five sub-stages, while the factor analysis extracted four sub-stages (formulating the hypothesis, planning, controlling variables and measuring). According to the main four decision rules to identify the constructs as formative or reflective as listed by Jarvis et al. (2003), the Investigation stage is considered a second order construct with the four first order reflective construct as in Table 6.13.

**Table 6.13:** Decision Rules to Identify the Sub-Stages of the Investigation Construct as Formative or Reflective

| Criteria | Construct Analysis | Decision | |
|---|---|---|---|
| | | Formative | Reflective |
| **Rule1:** Direction of causality from construct to measure implied by the conceptual definition | The sub-stages of the Investigation construct measures are considered manifestations of the construct (investigation), thus changes in the items will not cause change in the construct, and any change in the construct will cause changes in the items. | | √ |
| **Rule2:** Interchangeability of the indicators/items | All measurement items are interchangeable, thus dropping any of the measures (sub-stages items) will not affect the construct. | | √ |
| **Rule3:** Covariation among the indicators | Investigation sub-stage items are covary with each other. Such as formulating hypothesis would aid students to control variables | | √ |
| **Rule4:** Nomo logical net of the construct indicators | All the indicators would have the same antecedents and consequences as all of them reflect the similar content. | | √ |
| Final Decision | Investigation stage is a second order formative construct and the four sub-stages are first order reflective construct. | | √ |

Explanation stage: Regarding the third construct of the HOT teaching model (Explanation stage), through connecting knowledge and understanding it to express new ideas about the entity under study will help students to explain the collected data. Thus, the specific steps to carry out the explanation are represented by the learning activities (sub-stages) that aid students in explaining the scientific concept that reduced after exploratory factor analysis into three sub-stages (organizing data (ORG), summarizing (SUM), and checking (CHEK). Table 6.14 illuminates in detail the decision rule to identify the Explanation stage with the three sub-stages are reflective or formative construct.

**Table 6.14:** Decision Rules to Identify the Sub- Stages of the Explanation Construct as Formative or Reflective

| Criteria | Construct Analysis | Decision: Formative | Decision: Reflective |
|---|---|---|---|
| **Rule1:** Direction of causality from construct to measure implied by the conceptual definition | The sub-stages of the Explanation stage are considered manifestations of the construct, thus changes in the items will not cause change in the construct, and any change in the construct will cause changes in the items. | | √ |
| **Rule2:** Interchangeability of the indicators/items | All measurement items are interchangeable, all the items have the same content that reflect explanation content and environment, moreover, dropping one of the measures will not affect the construct. | | √ |
| **Rule3:** Covariation among the indicators | Explanation items covary with each other, e.g., organizing data will help students to summarize it in graphs. | | √ |
| **Rule4:** Nomo logical net of the construct indicators | All the indicators would have the same antecedents and consequences as all of them reflect the similar content. | | √ |
| Final Decision | explaining is a first order reflective construct while organizing data, summarizing and checking is a second order reflective construct | | √ |

Conclusion stage: The fourth stage of the model aimed at extending students' conceptual understanding, explore applications of the concept or product in new situations, and extend the pattern found in the previous stage to new situations. These activities are concluded into three sub-stages; expanding (EXP), defining operationally (DEF) and producing (PROD). Thus, the Conclusion stage is a second order formative construct and the decision for the three sub-stages is described in Table 6.15.

**Table 6.15:** Decision Rules to Identify the Sub- Stages of the Conclusion Construct as Formative or Reflective

| Criteria | Construct Analysis | Decision: Formative | Decision: Reflective |
|---|---|---|---|
| **Rule1:** Direction of causality from construct to measure implied by the conceptual definition | The sub-stages of the conclusion construct measures are considered manifestations of the construct (Conclusion stage), thus changes in the items will not cause change in the construct. | | √ |
| **Rule2:** Interchangeability of the indicators/items | All measurement items are interchangeable, all the items have the same content that reflect the accuracy and adequacy of the uploaded information, thus dropping any of the measures will not affect the construct. | | √ |
| **Rule3:** Covariation among the indicators | Conclusions' sub-stage items covary with each other. Such as expanding the concept would help students to define the concept ooperationally. | | √ |
| **Rule4:** Nomo logical net of the construct indicators | All the indicators would have the same antecedents and consequences as all of them reflect the similar content. | | √ |
| Final Decision | Conclusion stage is a second order formative construct and expanding, defining operationally and producing are first order formative construct | | √ |

Reflection stage: This fifth construct of the HOT teaching model or the final stage of the model aims to get feedback of what has been done in systematizing the process, such as establishing to what extent answers to questions have been found, take decisions concerning how to use the learned strategies to solve various types of problems and anticipate ways and means that allow a shortcut to further research procedures. There are three sub-stages for the reflection construct; evaluation of arguments (EVAL), making judgment (JUDG) and conceptualizing (CONSP). Based on the main four decision rules to identify the construct is formative or reflective (Jarvis et al, 2003), the Reflection stage is considered a second order construct with the three first order reflective constructs as in Table 6.16.

**Table 6.16:** Decision Rules to Identify the Sub- Stages of the Reflection Construct as Formative or Reflective

| Criteria | Construct Analysis | Decision: Formative | Decision: Reflective |
|---|---|---|---|
| **Rule1:** Direction of causality from construct to measure implied by the conceptual definition | The sub-stages of the reflection construct measures are considered manifestations of the construct, thus changes in the items will not cause change in the construct. | | √ |
| **Rule2:** Interchangeability of the indicators/items | All measurement items are interchangeable, all the items have the same content that reflect the accuracy and adequacy of the uploaded information, thus dropping any of the measures will not affect the construct. | | √ |
| **Rule3:** Covariation among the indicators | Reflection sub-stage items covary with each other | | √ |
| **Rule4:** Nomo logical net of the construct indicators | All the indicators would have the same antecedents and consequences as all of them reflect the similar content. | | √ |
| Final Decision | Reflection stage is a second order formative construct while evaluation of arguments, making judgment and conceptualizing are first order formative constructs | | √ |

In order to evaluate the overall model, HOT construct has been constructed one dimension that describes the usability of the model in its implementation in the science classroom for improving students' higher cognitive skills, in which this construct is reflective of the model. Thus, based on the main four decision rules introduced by Jarvis et al. (2003) to identify whether the construct is formative or reflective, the HOT construct is considered a first order reflective construct.

According to the preceding discussion, each construct is assigned and discussed in detail. Table 6.17 summarizes each construct type and hierarchical order, in addition to the number of items remaining after the EFA test:

**Table 6.17:** Measurements of Constructs

| First-Order Constructs | Type | Items | Second-Order Constructs | Type |
|---|---|---|---|---|
| Asking Critical Question | Reflective | 3 | Engagement stage | Formative |
| Making Comparisons | | 3 | | |
| Formulating Problems | | 4 | | |
| Estimation | | 2 | | |
| Formulating the Hypothesis | | 4 | Investigation stage | |
| Planning, | | 4 | | |
| Controlling Variables | | 3 | | |
| Measuring | | 2 | | |
| Organizing data | | 5 | Explanation stage | |
| Summarizing | | 4 | | |
| Checking | | 2 | | |
| Expanding | | 3 | Conclusion stage | |
| Defining operationally | | 4 | | |
| Producing | | 3 | | |
| Evaluation of arguments | | 6 | Reflection stage | |
| Making judgment | | 2 | | |
| Conceptualizing | | 2 | | |
| HOT | | 8 | | |
| **All** | | **64** | **5** | |

Coltman et al. (2008) asserted that the formative and reflective constructs are distinct, and they should not be treated in the same way in the measurement model. However, reflective constructs are applicable to be assessed for reliability and validity by conducting CFA using PLS-SEM. Since the reliability for formative construct is irrelevant, thus, no reliability testing will be conducted for formative constructs except for validity (Petter, Straub, & Rai, 2007). As specified, all the constructs in this study are measured using multiple items. For multi-items construct, it is important to appropriately categorize them as formative or reflective before assessing measurement properties. Miss-specified measurement models may lead to measurement errors that in turn affect the structural model validity (Jarvis et al., 2003). Table 6.18 summarizes the systematic steps that will be used to evaluate and test the HOT teaching model:

**Table 6.18:** Systematic Evaluation of PLS-SEM Results

| Step | Evaluation |
|---|---|
| **Step1:** Evaluation of the Measurement Model | |
| **Step 1a**: Reflective Measurement Model(stages and sub-stages)<br>• Internal Consistency (reliability)<br>• Convergent Validity<br>• Discriminant Validity | **Step 1b**: Formative Measurement Model (stages)<br>• Collinearity among indicators<br>• Significance and relevance of Outer weights |
| **Step 2:** Analyzing Research Model and Validating Second-Order Constructs | |
| **Step 3**: Evaluation of Structural Model (usability of the model)<br>• Significance and the relevance of the structural model path coefficients<br>• Coefficient of determination $R^2$<br>• $f^2$ effect sizes<br>• The predictive relevance $Q^2$ and $q^2$ effect sizes | |

*(Hair et al., 2013)*

In step 1, the sub-stages of HOT teaching model (measurement model) will assessed using various measures of reliability and validity (Howell, Breivik, & Wilcox, 2007). Furthermore, in order to estimate measurement parameters, it is important to draw all the relevant links between the constructs and their items (e.g., loadings), in addition to the linear links between various constructs (e.g., path coefficients) concurrently.

In step 2, the stages of the HOT teaching model will be analyzed and second-order constructs will be validated. Furthermore, the proposed stages and sub-stages will be tested using unidimensional and multidimensional constructs, and the results are compared. Lastly, the final research model was presented and confirmed based on this step's results.

In step 3, structural model (the overall model) assessment was conducted on the final research model. Several assessments were performed to test the model by evaluating the significance and the relevance of the structural model path coefficients, testing coefficient of determination$R^2$, assessing $f^2$ effect sizes, and evaluating the predictive relevance $Q^2$and $q^2$effect size.

#### 6.3.3.1 Measurement Model Assessment

This section discussed the findings for the first research question in phase three Do the stages and sub-stages of HOT teaching model positively influence students' HOT?

The assessment of the stages and sub-stages of the HOT teaching model aimed to identify the importance of employing these specific learning activities on student's higher order thinking skills. The specific steps in Table 6.18, were used to evaluate the model elements. As discussed earlier, the sub-stages of the HOT teaching model are reflective measurement model. Therefore, following the steps of evaluating reflective measurement model, the sub-stages of the model were evaluated as presented in the following sections.

**(a) Reliability of the Model Sub-Stages**

Reliability refers to the "extent to which a variable or set of variables is consistent in what it is intended to measure" (Hair & Anderson, 2010). To further investigate the reliability of reflective constructs (sub-stages), Cronbach's alpha and composite reliability measures can be extracted by PLS-SEM. The measurements with Cronbach's alpha and composite reliability above .70 are considered reliable (Götz, Liehr, Gobbers, & Krafft, 2010). Compared to Cronbach's alpha, Composite reliability is regarded as a more rigorous assessment of reliability. The reliability of all items is identified; as a result 3 items from the Engagement stage were dropped due to their loading of less than (0.7).

Two items from the Investigation stage were dropped and one item was dropped from the Explanation stage. Furthermore, 2 items were dropped from the Conclusion stage. The number of items for each construct and the reliability level of all reflective constructs are reported in Table 6.19. After dropping the items with composite reliability less than (0.7) Table 6.19 shows the results of the items that exceed the value .70, while the Cronbach's alpha ranged from .7 to 1; consequently, all reflective items realized an acceptable level of reliability.

**Table 6.19:** Reflective Constructs (Sub-Stages) Reliability

| Constructs | Items | Composite Reliability | Cronbach's Alpha |
|---|---|---|---|
| **Engagement Stage** | | | **Formative** |
| Asking Critical Question (ASK) | 3 | .8463 | .7282 |
| Making Comparison (MAC) | 3 | .8609 | .7818 |
| Problem Construction ( PROB) | 2 | .8068 | .7066 |
| Estimation (EST) | 1 | 1 | 1 |
| **Investigation Stage** | | | **Formative** |
| Formulating Hypothesis (FOM) | 4 | .7845 | .9096 |
| Controlling Variables (CON) | 2 | .7162 | .7078 |
| Planning ( PLAN) | 3 | .7931 | .7348 |
| Measuring (MSUR) | 2 | 1 | 1 |
| **Explanation Stage** | | | **Formative** |
| Organizing Data (ORG) | 5 | .814 | .7261 |
| Checking (CHEK) | 3 | .7812 | .7195 |
| Summarizing (SUM) | 2 | .7475 | .7091 |
| **Conclusion Stage** | | | **Formative** |
| Expanding (EXPN) | 3 | 1 | 1 |
| Defining Operationally (DFN) | 2 | .7166 | .76 |
| Producing (PROD) | 3 | .7884 | .7097 |
| **Reflection Stage** | | | **Formative** |
| Evaluation of Arguments (EVAL) | 6 | .9382 | .9196 |
| Conceptualizing (CONSP) | 2 | 1 | 1 |
| Making Judgment (JUDG) | 2 | 1 | 1 |
| HOT Construct (HOT) | 8 | .8469 | .7578 |

### (b) Validity of the Model Sub-Stages

Validity in general refers to the level to which a measure correctly signifies what it is expected to. “Validity is concerned with how well the concept is defined by the measure(s)” (Chin, 2010). There are two types of validity, which are applicable to be executed on reflective measures: convergent validity and discriminant validity. Convergent validity investigates “the degree to which two measures of the same concept are correlated” (Hair & Anderson, 2010), in other words, it refers to the level of correlation between the measures of the same construct. While discriminant validity is "the degree to which two conceptually similar concepts are distinct" (Petter et al., 2007).

### Convergent Validity

Convergent validity can be evaluated by the average variance extracted (AVE) values, which refers to the degree the construct identifies the variance of its indicators as the amount of variance for asking critical questions (ASK) sub-stage explained by items (ASK1, ASK2). The threshold value of AVE must be reported if it exceeds 0.50 (Hair Jr et al., 2013). In addition, confirmatory factor analysis (CFA) is another indicator of convergent validity by using (PLS-SEM). The convergent validity is realized if the indicators or variables of each construct load exceeds .70 on their construct more than the other constructs (Hair et al., 2014). Table 6.20 shows the items loading and the (AVE) values for all reflective constructs and the (AVE) values exceed the cut-off point 0.50. Consequently, the convergent validity was achieved among all constructs.

**Table 6.20:** Item Loadings and AVE for the Sub-Stages of the Model

| Item Loading | Original Sample | Sample Mean | Standard Deviation | Standard Error | T Statistics | AVE |
|---|---|---|---|---|---|---|
| **Asking Critical Questions** | | | | | | |
| ASK1 | 0.7716 | 0.7703 | 0.0386 | 0.0386 | 20.0099 | **0.647** |
| ASK 2 | 0.8564 | 0.8557 | 0.0309 | 0.0309 | 27.7504 | |
| ASK 3 | 0.7839 | 0.7826 | 0.0352 | 0.0352 | 22.2676 | |
| **Making Comparison** | | | | | | |
| MAC1 | 0.8386 | 0.8351 | 0.0372 | 0.0372 | 22.5225 | **0.674** |
| MAC2 | 0.8822 | 0.8837 | 0.0233 | 0.0233 | 37.9432 | |
| MAC3 | 0.7368 | 0.7269 | 0.0608 | 0.0608 | 12.1234 | |
| **Formulating Problem** | | | | | | |
| PROB1 | 0.7347 | 0.6875 | 0.2262 | 0.2262 | 3.2483 | **0.678** |
| PROB2 | 0.904 | 0.8664 | 0.1586 | 0.1586 | 5.6986 | |
| **Estimation** | | | | | | |
| EST | 1 | 1 | 0 | 0 | 0 | **Single item** |
| **Formulating Hypothesis** | | | | | | |
| FORM1 | 0.9142 | 0.9152 | 0.0185 | 0.0185 | 49.5487 | **0.7845** |
| FORM2 | 0.8562 | 0.8529 | 0.0334 | 0.0334 | 25.6437 | |
| FORM3 | 0.9142 | 0.9152 | 0.0185 | 0.0185 | 49.5487 | |
| FORM4 | 0.8562 | 0.8529 | 0.0334 | 0.0334 | 25.6437 | |
| **Controlling Variable** | | | | | | |
| CON1 | 0.5946 | 0.5869 | 0.0727 | 0.0727 | 8.183 | **0.716** |
| CON2 | 0.7908 | 0.7856 | 0.0556 | 0.0556 | 14.2196 | |
| **Planning** | | | | | | |
| PLAN1 | 0.8484 | 0.8489 | 0.0288 | 0.0288 | 29.4268 | **0.566** |
| PLAN2 | 0.8087 | 0.8052 | 0.0452 | 0.0452 | 17.8894 | |
| PLAN3 | 0.8822 | 0.8818 | 0.0325 | 0.0325 | 27.1405 | |
| **Measuring** | | | | | | |
| MSUR1 | 0.9892 | 0.9794 | 0.0261 | 0.0261 | 37.962 | **1** |
| MSUR2 | 0.5593 | 0.5578 | 0.1308 | 0.1308 | 4.094 | |
| **Organizing data** | | | | | | |
| ORG1 | 0.6304 | 0.6205 | 0.0691 | 0.0691 | 9.1235 | **0.568** |
| ORG2 | 0.7032 | 0.6972 | 0.0509 | 0.0509 | 13.8026 | |
| ORG3 | 0.7092 | 0.7059 | 0.0426 | 0.0426 | 16.6445 | |
| ORG4 | 0.5992 | 0.597 | 0.0623 | 0.0623 | 9.6112 | |
| ORG5 | 0.7678 | 0.7639 | 0.0429 | 0.0429 | 17.8827 | |
| **Checking** | | | | | | |
| CHEK1 | 0.5600 | 0.5370 | 0.1368 | 0.1368 | 4.090 | **0.5361** |
| CHEK2 | 0.5603 | 0.5378 | 0.1368 | 0.1368 | 4.096 | |
| CHEK3 | 0.8884 | 0.8821 | 0.0594 | 0.0594 | 14.9646 | |

**Table 6.20:** Item Loadings and AVE for the Sub-Stages of the Model

| | | | | | | |
|---|---|---|---|---|---|---|
| **Summarizing** | | | | | | |
| SUM1 | 0.9556 | 0.9203 | 0.1293 | 0.1293 | 7.3902 | **0.6127** |
| SUM2 | 0.5588 | 0.5085 | 0.2627 | 0.2627 | 2.1271 | |
| **Expanding** | | | | | | |
| EXP1 | 1 | 1 | 0 | 0 | 0 | |
| EXP2 | 1 | 1 | 0 | 0 | 0 | **1** |
| EXP3 | 1 | 1 | 0 | 0 | 0 | |
| **Defining Operationally** | | | | | | |
| DFN1 | 0.9523 | 0.9372 | 0.0628 | 0.0628 | 15.1533 | **0.580** |
| DFN2 | 0.504 | 0.48 | 0.1988 | 0.1988 | 2.5349 | |
| **Producing** | | | | | | |
| PROD1 | 0.54588 | 0.5085 | 0.2627 | 0.2627 | 2.0271 | |
| PROD2 | 0.9879 | 0.9789 | 0.035 | 0.035 | 28.2517 | **0.650** |
| PROD3 | 0.9879 | 0.9789 | 0.035 | 0.035 | 28.2517 | |
| **Evaluation of arguments** | | | | | | |
| EVL1 | 0.7306 | 0.7311 | 0.0347 | 0.0347 | 21.0344 | |
| EVL2 | 0.8141 | 0.8139 | 0.0268 | 0.0268 | 30.3365 | |
| EVL3 | 0.9216 | 0.92 | 0.0162 | 0.0162 | 56.9845 | **0.7182** |
| EVL4 | 0.7749 | 0.7741 | 0.0375 | 0.0375 | 20.659 | |
| EVL5 | 0.9019 | 0.8998 | 0.0185 | 0.0185 | 48.6779 | |
| EVL6 | 0.9216 | 0.92 | 0.0162 | 0.0162 | 56.9845 | |
| **Making judgment** | | | | | | |
| JUDG1 | 1 | 1 | 0 | 0 | 0 | **1** |
| JUDG2 | 1 | 1 | 0 | 0 | 0 | |
| **Conceptualizing** | | | | | | |
| CNSP1 | 1 | 1 | 0 | 0 | 0 | **1** |
| CNSP2 | 1 | 1 | 0 | 0 | 0 | |
| **HOT MODEL (HOT)** | | | | | | |
| HOT1 | 0.8062 | 0.8037 | 0.0421 | 0.0421 | 19.1267 | |
| HOT2 | 0.8778 | 0.8785 | 0.0161 | 0.0161 | 54.6677 | |
| HOT3 | 0.7841 | 0.7786 | 0.0489 | 0.0489 | 16.0231 | **0.806** |
| HOT4 | 0.5571 | 0.5561 | 0.0606 | 0.0606 | 9.1944 | |
| HOT5 | 0.7708 | 0.7708 | 0.0333 | 0.0333 | 23.1328 | |
| HOT6 | 0.7822 | 0.779 | 0.0372 | 0.0372 | 21.0196 | |
| HOT7 | 0.8199 | 0.8202 | 0.0204 | 0.0204 | 40.2778 | |
| HOT8 | 0.7335 | 0.7335 | 0.0392 | 0.0392 | 18.6937 | |

### Discriminant Validity

Discriminant validity refers to the degree the construct is distinct from the other constructs. Discriminant validity can be evaluated in two ways: the level of correlation between the construct and other constructs, and the degree the measures of the construct represent it and differentiate it from other constructs (Hair & Anderson, 2010). Discriminant validity can be evaluated by comparing the square root of AVE values for each construct with the correlation values between the construct and other constructs (Chin, 1998). The results in Table 6.21 shows that, all square roots of (AVEs) are larger than constructs' correlations, implying that the variance outlined by the particular construct is greater than the measurement error variance. Consequently, discriminant validity of the measurement instrument was confirmed.

**Table 6.21:** Correlation Matrix of Constructs

| | ASK | MAC | PROB | EST | FORM | CON | PLAN | MSUR | ORG | CHEK | SUM | EXPN | DFN | PROD | EVL | JUDG | CONS | HOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ASK** | **0.804** | | | | | | | | | | | | | | | | | |
| **MAC** | 0.198 | **0.821** | | | | | | | | | | | | | | | | |
| **PROB** | 0.209 | 0.230 | **0.823** | | | | | | | | | | | | | | | |
| **EST** | 0.605 | 0.203 | 0.237 | **Single item** | | | | | | | | | | | | | | |
| **FORM** | 0.188 | 0.328 | -0.166 | 0.100 | **0.885** | | | | | | | | | | | | | |
| **CON** | 0.005 | 0.069 | 0.209 | -0.025 | 0.024 | **0.846** | | | | | | | | | | | | |
| **PLAN** | 0.484 | 0.669 | 0.290 | 0.459 | 0.268 | -0.086 | **0.752** | | | | | | | | | | | |
| **MSUR** | 0.293 | 0.488 | 0.251 | 0.325 | 0.233 | 0.135 | 0.214 | 1 | | | | | | | | | | |
| **ORG** | 0.417 | 0.267 | 0.325 | 0.374 | 0.245 | 0.221 | 0.087 | 0.142 | **0.753** | | | | | | | | | |
| **CHEK** | 0.008 | 0.054 | -0.102 | 0.136 | 0.141 | -0.145 | 0.0302 | 0.016 | -0.090 | **0.732** | | | | | | | | |
| **SUM** | 0.4701 | 0.465 | 0.263 | 0.579 | 0.276 | 0.294 | 0.504 | 0.478 | 0.489 | -0.068 | **0.782** | | | | | | | |
| **EXP** | 0.609 | 0.108 | 0.232 | 0.564 | 0.208 | 0.127 | 0.364 | 0.281 | 0.354 | -0.078 | 0.369 | **1** | | | | | | |
| **DFN** | 0.238 | 0.285 | 0.465 | 0.332 | -0.088 | 0.205 | 0.345 | 0.337 | 0.421 | -0.305 | 0.381 | 0.320 | **0.761** | | | | | |
| **PROD** | 0.409 | 0.444 | 0.113 | 0.448 | 0.245 | -0.206 | 0.540 | 0.426 | 0.434 | 0.136 | 0.407 | 0.439 | 0.248 | **0.806** | | | | |
| **EVL** | 0.437 | 0.568 | 0.630 | 0.426 | 0.077 | 0.164 | 0.074 | 0.547 | 0.252 | -0.245 | 0.585 | 0.361 | 0.032 | 0.377 | **0.847** | | | |
| **JUDG** | 0.402 | 0.324 | 0.353 | 0.440 | 0.008 | -0.198 | 0.475 | 0.372 | 0.374 | 0.163 | 0.355 | 0.345 | 0.304 | 0.415 | 0.468 | **1** | | |
| **CNCP** | 0.650 | 0.409 | 0.214 | 0.575 | 0.420 | -0.054 | 0.198 | 0.429 | 0.518 | 0.094 | 0.378 | 0.334 | 0.258 | 0.487 | 0.469 | 0.441 | **1** | |
| **HOT** | 0.437 | 0.542 | 0.341 | 0.300 | 0.173 | 0.282 | 0.640 | 0.590 | 0.309 | -0.207 | 0.570 | 0.324 | 0.437 | 0.354 | 0.369 | 0.283 | 0.466 | **0.806** |

- Items on the diagonal are square roots of AVE scores.
- All correlations are significant at the .01 level

#### (c) Validity of the Model Stages

The stages of the HOT teaching model are considered formative measurement model as discussed earlier. Therefore, following the steps for evaluating formative model that presented in Table 6.18, were used to validate the stages of the HOT model validate in smart PLS through using two major steps: first, assessing collinearity issues and second, assessing the significance and relevance of formative measures.

#### (d) Formative Measures Collinearity

According to the nature of reflective indicators with interchangeable and correlation, formative indicators collinearity are considered a problematic issue from a methodological and interpretational perspective. The presence of collinearity between formative indicators (stages) affects the weights and statistical significance of the indicators (sub-stages) (Diamantopoulos, Riefler, & Roth, 2008). The level of collinearity can be assessed by tolerance index (TI) and variance inflation factor (VIF). In the context of PLS-SEM, (TI) value of 0.20 or less, and (VIF) value of 5.0 or higher reflect a potential collinearity issue. The VIF and TI are identified earlier in Table 6.11 shows that there is no collinearity between the stages of HOT teaching model as all (TI) values are above 0.20, and (VIF) values are below 5.0.

#### 1) Significance and Relevance of the Formative Indicators

The last step of assessing the contribution of formative indicators (sub-stages) and their relevance and outer weight is done by performing multiple regressions (Hair & Anderson, 2010). In order to form study second-order formative-reflective construct (stage), the latent variable scores for all first-order constructs (sub-stages) are generated by PLS-SEM, and are linked as formative indicators to the second-order constructs.

However, to picture this, the latent second-order construct are treated as a dependent construct and the formative indicators (latent scores) as independent constructs. This procedure is recommended by Hair Jr et al. (2013) when first-order constructs have different numbers of items, as in the case of this study. Furthermore, by comparing the value of outer weights indicators, one can decide the relative contribution of a particular indicator by taking into account its level of significance.

In the context of this study, model stages (Engagement, Investigation, Explanation, Conclusion, and Reflection) are proposed as second-order formative-reflective constructs. Table 6.22 concludes that the sub-stages of HOT teaching model are positive and significant based on their outer weights with the exception of estimation which is a negative significant sub-stage. Thus all five stages' constructs can be represented in formative way by retaining all their indicators.

**Table 6.22:** Formative Indicators Outer Weight and Significance

| Formative Construct (Stages) | Indicators (Sub-Stages) | Weight | Std. Deviation | Std. Deviation | Standard Error | T Statistics |
|---|---|---|---|---|---|---|
| **Engagement Stage** | Asking Critical Question (ASK) | 0.3966 | 0.3969 | 0.0694 | 0.0694 | 5.7134 |
| | Making Comparison (MAC) | 0.756 | 0.7547 | 0.0594 | 0.0594 | 12.7385 |
| | Problem Construction( PROB) | 0.0464 | 0.0558 | 0.0402 | 0.0402 | 1.9646 |
| | Estimation (EST) | -0.1351 | -0.1344 | 0.0581 | 0.0581 | 2.324 |
| **Investigation Stage** | Formulating Hypothesis (FORM) | 0.7802 | 0.78 | 0.0312 | 0.0312 | 24.9958 |
| | Controlling Variables (CON) | 0.3171 | 0.3164 | 0.0151 | 0.0151 | 21.0344 |
| | Planning ( PLAN) | 0.1633 | 0.1582 | 0.0367 | 0.0367 | 4.4497 |
| | Measuring (MSUR) | 0.3966 | 0.3969 | 0.0694 | 0.0694 | 5.7134 |
| **Explanation Stage** | Organizing Data (ORG) | 0.6042 | 0.6074 | 0.0541 | 0.0541 | 11.1617 |
| | Checking (CHEK) | 0.4645 | 0.461 | 0.0482 | 0.0482 | 9.6374 |
| | Summarizing (SUM) | 0.2598 | 0.2563 | 0.0546 | 0.0546 | 4.7591 |
| **Conclusion Stage** | Expanding (EXPN) | 0.4758 | 0.4768 | 0.044 | 0.044 | 10.8171 |
| | Defining Operationally (DFN) | 0.1073 | 0.1068 | 0.0384 | 0.0384 | 2.7969 |
| | Producing (PROD) | 0.6158 | 0.6146 | 0.0428 | 0.0428 | 14.4009 |
| **Reflection Stage** | Evaluation of Arguments (EVL) | 0.9365 | 0.9356 | 0.0162 | 0.0162 | 57.7117 |
| | Conceptualizing (CONSP) | 0.0594 | 0.0608 | 0.0298 | 0.0298 | 1.9923 |
| | Making Judgment ( JUDG) | 0.105 | 0.1055 | 0.029 | 0.029 | 3.6188 |

### 6.3.4 Analysis of Proposed Research Model

This section describes testing the HOT teaching model using PLS-SEM by proposing and evaluating alternative models. First, the Unidimensionality of the whole model is tested by treating the entire model constructs as first level constructs. Then, the proposed second-order constructs are validated by testing the proposed dimensions separately unidimensional with other hypothesized constructs, and comparing with second-order multidimensional construct's results. Finally, based on the comparison of various alternative models, the final research model is presented. The details about these steps in the following sections.

#### 6.3.4.1 Test for Overall Model Unidimensionality

All research model constructs were tested in PLS-SEM for their Unidimensionality relationship with all of the model sub-stages constructs Figure 6.1. The results for this test are presented in Table 6.23.

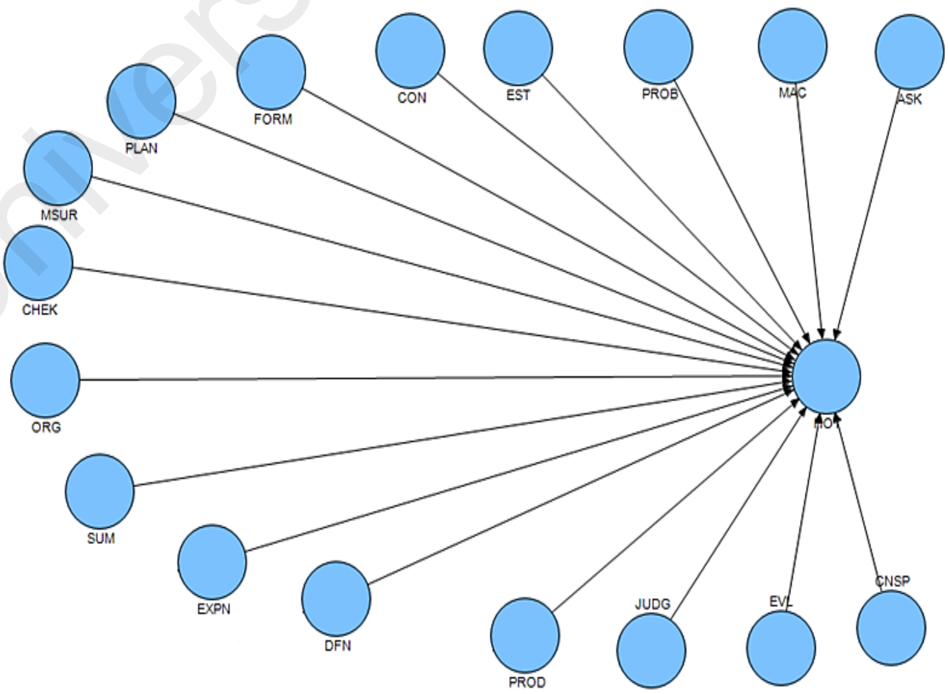



**Figure 6.1:** Measurement Model Between Unidimensional Construct

**Table 6.23:** Research Model Unidimensionality Relationship Results

| Dependent Construct | Independent Constructs | Path Coefficient | T Statistics |
|---|---|---|---|
| **Engagement** | Asking Critical Question (ASK) | 0.0966 | 4.4551 |
| | Making Comparison (MAC) | 0.2553 | 9.4968 |
| | Problem Construction ( PROB) | 0.0517 | 2.799 |
| | Estimation (EST) | -0.0871 | 4.1853 |
| **Investigation** | Formulating Hypothesis (FORM ) | -93.7555 | 1.1865 |
| | Controlling Variables (CON) | -0.0528 | 1.9647 |
| | Planning ( PLAN) | 0.0036 | 0.2786 |
| | Measuring (MSUR) | 0.0291 | 1.4165 |
| **Explanation** | Organizing Data (ORG) | 0.0291 | 1.5579 |
| | Checking (CHEK) | -0.1785 | 4.943 |
| | Summarizing (SUM) | 0.1668 | 7.0055 |
| **Conclusion** | Expanding (EXPN) | 54.8722 | 1.1841 |
| | Defining Operationally (DFN) | 0.0019 | 0.1502 |
| | Producing (PROD) | 51.2437 | 1.1895 |
| **Reflection** | Evaluation of Arguments (EVL) | 0.4759 | 16.5608 |
| | Conceptualizing (CONSP) | -0.024 | 1.2431 |
| | Making Judgment ( JUDG) | 0.0456 | 1.8134 |

Table 6.23 shows that most of the sub-stages of the Engagement stage are significantly related to the model meaning that the selected sub-stages are important to enhance students' HOT. The following sections discuss in detail the relation between each sub-stage and model stage, such as the importance of Engagement sub-stages in engaging students in using their higher cognitive skills in science learning.

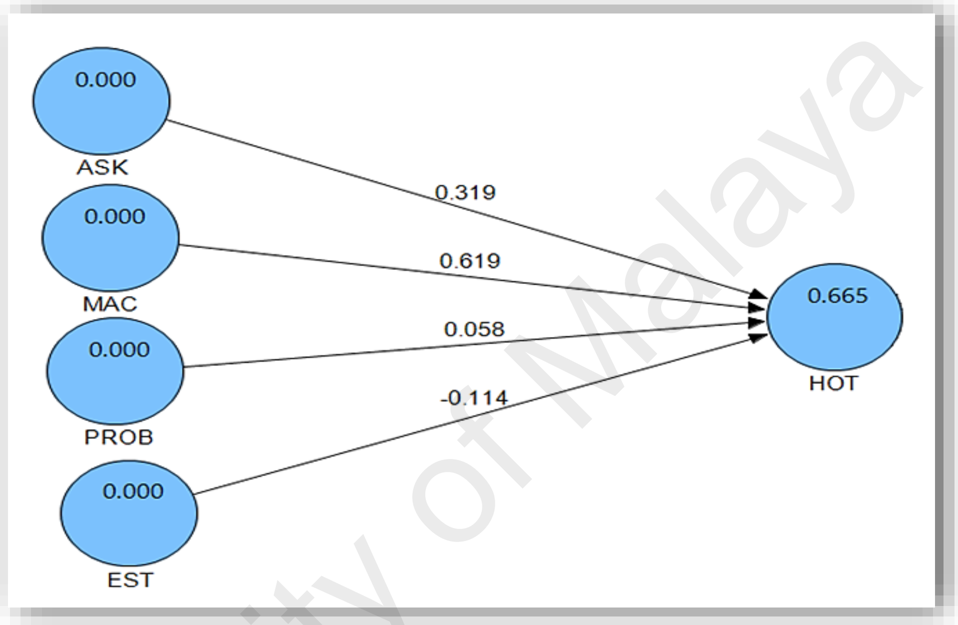
#### 6.3.4.2 Test for Second-Order Model (Model Stages)

The Engagement stage (ENG) is hypothesized to be a second-order formative construct with four first-order dimensions (sub-stages). The four first-order sub-stages; asking critical question, making comparison, formulating problem and estimation are measured by reflective indicators. Such a measurement model is appropriate for the multidimensional composite construct of the Engagement stage, because these first-order dimensions (sub-stages) signify various aspects of Engagement stage. Investigation stage

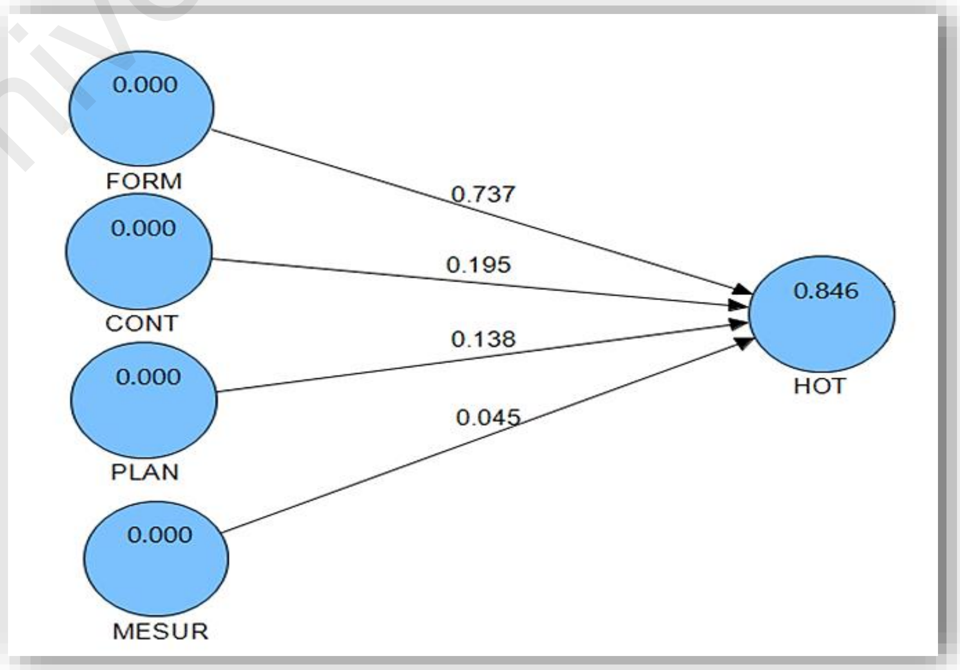
(INV) is a second-order formative construct with four first-order dimensions. These sub-stages are formulating hypothesis, controlling variables, planning and measuring. The third second-order formative construct is the Explanation stage (EXP) that consisted of three first-order dimensions (sub-stages) which are checking, organizing data and summarizing. While the fourth second-order formative construct is the Conclusion stage (CON) with three first-order dimensions (sub-stages). The three first-order expanding, defining operationally and producing are measured by reflective indicators. However the last second-order formative construct of HOT teaching model is Reflection stage (REF) with three first-order dimensions. These sub-stages are making judgment, evaluation of arguments and conceptualizing. Before evaluating the validity of second-order construct (stage), the measurement properties of first-order constructs (sub-stages) have been tested in terms of reliability, convergent, and discriminant validity in the above section. The results indicated that all the first-order constructs are reliable and valid multiple-item measurements.

To validate the second-order formative constructs (stages) of the model, alternative models were established for comparison with relative fit. However prior to evaluate the stages of the HOT teaching model it's important to identify the significance of the sub-stages in enhancing students' HOT. Thus, the established alternative model proposes the sub-stages as independent constructs linked directly to the dependent construct (HOT). Model A1 shows the Engagement sub-stages; asking critical questions, making comparison, formulating problem and estimation are the independent variables to the dependent variable, meaning the importance of using these sub-stages (activities) in developing students' HOT. Formulating hypothesis, controlling variables, planning and measuring are the sub-stages of the Investigation stage as in Model A2. The Explanation stage is the third dependent variable with three independent variable checking, organizing data and summarizing (Model A3). Model A4 shows the direct link between Conclusion sub-stages with the dependent construct. However the last model is analyzing the link between Reflection stage with three first-order dimensions sub-stages are; making judgment, evaluation of arguments and conceptualizing. Figure 6.2 shows these models that established to check the direct effect of all independent constructs on the dependent constructs. The following are the five models.

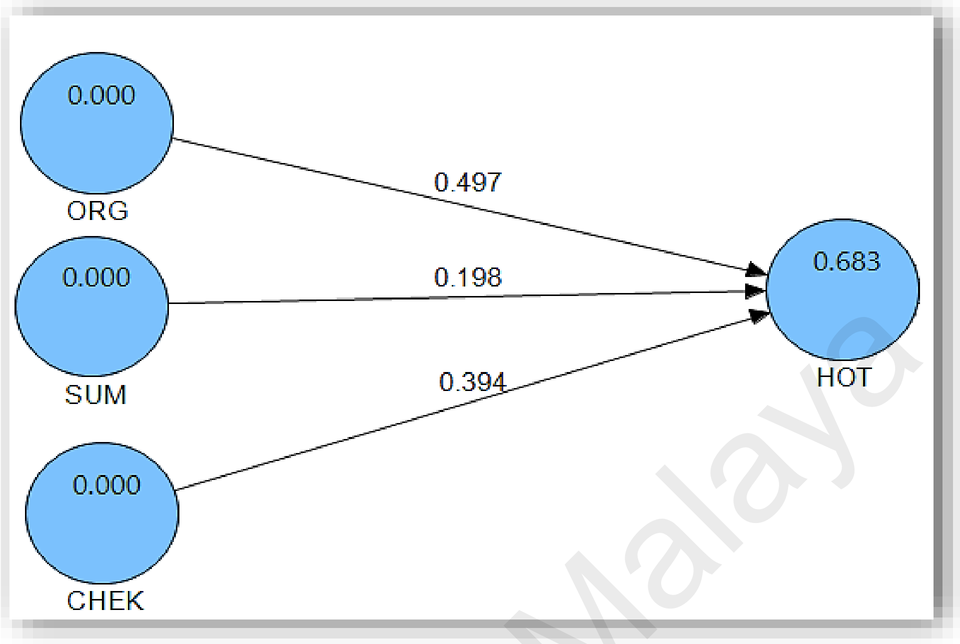
**Model A1**



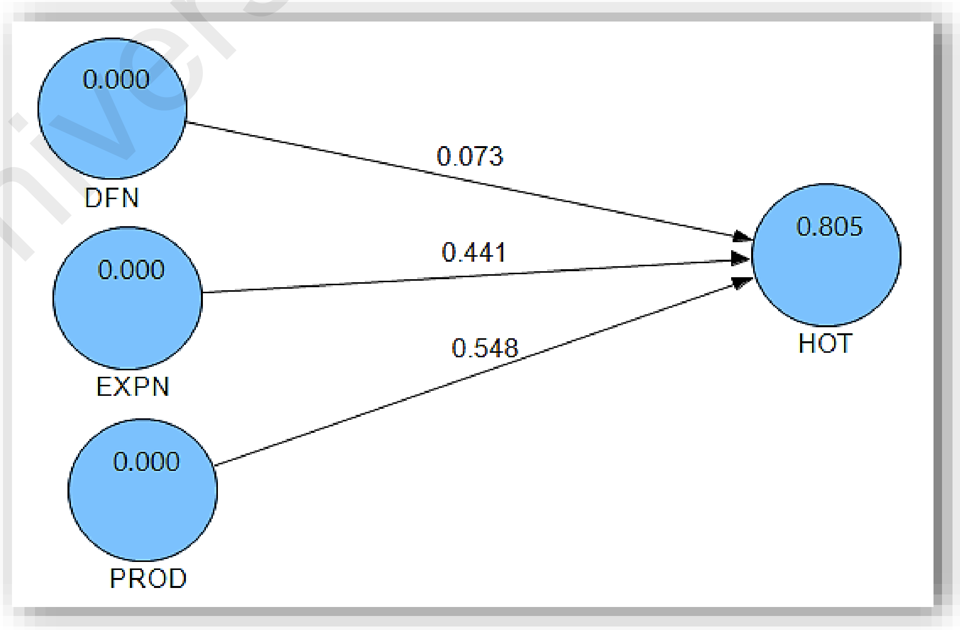

**Model A2**



**Model A3**




**Model A4**



**Model A5**

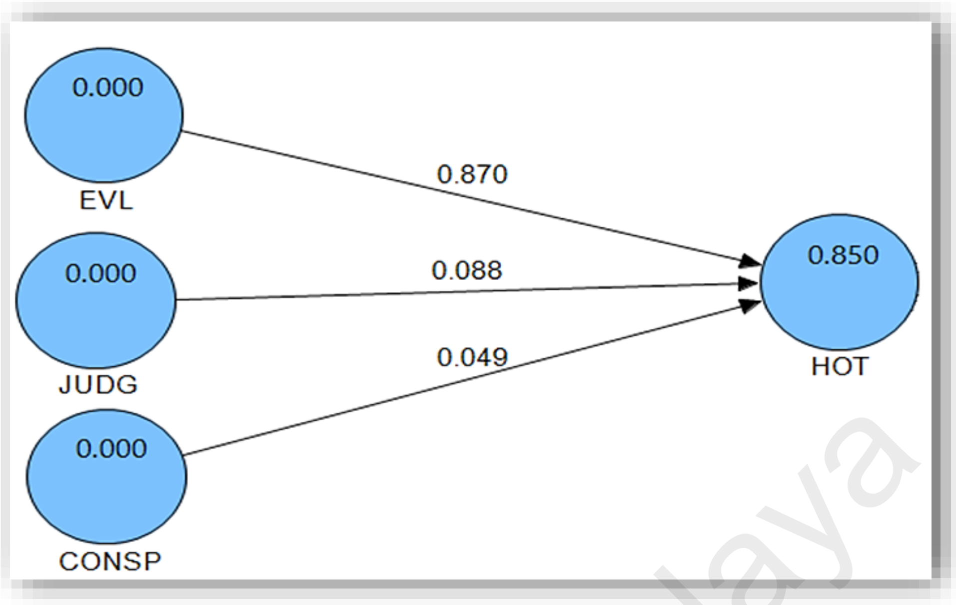



**Figure 6.2:** Direct Connection between Sub-Stages of the HOT Teaching with Dependent Construct.

**Model-A1**, shows the direct linkage of four independent constructs (sub-stages); asking critical questions, making comparison, formulating problem and estimation directly with HOT. The results revealed that HOT reported $R^2$0.665 with positive, weak, and significant relationships from all constructs, except formulating problem construct, which is not significant due to the value of T- Statistics which is less than 1.96 (Goodhue, Lewis, & Thompson, 2007). This means that formulating problem construct does not have significant impact in enhancing students' HOT, so as it is not usable to be implemented in the science classroom.

**Model-A2** Investigation stage connect directly with four independent constructs with HOT construct (usability of the model); formulating hypothesis, controlling variables, planning and measuring. The results show that HOT reported $R^2$ 0.846 with positive, weak, and significant relationships with all constructs except Measuring which is not significant.

**Model-A3** links the three independent constructs of the Explanation stage construct. The result pointed out that all the relationships are significant without any exceptions. In this model, $R^2$is reported to be 0.683.

**Model-A4** presents the relationship between all independent constructs of the Conclusion stage; expanding, defining operationally and producing with HOT construct. All the relationships in this model are positive, weak, and significant except Producing. It is important to highlight that $R^2$ on HOT model using the Conclusion sub-stages is reported to be 0.805.

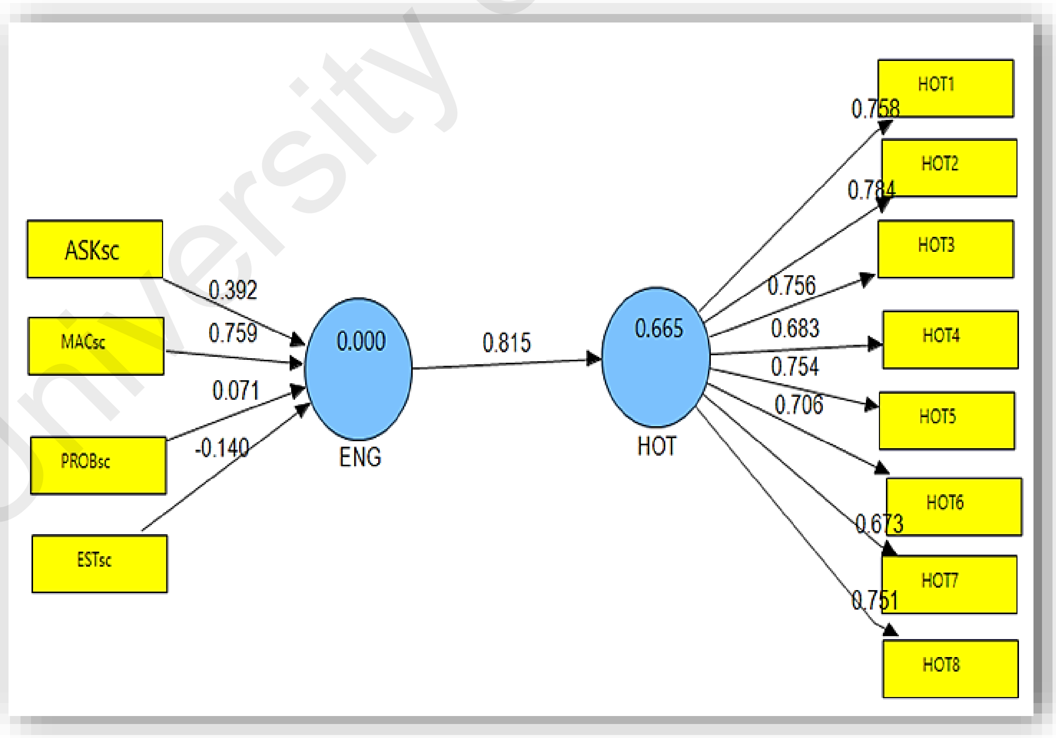
**Model-A5** shows the direct linkage of three independent constructs; making judgment, evaluation of arguments and conceptualizing with dependent construct. The results revealed the reported $R^2$ is 0.850 with positive, weak, and significant relationships from all constructs, except conceptualizing which was not significant. Table 6.24 summarizes the results from all of the models.

**Table 6.24:** First-Order Models

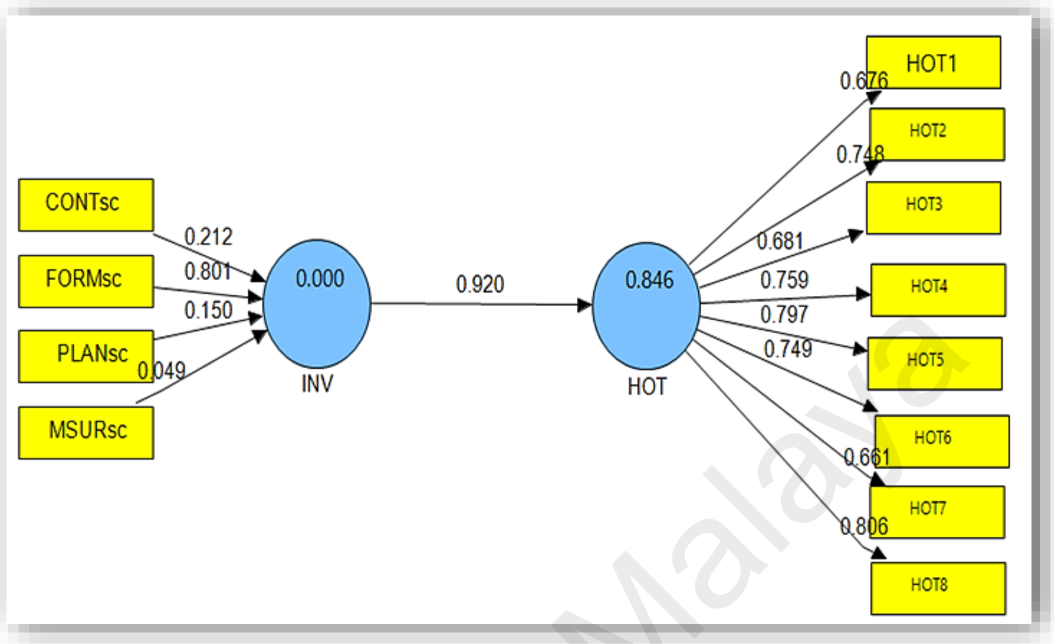
| Model | Dependent Construct | Independent Constructs | Path Coefficient | T Statistics | $R^2$ |
|---|---|---|---|---|---|
| Model-A1 | Engagement Stage | Asking Critical Questions | 0.3194 | 7.1047 | 0.665 |
| | | Making Comparison | 0.6191 | 13.9827 | |
| | | Formulating Problem | 0.0582 | 1.6143 | |
| | | Estimation | -0.1142 | 2.8236 | |
| Model-A2 | Investigation Stage | Formulating Hypothesis | 0.7368 | 27.0396 | 0.846 |
| | | Controlling Variable | 0.1945 | 5.0958 | |
| | | Planning | 0.0452 | 4.6749 | |
| | | Measuring | 0.1383 | 1.3568 | |
| Model-A3 | Explanation Stage | Organizing Data | 0.497 | 11.3578 | 0.683 |
| | | Checking | 0.394 | 10.2752 | |
| | | Summarizing | 0.1984 | 4.5246 | |
| Model-A4 | Conclusion Stage | Defining Operationally | 0.073 | 2.526 | 0.805 |
| | | Expanding | 0.440 | 12.168 | |
| | | Producing | 0.547 | 15.731 | |
| Model-A5 | Reflection Stage | Evaluation of Arguments | 0.8697 | 59.1093 | 0.850 |
| | | Making Judgment | 0.0878 | 3.6678 | |
| | | Conceptualizing | 0.0487 | 1.8074 | |

In this study, Engagement stage, Investigation stage, Explanation stage followed by Conclusion stage and Reflection stage were hypothesized to be second-order formative constructs. In order to identify the significance of each of these constructs in the HOT teaching model, the two-steps approach was employed to measure this second-order construct. Two-step approach is recommended in case the dimensions do not have the same number of indicators, as in the case of this study. Two-step approach is implemented by using latent constructs scores, which is calculated by PLS-SEM. The latent constructs scores are directly connected to the higher order as formative indicators (Hair Jr et al., 2013). The score of the sub-stages are directly connected to the stages. Therefore, another five models were formed by including second order formative constructs (model stages). These models are described in the following subsections:

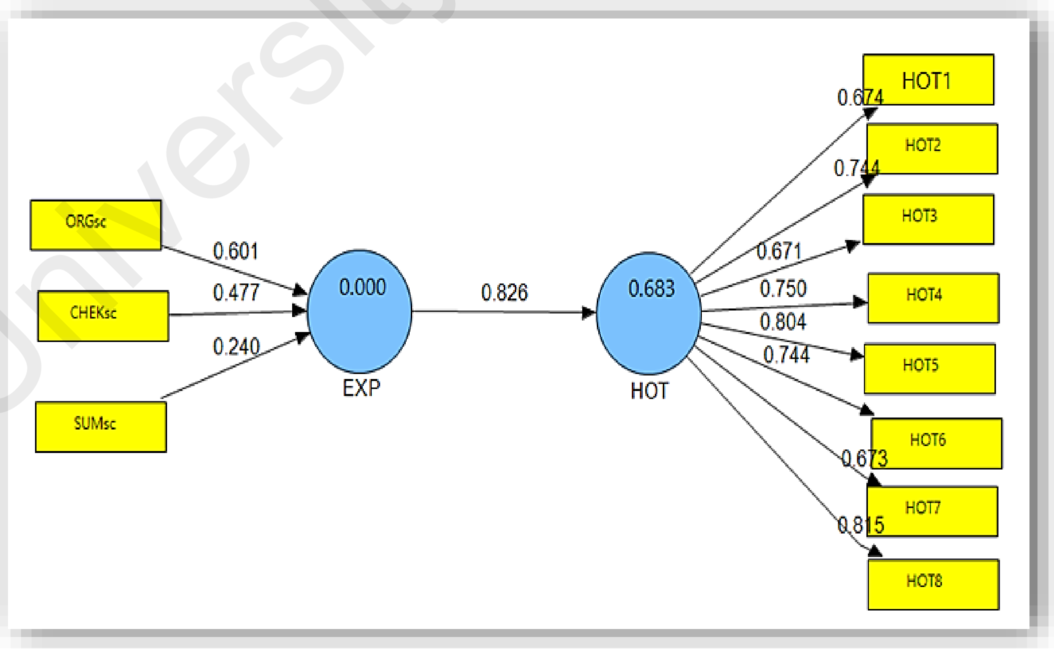
**Model B1**



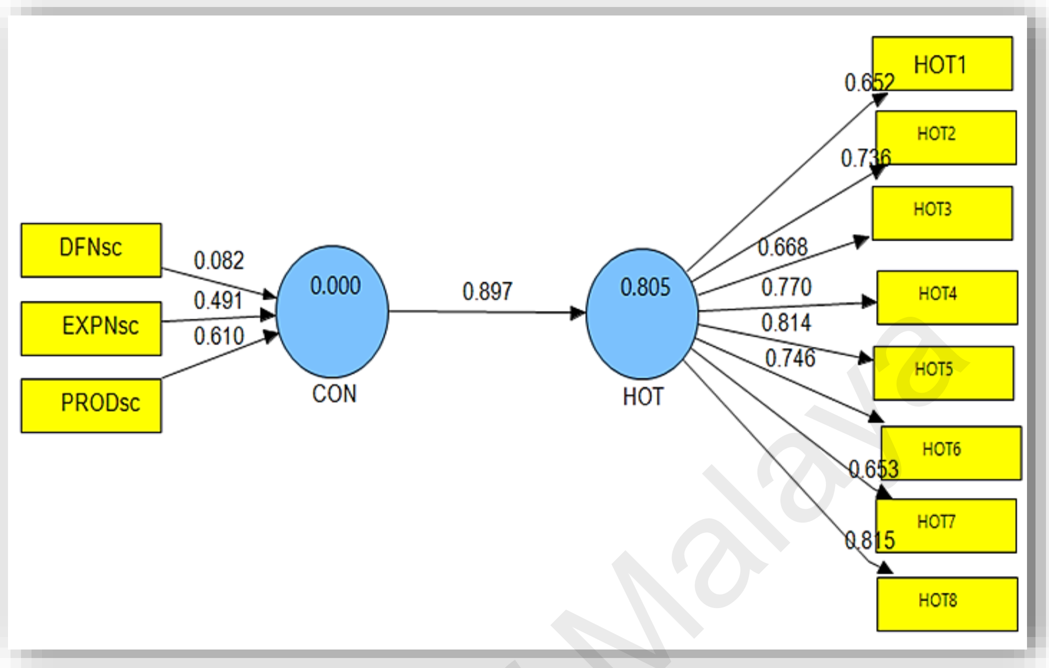
**Model B2**




**Model B3**



**Model B4**




**Model B5**

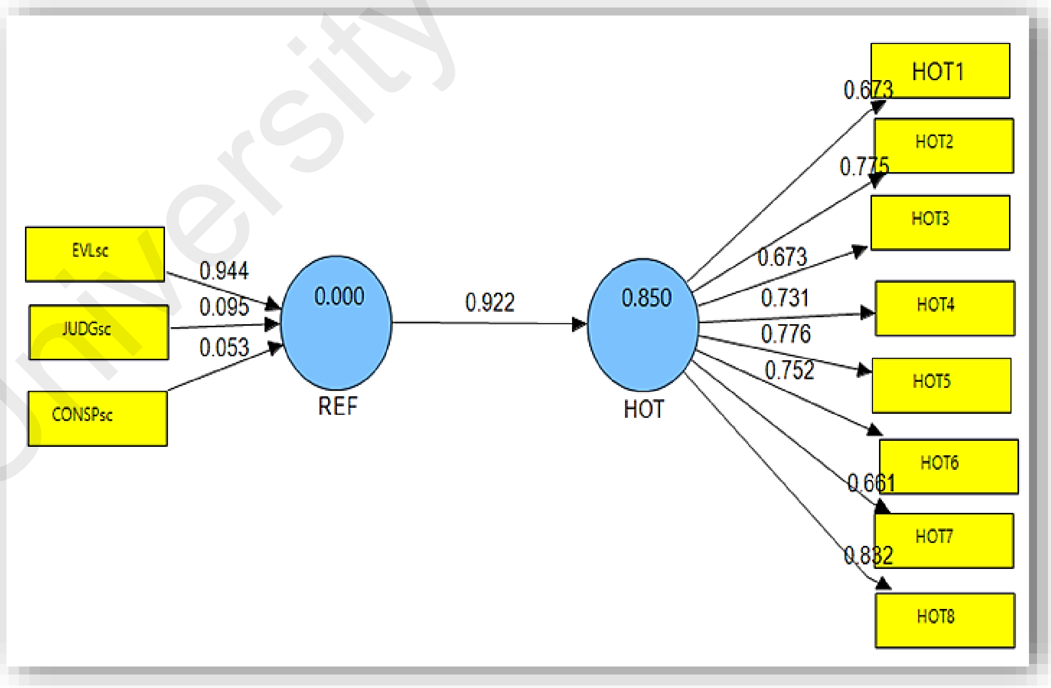



**Figure 6.3:** Direct Connection between Sub-Stages of the HOT Teaching with Dependent Construct

**Model-B1** presents the direct connection between Engagement stage second order construct with HOT construct, and the result showed high positive and significant path coefficient of 0.8153 between the two constructs. This model reported $R^2$ value of 0.6647, in addition, it shows that all T-Statistics between the four sub-stages and Engagement stage construct are significant, except the Formulating problem sub-stage, which is not significant.

**Model-B2** shows the direct connection between Investigation stage second order construct with HOT; the results showed a high positive and significant path coefficient of 0.919 between the two constructs. This model reported $R^2$value of 0.845, in addition, it shows that all outer weights between the four indicators and their formative construct are significant, except for the measuring construct.

**Model-B3** shows the relation between the three sub-stages of Explanation stage and HOT, and the results displayed a positive high significant path coefficient 0.826 with $R^2$value of 0.683. Moreover, this model shows that all outer weights of the three dimensions are significant, without any exceptions.

**Model-B4** demonstrated a direct connection between Conclusion stage second order construct and HOT. The results showed a high positive and significant path coefficient between the two constructs (0.897). This model reported $R^2$value of 0.805**.** In addition, it shows that all outer weights between the three indicators and their formative construct are significant without any exceptions.

**Model-B5** Reflection stage is connected directly with HOT dependent construct. The results showed that HOT reported $R^2$ 0.849 with positive and high significant relationship the two constructs (0.921).

**Table 6.25:** Summaries of the Five Models Values

| Model | Dependent Construct | Independent Constructs | Outer Weight | T Statistics | Path Coefficient | $R^2$ |
|---|---|---|---|---|---|---|
| Model-B1 | **Engagement Stage** | Asking Critical Questions | 0.391 | 6.866 | 0.815 | 0.665 |
| | | Making Comparison | 0.759 | 15.508 | | |
| | | Formulating Problem | 0.071 | 1.589 | | |
| | | Estimation | 0.140 | 2.86 | | |
| Model-B2 | **Investigation Stage** | Formulating Hypothesis | 0.801 | 27.679 | 0.919 | 0.846 |
| | | Controlling Variable | 0.211 | 5.127 | | |
| | | Planning | 0.150 | 4.63 | | |
| | | Measuring | 0.049 | 1.339 | | |
| Model-B3 | **Explanation stage** | Organizing Data | 0.601 | 11.631 | 0.826 | 0.682 |
| | | Checking | 0.476 | 10.030 | | |
| | | Summarizing | 0.240 | 4.517 | | |
| Model-B4 | **Conclusion Stage** | Defining Operationally | 0.081 | 2.531 | 0.897 | 0.805 |
| | | Expanding | 0.491 | 12.119 | | |
| | | Producing | 0.610 | 15.705 | | |
| Model-B5 | **Reflection Stage** | Evaluation of Arguments | 0.943 | 64.149 | 0.921 | 0.850 |
| | | Making Judgment | 0.095 | 3.604 | | |
| | | Conceptualizing | 0.052 | 1.792 | | |

After comparing two sets of models, model set (A1-A4) dealt with sub-stages of HOT teaching model independent constructs, while model set (B1-B4) employed the second order construct, which are model stages. We find that the path coefficients for all constructs in model set (A1-A4) from Table 6.24 are lower compared to outer weights reported in model set (B1-B4) from Table 6.25. In addition, the results indicated that the level of significance in both model sets are similar, for example, in model-A1, all independent constructs are reported to be significant except the formulating problem construct; this is seen in model-B1 as well, which confirmed that all the formative indicators are significant, except formulating problem indicator. Furthermore, all values of $R^2$ are reported to be similar in both model sets, with slight differences that do not exceed 0.001. In conclusion, the similarity between both model sets confirms the validity of using model stages as a second-order formative-reflective construct.

### 6.3.5 Structural Model Assessment

The measurement model (stages and sub-stages) of the HOT teaching has been examined in terms of reliability and validity of all study constructs. Following that, the use of second-order formative-reflective constructs is validated by providing and comparing the second-order constructs with alternative models. As illustrated in chapter 3, following the assessment of the measurement model is testing of the overall model (structural model) as in Figure 6.4.Using science teacher's views the usability of the overall model was identified according to the following research question:

Is the HOT teaching model usable to be implemented in science teaching?

Following the specific steps for evaluating the structural model as illustrated in Table 6.18.

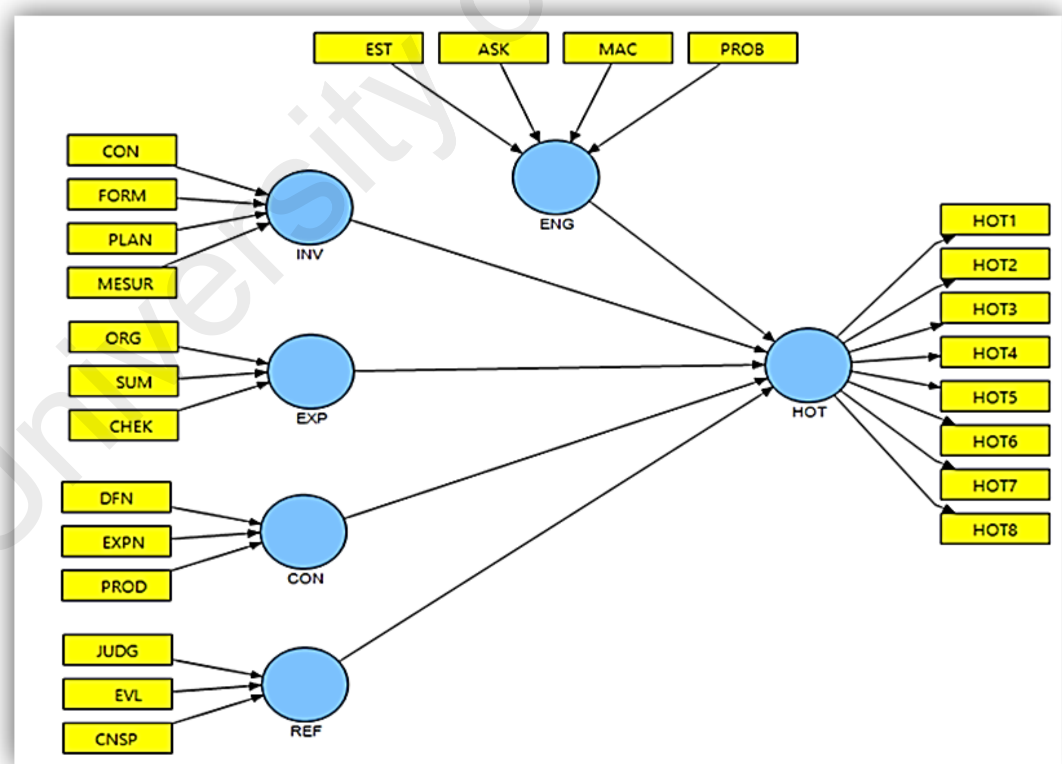



**Figure 6.4:** Structural Model Assessment.

Evaluation of the structural model is vital to show how the empirical data prove and support the underlying theories used in the study (Hair et al., 2013). In addition, it evaluates the level of predictability the model provides and the relationships among the constructs, as the using of the selected model stage in enhancing students' HOT as well as the usability of these stages in its implementation in science classroom.

There are four criteria for evaluating structural model in PLS-SEM: (1) the significance of the path coefficients; (2) the level of $R^2$values; (3) the $f^2$ effect size; (4) the predictive relevance$Q^2$ , and the $q^2$ effect size (Hair Jr et al., 2013).

#### 6.3.5.1 Significance and the Relevance of the Structural Model Path Coefficients

The measurement model in the previous sections generates the path coefficients of all the proposed paths in the study model in Figure 6.1. The structural model is an important for assessing the significance level of the path coefficients, since the assessment of structural model using PLS-SEM requires the execution of bootstrapping. Table 6.26 describes the configurations and setting used to operate bootstrapping:

**Table 6.26:** Bootstrapping Settings

| | **Selected Option** | **Reference** |
|---|---|---|
| **Sign Changes** | No Sign Changes | ( Hair Jr et al., 2013)<br>(Hair et al., 2011) |
| **Cases** | 315.00 | |
| **Samples** | 5000.00 | |

After operating bootstrapping, the results of path coefficient, *t*-values and significance level are presented in Table 6.27.

**Table 6.27:** Significance Testing Results of the Structural Model Path Coefficients

| | Path Coefficient | *t* values | Significance Level | *p* Values |
|---|---|---|---|---|
| **ENG -> HOT** | 0.2425 | 11.9949 | S | .000 |
| **INV -> HOT** | 0.1773 | 3.5712 | S | .000 |
| **EXP -> HOT** | -0.0051 | 0.2528 | S | -0.02 |
| **CON -> HOT** | 0.2065 | 3.177 | S | .000 |
| **REF -> HOT** | 0.4792 | 17.5352 | S | .000 |

*Level of significance : $p < .05$*

**Legend:**

ENG: engagement stage, INV: Investigation stage, EXP: Explanation stage, CON: Conclusion stage, REF: Reflection stage, HOT: usability of the overall model.

After evaluating the significance of the relationships between the constructs (stages) of the HOT teaching model, it is essential to evaluate the relevance of the significance of the relationships (Hair et al., 2013). Furthermore, in many cases, the path coefficients is significant, while its size is very small to deserve managerial consideration (Hair et al., 2013). In addition, analyzing the relevance of the structural model relationships is essential for results' interpretation.

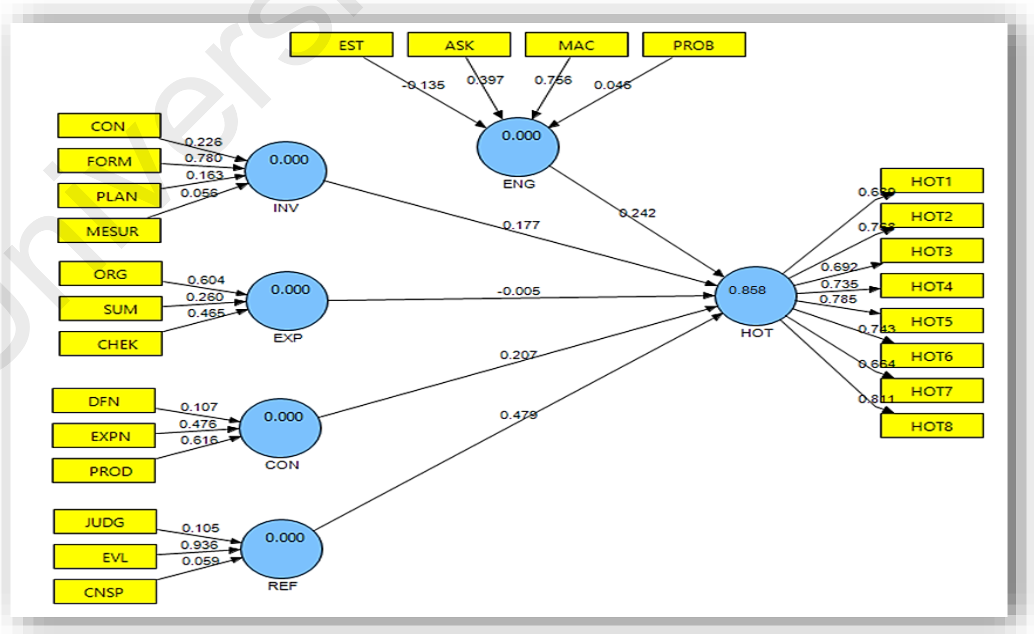
The results of Table 6.27 show that the Engagement stage (ENG), Investigation stage (INV), Conclusion stage (CON) and Reflection stage (REF) significantly contribute to the HOT construct, meaning that using these stages would enhance students' HOT. Moreover, Reflection stage (REF) reports the highest contribution ($\beta = 0.479$, *t*-value ($17.535 > 1.96$), followed by Engagement stage ($\beta = 0.242$, *t*-value ($11.994 > 1.96$). The results also revealed that Investigation stage has a direct significant influence ($\beta = 0.177$, *t*-value ($3.5712 > 1.96$), whereas the Conclusion stage (CON) has a significant but weak ($\beta = 0.206$, *t*-value ($3.177 > 1.96$) impact on HOT. Finally, the result showed that Explanation stage has a negative significant impact on HOT ($\beta$ = 0.-0.0051, *t*-value ($0.2528 < 1.96$).

#### 6.3.5.2 Coefficient of Determination $R^2$

The coefficient of determination $R^2$ is considered as a measure of a model's predictive accuracy, and is calculated as the squared correlation between dependent construct and predicted values (Hair et al., 2013). In addition, it reflects the independent constructs joint effects on the dependent construct (Hair et al., 2013). In other words, it reflects the amount of variance in the dependent construct, which is explained by all the independent constructs that influenced it (Hair et al., 2013). According to Hair et al. (2011), $R^2$ values of 0.75 or more are considered strong for dependent constructs, while 0.50, or 0.25 is considered moderate, and weak, respectively.

Figure 6.5 presents the measurement model of this study and displays the $R^2$ values. However, $R^2$ value for the HOT construct is 0.858, which is considered strong; this indicated that 85.8% of the variance in the HOT is explained by stages, meaning that by implementing HOT teaching model in the science classroom 85.8% students' HOT would improve in science learning.






**Legend**:
ENG: engagement stage, INV: Investigation stage, EXP: Explanation stage, CON: Conclusion stage, REF: Reflection stage, HOT: usability of the overall model.

**Figure 6.5:** The Measurement Model

#### 6.3.5.3 $f^2$ Effect Sizes

The effect size ($f^2$) is the assessment of $R^2$ in a case when a particular independent construct is removed from the model. Thus, it evaluates the impact size of the removed independent construct on the dependent construct (Hair et al., 2013). The effect of the size of $f^2$ can be calculated as:

$$f^2 = \frac{R^2 included - R^2 excluded}{1 - R^2 included} \quad \text{6-1}$$

The value of $f^2$ can be contrasted to 0.02, 0.15, and 0.35 to report small, medium, and large effects, respectively (Goodhue, Lewis, & Thompson, 2006). Table 6.28 shows that the effect of the size of all independent constructs on the dependent is small, or less than 0.15, except the effect of Reflection stage on HOT, which showed a large size effect.

**Table 6.28:** Results of R2 and f 2 Values

| **Dependent Construct** | **Independent Construct** | $R^2$ **Included** | $R^2$ **Excluded** | $f^2$ |
|---|---|---|---|---|
| **HOT** | | 0.858 | | |
| | ENG | | 0.855 | 0.021 |
| | INV | | 0.851 | 0.049 |
| | EXP | | 0.855 | 0.021 |
| | CON | | 0.837 | 0.147 |
| | REF | | 0.820 | 0.26 |

**Legend:**
ENG: engagement stage, INV: Investigation stage, EXP: Explanation stage, CON: Conclusion stage, REF: Reflection stage, HOT: usability of the overall model.

"It is important to understand that a small $f^2$ does not necessarily imply an unimportant effect. If there is a likelihood of occurrence for the extreme moderating conditions and the resulting beta changes are meaningful, then it is important to take these situations into account" (Goodhue et al., 2006).

#### 6.3.5.4 The Predictive Relevance $Q^2$ and $q^2$ Effect Sizes

$Q^2$ value "is a measure of predictive relevance based on the blindfolding technique" (Hair Jr et al., 2013, p. 203). Blindfolding procedure can be regarded as a resampling process that specifies and deletes data points of the indicators in a systematic way to predict the measurement model of the reflective dependent constructs (Hair et al., 2013). Blindfolding technique depends on the omission distance (D) that "determines which data points are deleted when applying the blindfolding procedure." However, as $Q^2$ value can be extracted and calculated for reflective dependent constructs only, we used the blindfolding technique was used in this study to specify the omission distance of (D = 7). According to Hair et al. (2013), the path will have predictive relevance if $Q^2$ exceeds zero, and referring to Table 6.29, the values of $q^2$ is reported to exceed zero.

**Table 6.29:** Results of Q2 and q 2 Values

| Dependent Construct | Independent Construct | $Q^2$ Included | $Q^2$ Excluded | $q^2$ |
|---|---|---|---|---|
| HOT | | 0.511 | | |
| | ENG | | 0.494 | 0.068 |
| | INV | | 0.508 | 0.0006 |
| | EXP | | 0.5084 | 0.053 |
| | CON | | 0.500 | 0.224 |
| | REF | | 0.49 | 0.429 |

**Legend:**
ENG: engagement stage, INV: Investigation stage, EXP: Explanation stage, CON: Conclusion stage, REF: Reflection stage, HOT: usability of the overall model.

#### 6.3.5.5 Goodness of Fit (GoF)

Contrary to CB-SEM that has the ability to apply the measures of goodness of fit, PLS-SEM is evaluated according to "heuristic criteria", which are identified by the model's predictive capabilities (Wetzels et al., 2009). As reported by Tenenhaus,Vinzi, Chatelin, and Lauro (2005) "… PLS path modelling does not optimize any global scalar function so that it naturally lacks of an index that can provide the user with a global validation of the model (as it is instead the case with $x^2$ and related measures in SEM-

ML). The GoF represents an operational solution to this problem as it may be meant as an index for validating the PLS model globally." Evaluating goodness-of-fit (GoF) can be realized by calculating the geometric mean of the average communality and the average $R^2$ using the following equation:

$$\boldsymbol{GoF = \sqrt{Average\ communality * Average\ R^2}} \qquad 6\text{-}2$$

The indices for communality and explained variability $R^2$are 0.552 $0.858$ . thus the GoF index is described in the following form:

$$\boldsymbol{GoF = \sqrt{0.858 * 0.552} = 0.687} \qquad 6\text{-}3$$

Meaning that the model is able to take into account 68.7% of the achievable fit, and indicative of the fact that the model is satisfactory (Tenenhaus et al., 2005).

## 6.4 Conclusion

The HOT teaching model was evaluated based on science teachers' views and responses to the survey evaluation questionnaire using the PLS-SEM approach. Prior to evaluation its construct validity had been identified by using factor analysis (EFA and CFA). The model was evaluated in terms of identifying the effect of using both stages and sub-stages in influencing students' HOT in science learning. The findings indicated that the HOT teaching model has a great impact on improving students' HOT in science learning according to$R^2 0.858$. Moreover, all the stages (engagement, investigation, conclusion and reflection) are usable and have positive and significance influence on students' HOT except Explanation stage which has a significance and negative influence on students' HOT.

## 6.5 Summary

The prototype 1 HOT teaching model that was developed in chapter five using Fuzzy Delphi method was evaluated in this chapter using the PLS-SEM approach. The evaluation was carried out with 355 science teachers using a survey evaluation questionnaire. The model was evaluated in terms of the measurement model and structural model. However, the evaluation of the measurement model was aimed at assessing the importance of employing stages and sub-stages of the HOT teaching model in enhancing student's higher order thinking skills in science learning. While the assessment of structural model was aimed at assessing the usability of the model in its implementation in science class. The results indicated that overall 5 stages with 17 sub-stages (learning activities) that combine reflective thinking skills with science process skills were found to be the elements of the HOT teaching model that have a positive effect on students' HOTS.

# CHAPTER 7: DISCUSSION OF FINDINGS

## 7.1 Introduction

In chapters four, five and six the findings concerning the design and evaluation of the HOT teaching model, through the three phases of the study, namely, needs analysis phase, design and development of the model phase and phase three evaluation of the developmental model were presented. Briefly, the needs analysis phase concluded with the needs to adopt a solution to improve students' HOT skills through using effective teaching models. In responding to this need, the development phase focused on developing a HOT teaching model for basic education students as a solution to help them improve their HOT in science learning. Finally, the evaluation phase involved evaluation of the HOT teaching model based on science teachers' views in terms of evaluating the importance of employing model elements (stages and sub-stages) on enhancing students HOTS. Besides, the usability of the model in its implemented in the science classroom was assessed through evaluation of the structural model. This chapter provides the discussion of findings for each stage followed by the implications and recommendations of the study.

## 7.2 Discussions of Findings from Phase One / Needs Analysis

Following the growing trend of applying the research findings of educational psychology in the classroom, this study has attempted to develop a teaching model for enhancing students' higher order thinking based on the theories of cognitive development and teaching models. Substantial research evidence has shown the correlation between teacher strategy use and students' cognitive development. Therefore, the needs analysis was conducted to identify the student's level of higher order thinking skills besides identifying the association between students' cognitive skill level and their gender.

Therefore, the higher order thinking level test (HOTL) was used to assess the students' current level of cognitive development that attempts to identify the specific skills that students need to improve in science learning.

The test was developed based on the six constructs of the Bloom taxonomy for cognitive domain; the test consisted of 25 items distributed into two levels of cognitive skills, 13 items for LOT and 12 items for HOT. The test was conducted on 418 7th grade students in the Iraqi Kurdistan region and mainly aimed at assessing the students' needs in terms of enhancing their higher level of cognitive skills. The data were analyzed using descriptive statistics via SPSS. The findings indicated that most of the 7th grade students are in the lower level of thinking as shown in Table 4.2. Especially in synthesis and evaluation constructs, which are the skills that improve students' creativity in science (Swift et al., 1996; Zohar, 2013). This justifies the needs to incorporate a solution to improve these skills among students. Moreover, the findings indicated a slight difference between the levels of thinking skills linked to student's gender, as the number of male students in the lower level of thinking skills (LOTS) were higher than the number of the female students at the same level. However, the chi square test results show no significant difference between students' level of thinking skills with regard to gender ($p > .05$) which could be attributed to the fact that both male and female were learning in the same learning environment. These findings support previous research on cognitive skills (e.g., Aktamis & Yenice, 2010; Durmaz & Mutlu, 2012; Vernez et al., 2014). Based on the literature of cognitive development the lower level of cognitive skill among students is caused by two main factors which are:

1- Curriculum: The nature of the science curriculum should allow students the ability to fully understand how science as discipline function can help student to think in a higher level (Zawilinski, 2009). However, in 2009 the curriculum in Iraqi Kurdistan region has been reformed and the main aims of the new science curriculum is to promote student' cognitive skills.

2- Teacher: In science education students should have the opportunity to begin thinking like scientists by engaging them in the process of thinking instead of merely ingesting the product of the scientists' disciplines (Gillies et al., 2014). The teaching of science requires teachers to use appropriate teaching methods to engage students' active participation in the learning process. Substantial research evidence in science education has shown the correlation between students' cognitive skills and teaching strategy (Bushman & Peacock, 2010; Gillies et al., 2014). Thus, the second research question was aimed at investigating the strategies used by science teachers to teach higher cognitive skills in the science learning as well as to determine whether there are differences in using the teaching strategies by science teachers according to gender and years of experience.

Strategies use survey questionnaire (SUSQ) was developed and posed to 212 7th grade science teachers in the Iraqi Kurdistan region so as to identify the weakness of teaching methods to be improved in the development model. The data collected on 7th grade science teacher strategies use indicated that the most popular strategies among 7th grade science teachers is the strategies for acquiring knowledge which focus more in memorizing basic concepts in science, while the least strategies use by science teacher is the strategies for applying knowledge such as problem solving and hands-on activity by using science laboratory, which are the strategies that improve students' higher cognitive skills. The findings of this study supported the Miri et al. (2007) study highlighting that for promoting students' HOT the male science teachers focused more on strategies for applying knowledge. The female science teachers focused more on employing the strategies for reflection on knowledge; the findings of this study were consistent with Miles (2010). Moreover, the findings indicated that most of the experienced science teachers rather than less than ten years experienced science teacher's focus on strategies for improving students' basic thinking skills. These findings of this study supported the claim by Hamzeh (2014) that young teachers believe in students' freedom and try to enhance students' confidence and allow them to express it more in their learning. This finding justifies the need for developing a teaching model with the focus on learning activities that engage students in the knowledge construction process such as problem solving and hands-on activities. Moreover, a link between class activities and development of higher order thinking skills was suggested by Wenglinsky (2002). Findings revealed that textbook and supplemental guide activities put more emphasis on information gathering, remembering, and organizing skills than on focusing, integrating, evaluating, and analyzing skills. He stressed the importance of cognitive engagement in making classroom activities effective. This is reflected in study conducted by (Zohar & Schwartzer, 2005). This finding also supports (Ramirez & Ganaden, 2010) study who asserted that, to equip students with HOT skills and make them competitive, educators need to teach cognitive strategies that help their students to think reflectively, solve problems and make decisions. Additionally alternative assessment methods are very useful to prevent students from rote learning, such as open-ended problems that increase students' higher order thinking skills (Krajcik & Naaman, 2006). Thus, this study aimed at developing a HOT teaching model which focuses more on the activities that engage students in using higher cognitive skills in science.

## 7.3 Discussion of Findings from Phase Two / Design and Development

In developing the model for improving basic education students' HOT in science learning, this phase sought to answer the following questions:

1- What are the experts' views on the stages and sub-stages that should be included in the development of HOT teaching model?

2- Based on the experts' agreement, how should the HOT teaching model stages and sub-stages be arranged in the implementation of the model?

Before answering these research questions, a prelisting of initial elements was identified through experts' views using interview; based on their opinions a Fuzzy Delphi Questionnaire was developed. The survey was conducted with 20 experts, according to their responses to a set of 29 questions divided into two parts. The first part sought to elicit expert's views on the stages of the model, while the second part is on the selection of sub-stages (RT and SPS) that should be included in each stage. Based on the threshold value (Table 5.1) and the defuzzification values, the model consisted of five stages and 24 sub-stages (see Table 5.15). furthermore on elaboration how the model can be implemented in the science classroom, the priority of the elements have been identified by using ranking process, the prototype I of HOT teaching model is in Figure 5.1. Guiding the development of this model, Bruner's cognitive development theory and Gagne theory are employed as a theoretical framework for the selection of the appropriate elements for the model. Based on this framework, the selected stages describes how the science teacher could help students to use reflective thinking skills RTS and science process skills SPS so as to improve their higher cognitive skills in order to achieve their learning goals in science learning. In addition, this model is further evaluated by science teachers in the phase three of research.

## 7.4 Discussion of Findings from Phase Three / Evaluation of the Model

Evaluation of the HOT teaching model is the final phase of the study. The evaluation phase aimed at evaluating the model according to the following aspects:

1- Evaluation of the stages and sub-stages of HOT teaching model (measurement model)

2- Evaluation of the usability of the HOT teaching model (structural model).

The first version of the survey evaluation questionnaire consisted of 67 questions (items) divided into six constructs, five constructs were about the five stages of the HOT teaching model and the sixth construct was about the usability of the overall model. The questionnaire was posed to 122 science teachers in the Iraqi-Kurdistan region for pilot study and mainly aimed to identify the reliability of the questionnaire and its content validity using factor analysis. Based on the factor analysis results, the survey evaluation questionnaire (see Appendix I) was used to evaluate the HOT teaching model which was conducted on 355 science teachers in the Kurdistan region; but 284 science teachers responded completely to the questionnaire items. Data from this phase were analyzed using PLS-SEM approach. In evaluating the HOT teaching model, the evaluation phase is aimed at answering the following research questions:

1- Do the selected elements (stages and sub-stages) of HOT teaching model positively influence students' HOT?

2- Is the HOT teaching model usable to be implemented in science teaching?

The findings for the research question one indicated that, the sub-stages of the Engagement stage; asking critical questions, making comparisons and estimation have a direct and significant effect on students' HOT except formulating problem sub-stage with $R^2$0.665. Meaning that engaging students in science activities will improve 66.5% of their HOT in science learning. This finding is supported by Krajcik and Naaman (2006) who indicated that asking questions and comparing between objects engage students in science and increased their motivation and interest in a topic. Besides helping the teacher diagnose students' understanding and tap into their thinking, thereby acting as aids in formative assessment and evaluating higher-order thinking. These findings are also supported by (Chin & Osborne, 2008). Moreover, the findings of the sub-stages of Investigation stage shows that three sub-stages; formulating the hypothesis, planning, controlling variables are significant with the exception of measuring with $R^2$ 0.846. The inclusion of this stage in the model is supported by (Ibrahim Bilgin, 2006) who identified the importance of inquiry process in improving students' SPS. Beside, Marshall and Horton (2011) and Schweingruber, Duschl, and Shouse (2007) advocated that using exploration in science class has a great influence on students' cognitive skills. While the findings of the sub-stages for Explanation indicated that all the sub-stages have a negative significance effect on enhancing students' HOT without any exception with $R^2$0.683. However, (Marshall & Horton, 2011) found a negative correlation between the percent of time spent explaining concepts and the students' cognitive level in science learning. Regarding Conclusion sub-stages, the findings showed that all the sub-stages have a positive significant effect on enhancing students' HOT without any exception with high variance $R^2$0.805. Finally, the findings of the sub-stages of Reflection stage shows that all sub-stages are significant with the exception of conceptualizing (refer to Table 6.24 and 6.25). These findings are supported by research conducted by Duschl and Osborne (2002) and Miri et al. (2007) who concluded the importance of summarizing results and evaluation of arguments will encourage students to use higher cognitive skills.

In terms of the importance of the model stages, the findings illustrated that all the stages of HOT teaching model are suitable for implementation in the science classroom and have a direct and significant positive effect on improving students' HOT in science learning except the Explanation stage, that showed a negative significant effect with HOT (refer to table 6.27) which is consistent with (Marshall & Horton, 2011). Moreover, the findings indicate that the Engagement stage and Reflection stage have significant and superior strong effect on enhancing students' HOT in science learning, which are further supported by research conducted by Paige, Sizemore, and Neace (2013) and Heong et al. (2012). Regarding the results of the usability of the model, the results revealed that implementing HOT teaching model in science class would improve (85.8%) of students higher order thinking. This concluded that, the overall HOT teaching model is suitable to be implemented in science class to enhance basic education students' HOT in science learning. The following section elaborates in detail how the stages and sub-stages of the HOT teaching model could aid basic education students to fulfil their learning needs in science.

## 7.5 HOT Teaching Model Application in Class

It has been well verified that higher order thinking skills are essential for effective learning and the development of these skills should form the central goal of science education. Based on the recent literature, teaching methods play a vital role in enhancing students' acquisition of HOT. Therefore, this study was conducted to describe how a novel teaching model could be used as a practical solution to support students in achieving their learning goals by encouraging active participation in the learning process. The HOT teaching model was developed using the Fuzzy Delphi Method in phase two and it was evaluated by science teachers in phase three. As a result five stages with 17 sub-stages have been identified to be included as elements for the model. According to Singer and Moscovici (2008), the elements of the specific teaching model needed to encourage students to build on their informal ideas in a gradual but structured manner, so that they re-build domain specific concepts and procedures.

Moreover, students need to be challenged to make sense of what they are doing. Guiding the development of this model, Bruner's cognitive development theory is employed to describe the development process of HOTS through discovery learning. Moreover, Gagne theory of learning hierarchy along with Kolb's theory for experiential learning are employed as a theoretical framework for the selection of the appropriate stages (steps) to be involved in the model. Based on this framework, the selected stages describe how the science teacher could help students to use reflective thinking skills (RTS) and science process skills (SPS). Additionally, cyclic learning model CLM and

IMSTRA models are employed in this study to guide the experts through the process of selecting sub-stages of the HOT teaching model to describe how the science teacher can help students to use activities that improve their higher cognitive skills in order to achieve their learning goals in science learning.

The specific stages of HOT teaching model can be arranged as in Figure 7.1, could help science teachers to build on students' understanding and encourage them to build on their informal idea in a gradual but structured manner so that they re-build the domain of specific concepts and procedures. Students need to be challenged to make sense of what they are doing so as to use their higher cognitive skills.

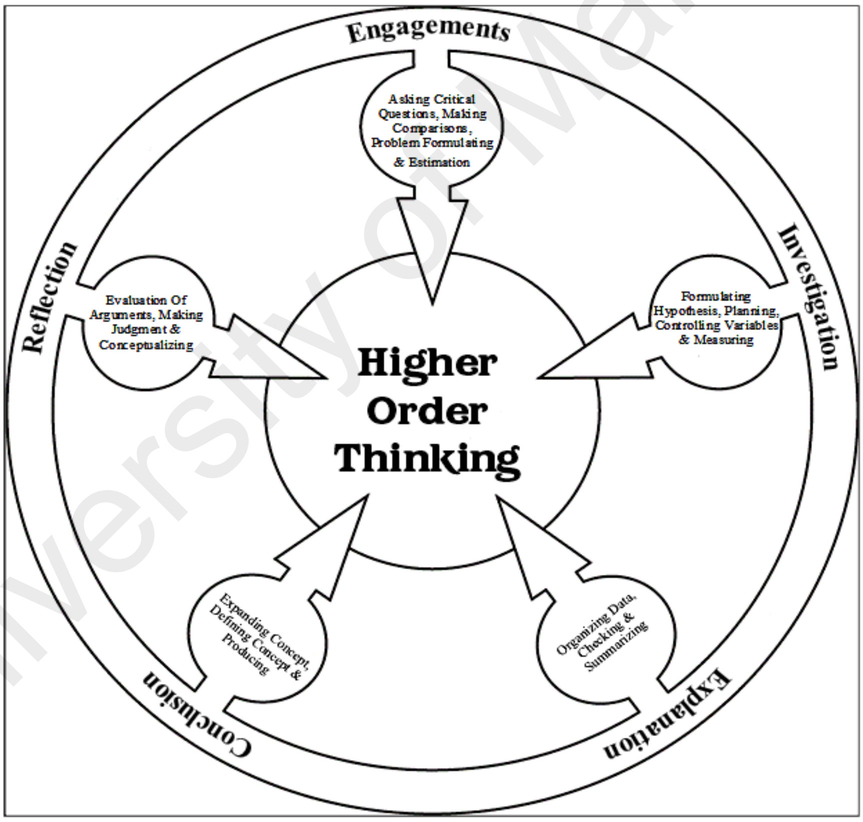



**Figure 7.1:** HOT Teaching Model for Basic Education Students in Science

As for stage one (engagement stage) that aims to activate students' prior knowledge. The science teacher should develop students' curiosity through offering problem (real-life problem) that aims to create conflicts. Hence, when students engage in the progression of knowledge construction, an element of uncertainty is presented into the instructional process and the results are not always expected. In aiding students to become creators of knowledge, generating activities that provide opportunities for them to engage in higher order thinking is the teacher's main instructional task. Four sub-stages (learning activities) would be used by science teachers to engage basic education students in the science learning such as asking critical questions, making comparisons, formulating precisely problems and estimation. Through adopting these sub-stages science teachers can identify the students' knowledge and understanding about the topic as well as create cognitive conflicts which motivate the students to engage in the task that seeks to develop students' basic thinking skills related to lower level of Bloom taxonomy such as knowledge and comprehension constructs.

According to Singer and Moscovici (2008) the second stage of the teaching model should move students to another level of understanding. Therefore, the second stage of the HOT teaching model focuses more on investigating the proposed problem by using specific sub-stages such as formulating hypothesis, controlling variable, measuring and planning. Through adopting these activities in science class, students should be able to determine the best method to solve the problem. Research suggests that the activities exposing students to a variety of resources connected to the topic, providing suggestions and cues to keep the exploration going and avoid defining terms or explaining evidence until the students have made enough trials to orient to the solution will facilitate the student's searching (Mayer, 2004). Using graphic organizers such as concept maps and hands-on activities are also useful in achieving the objectives of this stage which is further related to the application construct in Bloom's taxonomy.

Explanation was is the third stage for the HOT teaching model. This stage of the model emphasizes students' attention on a specific aspect of their engagement and investigation, and provides opportunities for them to verbalize their understanding and explain concepts in their own words. This occurs through connecting students' prior knowledge (stage One) to new discoveries by communicating new understandings (stage Two). The sub-stages of this stage such as organizing data, checking and summarizing the results are the higher cognitive skills that would help students interact in a positive, supportive manner in the process of explaining the concept. Using math skills and comparison tables have been recommended for better explaining the concept. Through these activities, students will be able to Process (record, compare, classify, represent) data using modalities adequate to the targets, compute partial results, trying to build their own understanding of the concept that are more related to synthesis construct in Bloom's taxonomy of higher cognitive skills.

The fourth stage of the HOT model, (Conclusion stage), serves to complete stage Three (Explanation). It aims to extend students' conceptual understanding, allow further chances for them to clarify the discovered understandings, and reach conclusions through new experiences. To aid students in reaching conclusions, three sub-stages are selected, includes reflective thinking (RT) and science process skills (SPS) were identified. These sub-stages are defining the concept operationally, expanding it into new situations, and producing. Past Research in science learning indicated that encouraging students to analyze the results and generate their ideas would assist them to move from concrete (personal experiences) and semi concrete (other students' experiences) to abstract and again to concrete experiences (planning experimentation and make first trials to solve the problem) (Singer, 1995, 2004). Consequently, expanding the concept means offering opportunities for students to independently apply the learned concept to develop their ideas in applications on their own. Past research suggested that after investigating the scientific concept, the science teacher should encourage students to extend and apply the concept to real situations. The Producing sub-stage requires students to use higher order thinking skills that make them creative thinkers and enable them to produce such as simple application model.

The final stage of the HOT teaching model in the science classroom is Reflection. The main objective of this stage is to get feedback on what has been done in the previous steps, by taking time to think again about the initial problem, the path taken to solve it, and the actual conclusions. Based on the study findings, three reflective thinking skills were identified to assist students in reflecting about their experiences: evaluating the argument, making judgment and conceptualizing. Moreover, activities such as journal writing, using subject connection, presentation, and asking students to create their own examples of the concepts can help students to achieve the objective of this stage. In which the conclusion and Reflection stage are more related to the evaluation construct of Bloom's taxonomy for higher order thinking which allow students to extend their results and evaluate their arguments.

Based on the preceding discussion, we realized that applying the HOT teaching model in science class would improve students' reflective thinking skills (RTS) that make them familiar with the use of higher-order thinking skills such as synthesis, analysis, evaluation, creation and expression of complex solutions to problems. Thus, through focusing on encouraging students to use reflective thinking skills and getting feedback after each stage beyond science process skills which would further help science teachers to assess their students' understanding about the topic make the HOT teaching model different from previous teaching models such as 5E model and problem solving model.

However, as the stages and sub-stages of the model are guided by the cyclic learning model and framed by Kolb's theory of experiential learning and based on the findings of the study, the learning activities (sub-stages) of the HOT teaching model that aid students to use reflective thinking skills RTS based on CLM are illustrated in Table 7.1.

**Table 7.1:** Distribution of Elements of HOT Teaching Model to CLM Stages

| CLM Model Stages | RTS in HOT teaching model |
|---|---|
| **Concrete Experience** | Asking Critical Questions<br>Formulating Problem<br>Estimation |
| **Reflective Observation** | Planning |
| **Abstract Conceptualization** | Summarizing<br>Checking |
| **Doing Stage** | Expanding<br>Evaluation of Arguments<br>Making Judgment<br>Conceptualizing |

According to Kim (2005) and Manolis et al. (2013), the first stage of CLM should help students to experience some activities that have the potential to add or change the students' knowledge by initiating new experience. However, the main objective of the first stage of the HOT teaching model is to activate students' prior knowledge in order to engage them in the process of construction knowledge in science learning. Thus, asking critical questions, formulating problem and estimation are the sub-stages (learning activities) of the Engagement stage that help students to engage in the process of constructing the knowledge and could be categorize under the first stage of CLM. In which, through asking questions the teacher can identify the students' knowledge and understanding about the topic as well as to create cognitive conflicts which motivate the students to engage in the task. Therefore, creating learning situations that generate the recall of the notion, operations and behaviours necessary to understand the new concept would help students to formulate pretext (real-life problems). The second stage of CLM is Reflective observation; this stage requires the students to reflect on experiences and think in the proper way to solve the problem (Bergsteiner, Avery, & Neumann, 2010). Therefore, in Investigation stage specifically planning sub-stage could be categorized as the reflective thinking skill that would facilitate the process of learning in this stage. While summarizing and checking are the sub-stages of the Explanation stage that could be categorized under abstract conceptualization or thinking stage of CLM that aims to analyze the experience through connecting the new experiences to past knowledge. According to Singer (1995, 2004) analyzing the results support students to move from concrete (personal experiences) and semi concrete (other students' experiences) to abstract and again to concrete (planning experimentation and make first trials to solve the problem). Demirbas and Demirkan (2007) advocated that the last stage of CLM (Doing stage) aid the students to apply their new knowledge into a new situation by doing and using theory to make a decision and solve problems. Therefore, the sub-stages of Conclusion and Reflection stages could be categorized under doing stage of CLM as in Table 7.1. Expanding the concept by offering opportunities for students to independently apply the learned concept to independently develop their ideas in applications. Expanding concept could systematize further connections such as the relationships of the studied concept with other concepts within the domain or with concepts from other domains or extend learning outside the classroom. While Evaluation of arguments is an important reflective thinking skills that would support students to take decisions concerning how to use the learned strategies to solve various types of problems (Duschl & Osborne, 2002). Furthermore, making judgment is a Reflection sub-stage that aid students to make trials to judge about the results and set up new criteria to assess the product (the final solution). Conceptualizing, is the last reflecting thinking skill in the HOT teaching model that help students to formulate the concept in a new and idealized way through models where the objects are explored and their features generalized to other objects.

Based on the preceding discussion, we recognised that applying the HOT teaching model in science class would improve students' reflective thinking skills (RTS) that make them familiar with the use of higher-order thinking skills such as synthesis, analysis, evaluation, and the creation and expression of complex solutions to problems.

Referring to the Gagne theory for learning hierarchy, we could deduce that the learning activities (sub-stages) of the HOT teaching model would help students to use varied science process skills in a hierarchy form from basic science process skills (BSPS) to integrated science process skills (ISPS). Hence, the study adopted Gagne's taxonomy for learning outcome in cognitive domain; in particular, Learning Intellectual Skills. Table 7.2 proposes the sub-stages of the HOT teaching model that could be categorized according to intellectual skills in Gagne taxonomy, such as Discrimination, Concrete concept, Define concept, Rule and Higher order rule (Problem Solving).

**Table 7.2:** Distribution of Elements of HOT of Teaching Model to Gagne Taxonomy

| Gagne's Domain Of Learning Intellectual Skills | SPS in HOT Teaching Model |
|---|---|
| **Discrimination** | Making Comparison |
| **Concrete Concept** | Formulating Hypothesis<br>Controlling Variable |
| **Define Concept** | Organizing Data<br>Defining Operationally |
| **Rule** | Measuring |
| **Higher Order Rule (Problem Solving)** | Producing |

According to Gagne's Domain of Learning Intellectual Skills, Discrimination is the lower thinking skills which refers to the ability to distinguish one feature of an object from another based on one or more physical dimensions. Therefore, asking critical questions and Making comparison could be categorized under Discrimination, in which these basic cognitive skills help students to identify the characteristic of the object. Formulating hypothesis and controlling variables could be categorized under Concrete concept, which are the skills that required students to know more about the variables underlying the problem. Moreover, organizing data and defining operationally are integrated science process skills that could be categorized under define concept? Through Organizing data, students will be able to Process (record, compare, classify, represent) data using modalities adequate to the targets, compute partial results, try to build their own understanding of the concept as well as to verbalize the concepts using their own words. Measuring is the sub-stage that aid students to use math skills using simple rules; therefore it could be categorized under the rule domain of Gagne intellectual skills. The Producing sub-stage require students to use higher order thinking skills that make them creative thinkers and able to produce new creations such as a simple application model. Therefore, this sub-stage of the HOT teaching model could be categorized under higher order rule (problem solving) which is the higher domain in Gagne's taxonomy for learning hierarchy.

### Relationship of HOT Teaching Model to IMSTRA Model

The IMSTRA model is a teaching and learning cycle model for science and mathematics learning. As the IMSTRA model is employed in the study and based on the findings of the study we could deduce that the stages and sub-stages (elements) of the model of the study support the use of higher order thinking skills as proposed in the IMSTRA model (Figure 2.3).

**Table 7.3:** Distribution of Elements of HOT Teaching Model to IMSTRA Model

| IMSTRA Model | | HOT Teaching Model | |
|---|---|---|---|
| **Phases** | **Sub-Phases** | **Stages** | **Sub-Stages** |
| **Immersion** | Evoking<br>Exploring | Engagement | Asking Critical Questions<br>Making Comparison<br>Formulating Problem<br>Estimation |
| **Structuring** | Synthesizing<br>Explaining | Investigation | Formulating Problem<br>Controlling Variable<br>Measuring<br>Planning |
| | | Explanation | Organizing Data<br>Summarizing<br>Checking |
| **Applying** | Practicing<br>Extending | Conclusion | Defining Operationally<br>Expanding<br>Producing |
| | | Reflection | Evaluation of Arguments<br>Making Judgment<br>Conceptualizing |

As shown in Table 7.3 the sub-stages of the HOT teaching model (asking critical questions and making comparison) support using basic skills as in the evoking sub-stage in the IMSTRA model. For example making comparison requires students to select concrete experiences from memory, experiences pertinent to the situation at hand, which require students to search for means to solve the problem. This is consistent with the Singer and Moscovici (2008) argument that the science teacher must offer the problems that create cognitive conflicts which motivate them to engage in the task; they indicated that the second stage of the teaching model should move students to another level of understanding. Therefore, the second stage of the HOT teaching model focuses more on investigating the proposed problem by using specific sub-stages such as Formulating problem, Controlling variable, Measuring and Planning. According to the IMSTRA model, the students explain their investigation result in stage two. While in HOT teaching model, the Explanation stage is the third stage of the model which not only allow students to explain the claim, but also create new situations in order to challenge their own claim and to add to the generalizability of the knowledge they produced by using three specific sub-stages; Organizing data, Summarizing and Checking. The final phase of the IMSTRA model is applying, which helps students to use the abstract pattern that they developed into related and unrelated situations. However, the fourth stage of the HOT teaching model is conclusion which aims at extending students' conceptual understanding, allow further chances for them to clarify the discovered understandings, and reach conclusions through new experiences. Reflection, the last stage of the HOT teaching model, aid students to make judgment and think of new was to solve the problem (Barak & Dori, 2009).

## 7.6 Conclusion

The present study was initiated to examine the potential of using effective models in enhancing student's higher order thinking in science education. More specifically, it aimed at determining the specific learning activities of HOT teaching model that have potential to develop students reflective thinking skills and science process skills in science learning. Design and developmental approach was employed with three main phases namely, needs analysis, design and development and model evaluation. Here are the main conclusion drown from each stage of the study.

First, the findings of the needs analysis concluded that majority of the $7^{th}$ grade students in Iraqi Kurdistan region are lacking in higher order thinking skills, especially in synthesis and evaluation constructs that could affect their achievement and creativity in science. As most of the literature in science education asserted that lower level of cognitive skills is caused by the teaching methods that science teachers use to teach scientific content. Therefore, the researcher was interested to investigate the strategies use by $7^{th}$ grade science teacher in the Iraqi Kurdistan region. However, the results indicated that a variety of higher cognitive skills teaching strategies are lacking among the teachers and that low processing strategies, such as focusing on learning student's memorizing basic concepts are dominant among 7th grade teachers that improve students' knowledge and comprehension levels. While strategies that encourage students to use higher cognitive skills that focus on exploration, reflection and sharing of idea which have been suggested in the literature such as problem solving, collaborative learning and inquiry strategies are less used by the teachers. Thus, there was a need to develop a teaching model to provide science teachers with a practical guide, through employing the specific activities that gives students the opportunities to practice scientific knowledge, so as to be able to apply it into real life situations.

Second, to enhance student's higher order thinking skills, proposals could be in the form of developing a module for science curriculum design or developing effective teaching models. However as mentioned in chapter one, the science curriculum in basic education in the context of Iraqi Kurdistan region have been revamped based on the new trends in science. Despite that, research emphasized that there is inefficiency among science teachers on how to use the new science curriculum. Therefore, the focus of this study was to design and develop a teaching model with emphasis on involving students in the learning activities that encourage them to use reflective thinking skills and science process skills as required in the new science curriculum for basic education students in Kurdistan region. The model was developed in phase two through adopting Fuzzy Delphi Method using experts' views. The findings showed that prototype1 HOT teaching model consisted of five stages (engagement, investigation, explanation, conclusion, and reflection) with overall 24 sub-stages (learning activities that engage students to use HOTS in science learning such as RTS and SPS).

Third, the prototype1 HOT teaching model was further evaluated in phase three using science teachers' views through utilizing the PLS-SEM approach. The evaluation was carried out using two major steps; evaluating the measurement model (stages and sub-stages) and evaluating the structural model (usability of the model). The findings of the measurement model indicated that engagement, investigation, conclusion and reflection have positive significance effect on students HOTS, whereas, the Explanation stage has a negative impact on students' HOT.  Besides, the findings also showed that the HOT teaching model is usable to be implement in science class. In addition, these findings supports Bruner's theory of cognitive development and Gagne theory of hierarchical process on how the students would participate in basic process skills gradually to integrated science process skills through discovery learning. The model findings also support Kolb's theory especially the cyclic learning model in aiding the concept of reflective thinking along with science process skills. Through this integration students would be able to become critical thinker's decision makers and are enabled to think about their own thinking to solve their real life problems.

## 7.7 Implications of the Study

With regard to the main findings of the study and the current issues of using effective teaching methods in science education, the study has provided insights into the following aspects:

### 7.7.1 Practical Implications of the Study

Given the importance of improving students' cognitive skills for academic success, understanding the process of higher order thinking skills as well as developing an effective teaching model in ways to facilitate the development of students' HOTS represent an important and central goal in science education. The results of this study contribute to the body of knowledge in developing an effective teaching model; this is demonstrated through development of HOT teaching model in science learning. More specifically the study is aimed at developing a model specifically for improving cognitive skills among basic education students for facilitating the model development. The study is further limited to develop a HOT teaching model among basic education students in the Iraqi-Kurdistan region. The results of the study have important implications for teachers and curriculum designers in science education in particular and education in general.

First, the science teachers could benefit from the findings of the study in assessing the students' level of cognitive skills so as to know the weakness of students' cognitive skills and make effort to improve these skills among students. Moreover, the science teacher could use the findings of the study in getting acquainted with the weakness of their teaching methods so as to make effort to improve through adopting various hand-on activities that encourage students to use their higher cognitive skills in science learning. Besides, a connection between class activities and increasing students' higher order thinking skills was recommended by Wenglinsky (2002). Findings emphasized that supplemental guide activities and textbook put more emphasis on remembering, gathering information and organizing skills than on evaluating and analyzing skills. He asserted on the importance of cognitive engagement in making classroom activities effective. This is reflected in studies conducted by (Ramirez & Ganaden, 2010; Zohar & Schwartzer, 2005) who asserted that, to equip students with higher cognitive skills and make them competitive, educators need to teach cognitive strategies that help their students to think reflectively, solve problems and make decisions. Additionally alternative assessment methods are very useful to prevent students from rote learning, such as problem dealing in class with real-world cases; encouraging open-ended class discussions, and fostering inquiry-oriented experiments that increase students' higher order thinking skills (Krajcik & Mamlok-Naaman, 2006). Therefore, the study is aimed at developing a teaching model with the focus of learning activities that engage students in the knowledge construction process. Through using science teacher's views, the result indicated that the HOT teaching model is a useful teaching method to be implemented in science class to improve students' reflective thinking and science process skills, as these two cognitive skills have positive impact on students' performance in science education.

Second, implication of the findings for curriculum development and teacher training. Curriculum designers could use the findings of this study to distinguish to what extent the new science curriculum has achieved its objectives so as to think about a serious solution to inculcating students' cognitive development capacity in science learning. Instructional designers could also use the findings of this study to distinguish to what extent the science teachers using the activities that encourage students to use their higher cognitive skills so as to think on a serious solution such as holding specialized courses for science teachers and encourage them to use the different teaching strategies, especially the cognitive strategies. Regarding teacher training, the HOT teaching model could be applicable in a professional development program for training new graduated teachers in teaching methods for science learning. The program addressed teachers who newly graduated from university; they have to take a specific course within 3 months. Therefore, as for inculcating students' cognitive development capacity in learning, it requires teacher specialized training or preparation to understand the concept of cognitive skill and be able to improve it. Thus, it is crucial to prepare teachers to use effective teaching models and classroom activities to create a supportive environment for improving learners' HOT skills that would help them to become critical thinkers and decision makers. Moreover, the model could be useful for curriculum development following the five main stages of the HOT teaching model (Engagement, Investigation, Explanation, Conclusion and Reflection) including various aspects of science education.

Third, policy makers should consider making the HOT teaching model within the methods of teaching science curriculum in colleges of education in the Iraqi Kurdistan region universities to train students on how to apply it in the teaching process. Based on the model policy makers could develop teachers' guide books through preparing appropriate lesson plans according to specific sub-stages of the model in order to fulfil the science learning objective so as to improve students' HOT in science learning. For example, based on the model finding for stage one the science teacher may start with offering problem (real-life problem) to create cognitive conflict while motivating students to engage in the task through asking critical questions and making comparison (activities in stage 1) before requesting students to formulate hypothesis (activities in stage 2) and performing the first trial to solve the problem, completing and adjusting the search steps. Therefore, the activities in stage 1 (asking question and making comparison) conducted earlier could facilitate the activities in stage 2 (formulating problem) which further allow students to recall the notions, operations and behaviours necessary to understand the new concept.

Moreover, the way the HOT teaching model is developed and evaluated can be used for developing teaching models for a specific area of science education as well as for other areas of education. Although the model is aimed at improving HOT among basic education students specifically in science education, this study might also contribute as an instructional design on developing teaching models for other areas of learning competence for another educational level.

### 7.7.2 Theoretical Implications of the Study

The model developed in this study aimed at enhancing students' higher order thinking in terms of enhancing their reflective thinking and science process skills. In guiding the process of developing the HOT teaching model, the theoretical framework of the study consisted of two parts. The first part deals with theoretical framework underlying the variable that contributes to the development of HOT in this study. Specifically, cognitive development theory (Bruner, 1956) is adopted in the study to describe the development of cognitive skills among basic education students through discovery learning. Moreover, Gagne theory for learning hierarchy is adopted to describe the process of solving a particular problem through using simple thinking skills gradually to more complex skills. The second part of the theoretical framework involved the adoption of cyclic learning model (CLM) from experiential learning theory and the IMSTRA (Immersion, Structuring, Application) model in framing the selection of elements of HOT teaching such as stages and sub-stages. Based on the framework, the selected stages describe the specific steps of conducting the HOT teaching model in science classrooms to describe how the science teacher could help students to use reflective thinking skills (RTS) and science process skills (SPS) so as to improve their higher cognitive skills in order to achieve their learning goals in science learning. The sub-stages describe the learning activities that involve both teacher and learner in the process of constructing the knowledge through discovery learning; thus, based on the preceding discussion, through the process of developing the HOT teaching model, the study implicated theoretically how both learning theories and models could be combined to develop an educational model.

### 7.7.3 The Developmental Research Approach (Methodology Implication)

This study contributes to the body of knowledge in research methodology, as the developmental research in this study involved three phases, namely, needs analysis phase, design and development phase and evaluation phase. This assisted the researcher in maintaining focus and allowed for reflections of the findings at each phase. The data collected at each phase contributed to developing a more effective teaching model. To elaborate, the study proposed the use of the Fuzzy Delphi Method (FDM) which is a powerful decision making approach in developing the HOT teaching model for this study. FDM is a popular decision making approach used in marketing, product development and other business and organization related fields. The use of FDM in educational field is a valuable tool. Moreover, few studies have been conducted on FDM in developing a specific product. Furthermore, the use of PLS approach in SEM as demonstrated in this study for evaluating the model is rarely used in educational research. The number of studies is further limited in using PLS in terms of using second order model with using both reflective and formative research approach as in this study.

However, despite the fact that the research methodologies used in this study are not new, the way these methods are integrated especially in using FDM for developing the model and PLS for evaluating it by using science teachers' opinions and views could serve as an example in using these methods for developing other educational models. The methodology used in this study through the process of developing the HOT teaching model could be replicated or adopted to develop models not only for other aspects in science education. The methodology could also be useful to develop other educational related models such as curriculum, and other areas of education.

## 7.8 Recommendations of the Study

Based on the study results, it is recommended that further attention be given to the context of programs that comprise higher order thinking to increase the level of acquisition of higher cognitive skills in science learning, especially through in service professional development programs for science teachers on how to use the science curriculum by giving students the opportunity to understand the scientific concepts and apply them to daily life situations. The convincing empirical evidence illustrated that if one persistently, meaningfully and purposely teaches for promoting students' higher order thinking, there are more opportunities for students to success. Therefore, this assumption should be made an essential component in the progression of changing teachers' beliefs and practices in this field.

The key significance of employing effective teaching model that target active participation of students is to generate individuals who would be more responsible and aware about their life as well as transfer the knowledge into real life situation. As an example, this study was conducted to describe how students' HOT could be improved by employing learning activities that encourage them to use reflective thinking skills and science process skills through discovery learning. This was proposed through developing the HOT teaching model for science learning. The model presented a practical guide on how to engage basic education students in the process of constructing knowledge through using various RTS and SPS. Although the model was developed for improving students'

HOTS in science learning, the methodology could be used to develop students HOTS in other area of learning disciplines for other types of learners.

## 7.9 Suggestions for Further Research

The final product of the study is the HOT teaching model for basic education students in science learning. Based on the model elements, it is recommended to develop science learning modules conducted on basic education students. This would further evaluate the model effectiveness in supporting learning process based on students' views. Besides, the model could be possibly further refined based on the findings of the evaluation through the modules. According to the concept of higher order thinking underlying this study that comprised reflective thinking skills and science process skills. Further research is suggested in developing more models for enhancing students' HOT skills including other variables such as critical and logical thinking.

Moreover, the findings of the study have provided evidence of the usability of the HOT teaching model using teacher opinions and views. Therefore, replication of the model using experimental design is required to further examine its effectiveness in enhancing students' HOT. Comparison studies between HOT teaching model and another teaching model such as IMSTRA model is also recommended, to further evaluate to what extent the HOT teaching model is effective to be implemented in teaching science.

## 7.10 Summary

This study yielded small body of results which will contribute to the research efforts of those who attempt to apply theories in educational psychology to classroom teaching and learning. It has been well verified that higher order thinking skills are essential for effective learning and form the central goal of science education. The present reformation in science education involves the shift from the traditional teaching methods for lower order thinking skills (LOTS) to higher order thinking skills (HOTS). Successful applications of the skills in the science classroom result in explanations, decisions, performances, and products that are valid within the context of available knowledge and experience and that promote continued growth in these and other intellectual skills. Yao (2012) asserted that one of the National Research Council's study (NRCS) recommendations on facilitating HOT among students is that teachers must create an environment where students feel comfortable sharing their ideas, inventions and personal meaning. More specifically, science teachers should use the teaching methods requiring active student participation, by engaging students in generating questions, representing their understanding, solving complex problems and reconstructing their own thinking. Therefore, the study aimed at developing a HOT teaching model for basic education students in science learning that would help them become decision makers capable of solving problems in daily life. This study is significant in integrating the notion of adopting effective teaching models for enhancing student higher order thinking skills in science. The generally positive responses of science teachers to the overall HOT teaching model indicate that it is important to provide science teachers with a practical guide on how to improve students' HOTS through using the learning activities that encourage their participation in the learning process.

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