The Effects of Teaching Physics Using the Systemic Cognitive Comprehensive Model (SCCM) in Developing Students' Scientific Thinking Skills

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Abstract

The aim of this study was to investigate the effects of teaching physics using the systemic cognitive comprehensive model (SCCM) on developing the scientific thinking skills of 11th graders, compared with the traditional method.

This model consists of three phases that address specific scientific reasoning skills, the phases are: cognitive, epistemological, and metacognitive phase. Many lessons that follow the SCCM model were developed for the "matter changes" unit included in the physics textbook for the 11th grade scientific stream pupils in Jordanian public schools. The sample of the study consisted of (120) subjects of a typical eleventh grade scientific stream pupil, with a mean age of 16 years, drawn randomly from two public schools in the city of Mafraq, one for boys, the other for girls. The results of the study indicated that the SCCM model of teaching is more effective than the traditional one in developing the scientific thinking skills of the study subjects.

Key Words: Scientific Thinking, Teaching Physics, Metacognitve, Epistemology, Systemic Model.[1]

Introduction:

Scientific thinking is an important consideration in modern education. All educators are interested in teaching scientific thinking to their students due to the fact that the ability to think scientifically is essential if individuals are to live, work, and function effectively in the current changing society (Trowbridge & Bybee, 1986; Kuhn, 1993; Yager, 2000a;).

Today's world is encountering an explosion of knowledge in which the prevailing outmoded educational systems are no longer adequate (Gallager, 2000; Yager, 2000a) because these systems are still employing the conventional teaching methods, which are unable to cope with the social and economic demands, the tremendous increases in populations, and the great expansion of science and technology.

Adult students will be living in a complex world where they have to solve problems in a scientific way. Both individual and collective actions will require effective selection, processing, and use of information (NSTA, 1982; Howe & Warren, 1989). Hence, students must make choices, assessments, and judgments everyday regarding definition of problems they are facing, stating hypotheses as possible solutions, and testing these hypotheses to select the best one.

Different curriculum guides contain goal and objective statements regarding the importance of scientific thinking skills. They call for increased emphasis on higher-order cognitive learning skills, including scientific reasoning skills (Yager, 2000a).

There is a wide gap between demonstrated achievements and expected goals. Schools need to review what they are doing, what they are

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achieving, and ways to improve student thinking abilities (Howe & Warren, 1989). It is evident that few students can solve real problems, quantitative and/or societal, in contexts where they are found in the real world (Piel, 1993; Yager, 2000 b).

According to related literature (Zohar et al., 1994), scientific knowledge is developed with the procedure of scientific inquiry. In order to think critically in scientific subjects, one has to be able to apply the methods by which scientific knowledge is obtained (Ergazaki et al., 2006).

The modern movement in instructional design development has produced a number of empirically validated models for improving the outcomes of learning in order to cope with requirements of today. One of these models is the Systemic Cognitive Comprehensive Model (SCCM) developed by Al-Qadere (2004). This model consists of three stages:

1- The Cognitive Phase: Instructional practices start with learning cognitive content by directing the student's attention to a related unfamiliar phenomenon or a strange idea or concept that might cover one or more of the following elements: Procedural knowledge, declarative knowledge, and conditional knowledge.
2- The Epistemic Phase: In this phase, the concept or idea is investigated through identification of the nature of the concept and the extent of it’s accuracy, validity, and consistency with logic and field evidence. These are considered the epistemological criteria used by the learners through the learning process.
3- The Metacognitive Phase: The instructional practices in this phase are designed to make the learners aware of their thinking processes related to the learning content, methods of constructing knowledge, and the extent of the accuracy of the field evidence with regard to the new learning content .This means that the phase tries to help learners be aware of their thinking processes used in the two previous phases.

The model can be represented by the figure (1):

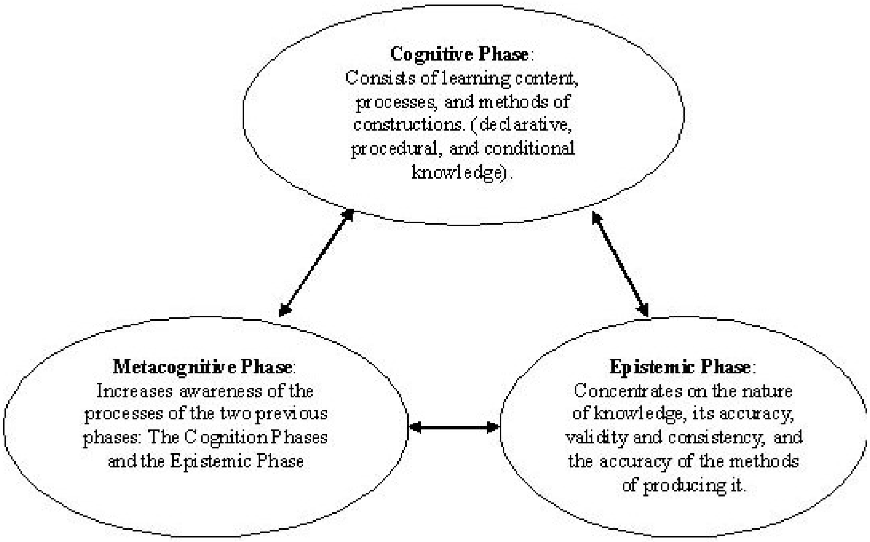


Figure (1)

Systemic of (SCCM) Model Phases

In the light of the model structure, it's obvious that SCCM model was designed to help teachers organize a classroom structure and activities that may be effective for teaching thinking skills more effectively. This is accomplished through emphasizing the correct way to understand and evaluate ("how to think") rather than the subject matter ("what to think"), that is widely prevalent in education.

In addition, the SCCM model concentrates on stimulating the students to think about the physics concept knowledge, the way of producing it, and to think about how to think about the concept knowledge, the ways of producing it, and its consistency with epistemological criteria like theoretical and empirical evidence, precision, accuracy and succinctness.

Since science represents an area to help students solve problems (Piel, 1993; Yager, 2000a), the unit on matter changes in physics was chosen to provide a context for developing scientific thinking skills as it includes many concepts that should be interconnected by the learner to create systemics and deal with scientific thinking skills.
The subject of "matter changes" that was to be taught in this study with the aim of developing scientific thinking includes mainly scientific procedures where skills of scientific method are applied. We considered the skill of hypothetical-deductive reasoning as a basic skill in scientific thinking. This skill is practiced in tasks concerning the following (Ergazaki, Dimitriadi, Dimitriadis, 2006):

· Defining problems
.Stating hypotheses to be tested
.Testing hypotheses
· Interpreting the results
· Drawing conclusions about the problems.

Statement of the Problem:

The purpose of this study was to investigate the SCCM model by comparing its effectiveness with that of the conventional model in developing scientific thinking skills in teaching physics. In addition, the effect of gender on scientific thinking skills was examined.

Questions of the Study:

In particular, the study tried to answer the following questions:

1- What is the effect of the SCCM model of teaching on developing the scientific thinking skills of the subjects of the study as compared to traditional teaching?

2- Is there any statistically significant impact on developing the scientific thinking level in general among the study sample due to the interaction between the model of teaching and gender?

3- Do the effects of the SCCM model of teaching differ according to the different fields (components) of the scientific thinking scale (defining problems, stating hypotheses, testing hypotheses, interpreting the results and drawing conclusions)?

Previous Studies:

The (SCCM) has been implemented in many studies; Aldahoon (2004) carried out a study aimed at investigating the effect of teaching science using the Systemic Cognitive Comprehensive Model (SCCM) in acquiring scientific concepts for 4^{th} graders compared with traditional method. A sample consisting of (160) students (male and female) of 4^{th} graders in Al-koura Educational Department was selected and assigned randomly into two groups: four classes represented the experimental group and were taught the (light) unit using (SCCM), while the other four classes represented the control group and were taught the same unit by using the traditional method. The findings of the study showed there were statistically significant differences due to the way of teaching in acquiring scientific concepts in favor of using (SCCM). Also, it indicated that the interaction between the methods of teaching and gender has statistically significant effect in acquiring scientific concepts in favor of the experimental females group.

Also, Olemat (2008) investigated the effect of teaching physics using the systemic cognitive comprehensive model (SCCM) on developing the metacognitive thinking skills and achieventmet in physics for a sample of (70) male students of 9th grader's assigned randomly into two groups: one represented experimental group and was taught the (temperature) unit using (SCCM), while the other represented the control group and was taught the same unit using traditional methods. The findings of the study showed that there were statistically significant differences in improving student's scientific achievement and on developing the metacognitive thinking skills in favor of teaching using (SCCM).

Although the previous studies have explored the effectiveness of teaching physics using (SCCM) model in enhancing students’ achievement(e.g., Aldahoon, 2004; Olemat ,2008) and their metacognitve thinking skills (e.g., Olemat ,2008) , there is still a dearth of research focusing on this topic with respect to scientific thinking skills. Accordingly, this study proposed to explore the effectiveness of teaching using (SCCM) model in improving students' scientific thinking skills in Jordan.

Significance of the Study:

While research on developing scientific thinking skills is prevalent in many developed countries, few studies have been conducted in Jordan and other Arab countries. Therefore, this study was designed to identify the effects of using the SCCM model on developing the scientific skills of a number of Jordanian students. The researchers hoped that such studies would bring about improvement in the methodology of developing scientific skills, especially in the field of physics concepts teaching. Also, the findings of the study would be helpful to teachers, researchers, and science educators.

Method and procedures:

Instructional Material:

The instructional unit designed for this study dealt with some concepts in physics. The organizational pattern of the unit differed from one group to another according to the two models under investigation. The instructional content was compiled by the researchers for the purpose of following a teaching sequence consistent with the nature of the subject matter and the type of teaching model. The instructional unit designed according to the SCCM model was submitted to five science educators for content validity. The instructional unit for the conventional teaching model was that of the textbook used in public schools in Jordan.

Instrumentation:

Scientific Thinking Skills Scale (STSS):

This scale was developed by Alqadere (2005). It consists of 32 multiple-choice items, each with three choices. Scientific thinking skills included: defining problems, stating hypotheses, testing hypotheses, interpreting the results and drawing conclusions. The scale was tested for validity and reliability. The corrected item total correlation coefficients for the subscalesvaried between(0.87)and (0.32), while their internal consistency coefficients varied between (0.89) and (0.83) (See Appendix-B).

Sample:

The sample of the study consisted of (120) subjects of a typical eleventh grade scientific stream pupil, with a mean age of 16 years, drawn randomly from two public schools in the city of Mafraq, one for boys, the other for girls. The class was considered as the unit of selection of the subjects. There were two sections for girls, and two sections for boys. Of the four sections, two classes, one from each school, were assigned randomly to the experimental group; and the two other classes, one from each school, were assigned to the control group. The socio-economic status (SES) of the study subjects was similar. The majority of subjects come from middle to upper class families. Table (1) shows the sample distribution:

Table(1)
Study Sample Distribution

GROUP	GENDER		Total
	Male	Female	
Experimental	30	30	60
Control	31	29	60
Total	61	59	120

Treatment:

In order to ensure the uniformity in teaching procedures, the present study employed the classes’ regular physics teachers**.** The male teacher has seven years experience in teaching physics, whereas the female teacher has six years experience. The experimental group was instructed using the SCCM model, in which learning is student-centered, whereas the control group was instructed using the traditional teacher-centered teaching (the ones the teachers usually used).

Before the study was conducted, the researchers met with each teacher in order to:

- Become acquainted with the participating physics teachers.

- Distribute teacher's guides and the unit of instruction.

- Review the prepared instruction

- Provide the teachers with the opportunity to ask questions concerning the SCCM model.

- Clarify any procedure associated with the instructional material or with the two methods of teaching.

Prior to treatment, the (STSS) scale was administered to all participating students in a 50 minute period. The SCCM model was used to create systemics that cover the concepts of physics considered. The systemic used learning environments that induced the development of reasoning skills. Many systemics were developed by subjects during activities to improve their awareness of scientific thinking skills. Subjects tested their thinking process by characterizing the different phases of inquiry (See Appendix).

The time devoted for the completion of the unit was sixteen sessions of instruction carried out during a four-week period for the two groups. The male teacher taught the male subjects and the female teacher taught the female subjects. The study took place during the second school term from April 15th to May 13th, 2006. Upon the completion of instruction, the STSS scale was administered to all participating students in a 50 minutes period. ANOVA and MANOVA analysis techniques were used to analyze the data of the study statistically.

Research Design:

In this study, pretest post-test control group design was used. The study involved one main independent variable: the type of instructional model with two levels (the conventional model, the SCCM Model) .The gender was considered as a classification variable. The dependent variable was the level of scientific thinking skills. The design was represented by symbols as follows:

1- Experimental Group (E G):

(Pretest - Teaching using (SCCM) Model - Post-test)

E G: (O1 - X - O2)

2- Control Group(C G):

(Pretest - Teaching using conventional method - Post-test)

C G: (O1 O2)

Where:
O1 refers to the pretest
O2 refers to post-test
X refers to manipulation

Findings of the Study:

Means and standard deviation of the gain (gain= posttest scores – pretest scores) for experimental and control groups on scientific thinking scale are reported in Table (2). A pretest post-test control group design utilizing the analysis of variance (ANOVA) was used for this study.

Table (2)
The Means and Standard Deviations of the Study Subjects Gain Scores on the Scientific Thinking Scale for Both Experimental and Control Group Level According to Their Gender(Male, Female)

GENDER	GROUP	Mean pretest	Std. Dev.	Mean Posttest	Std. Dev.	Mean (gain)	Std. Dev.	N
Male	Exp.	9.87	1.01	26.47	3.44	16.60	3.21	30
	control	8.10	2.06	19.00	4.55	10.90	3.99	31
	Total	8.97	1.85	22.67	5.50	13.70	4.60	61
Female	Exp.	9.40	1.00	25.07	3.21	15.67	2.82	30
	control	8.17	1.07	17.89	3.74	9.72	3.40	29
	Total	8.79	1.20	21.54	4.99	12.75	4.31	59

Total	Exp.	9.63	1.03	25.77	3.37	16.14	3.03	60
	control	8.13	1.64	18.47	4.18	10.34	3.73	60
	Total	8.89	1.56	22.12	5.27	13.23	4.47	120

Table 2 shows that students of the experimental group obtained higher scores than their counterpart of the control group on the scientific thinking scale. Also it reveals that the males of the experimental group obtained higher scores on the scientific thinking skills than the females of the control group.

ANOVA analysis was performed to test whether the previous differences were statistically significant. Table (3) contains the summary of ANOVA comparing the mean scores of the student's performance both in the experimental and control groups with respect to the gain.

Table (3)

Summary of ANOVA Analysis of Variance (Gain)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
GROUP	1015.49	1	1015.49	88.54	0.001
GENDER	33.45	1	33.45	2.92	0.090
GENDER * GROUP	.45	1	0.45	.04	0.843

The analysis revealed a significant difference ($p<0.001$) between the experimental and the control groups with respect to students' development of scientific thinking skills in favor of the experimental group. This means that the (SCCM) model was significantly superior to the traditional model with regard to developing scientific thinking skills.

Also, the analysis revealed that there was no significant difference between male and female students in terms of achieving scientific thinking skills.

The interaction term of the ANOVA, which tests the combined effect of teaching model and gender on developing scientific thinking skills was not significant.

This result indicates that the (SCCM) model is appropriate for male as well as female students. It may be attributed to the fact that using (SCCM) model in teaching create rich learning environment that provides both male and female students similar opportunities to learn effectively.
With respect to the effect of the two models of teaching on the different scientific thinking subscales. Table (4) shows the means and standard deviations of the students' scores on the scientific thinking subscales:

Table (4)

The Means and Standard Deviations of the Students' Scores on the Scientific Thinking Subscale for both Experimental and Control Group Level (Gain)

SUBSCALE	GROUP	Mean	Std. Deviation	N
Defining problems	Experimental	5.63	1.53	60
	Control	3.07	2.60	60
Stating hypotheses	Experimental	4.63	1.02	60
	Control	3.13	1.64	60
Testing hypotheses	Experimental	3.50	1.35	60
	Control	2.40	1.26	60
Interpreting the results	Experimental	3.30	1.31	60
	Control	2.23	1.16	60
Drawing conclusions	Experimental	3.70	1.17	60
	Control	2.63	1.39	60

A MANOVA analysis was performed to test whether there were any significant differences on developing the different scientific thinking skills between students who were taught using conventional model and those who were taught the same unit using the (SCCM) model. The results of this analysis are shown in Table (5).

Table (5)

SUMMARY OF MANOVA ANALYSIS OF VARIANCE

Source	Dependent Variable(subscale)	Sum of Squares	d f	Mean Square	F[2]	Sig.
GROUP	Defining problems	197.63	1	197.63	43.37	0.000
	Stating hypotheses	67.50	1	67.50	36.06	0.000
	Testing hypotheses	36.30	1	36.30	21.27	0.000
	Interpreting the results	34.13	1	34.13	22.46	0.000
	Drawing conclusions	34.13	1	34.13	20.71	0.000

Wilks’ [3]value=0.511,

The results shown in table (5) refer to a statistical significant differences between the experimental and control group on the five scientific thinking subscales involved in the study, in favor of the experimental group. This means that the (SCCM) model is more effective than the traditional one on developing the different scientific thinking skills.

Discussion:

The results of the study showed the highly significant effect of instruction received by the experimental group on developing scientific thinking skills as compared to the instruction received by the control classes. In this model, students analyze their own thought process after completion of the activity. They are encouraged to reflect on their learning processes. The model helps students become aware of what they have learned, how

[2]The F-test is used to test for differences among sample variance. The F test statistic is found by dividing the between group variance by the within group variance..

[3] Wilks's lambda is a general test statistic used in multivariate tests of mean differences among more than two groups.

they learned through the epistemological phase, and how to verify their learning outcomes through the metacognitive phase. This effect is due to the fact that individuals will clear predetermined metacognitve goals and standards allowing them to effectively monitor and regulate their cognitive strategies. This help learners to define problems, state and test hypotheses, and interpret and draw useful generalizations.

This effect may be due to the epistemological phase of the SCCM model that concentrates on: How do we come to know what we know, what is knowledge, what is truth, and what is reality? (Hogan & Maglienti, 2001; Venville, Gribble & Donovan, 2005). These are important questions for learners who study knowledge, as well for those interested in developing scientific thinking skills. This model helps the learners actively construct knowledge in their attempts to make sense of their world and emphasize the development of meaning and understanding. Hence their different scientific thinking skills will be developed.

These findings are consistent with Olemat (2008) study results which indicated that teaching physics using (SCCM) improve thinking skills.

Furthermore, these findings are consistent with the majority of previous research on epistemology and learning findings revealed that epistemological beliefs correlate with academic outcomes such as integrated conceptual understanding, and ability to reason on applied tasks (Lising & Elby 2004).

Additional Notes:

During the treatment, it was noticed that the EG subjects became more active during the lessons activities than the CG subjects. This was clear through the level of their involvement in the lessons activities. Also, the inquiry of the EG students that focused on the learning contents evolved remarkably, as well as on the ways of producing it, it's accuracy, and consistency with the theoretical and practical evidence. This indicates an improvement in their abilities to define problems, stating possible solutions for problems they faced, taking into consideration the different aspects of problems, including the evidence that supports and the evidence that contradicts, weighing the effects of each one, and drawing conclusions. These results refer to the high potential of the SCCM model and reveal its effectiveness in improving the scientific thinking skills of male and female pupils.

Recommendations:

In light of the study results, the following recommendations could be suggested:

1-Further application of the SCCM model, employed in this research, should be carried out by schools, since the findings of this study exhibit encouraging results.

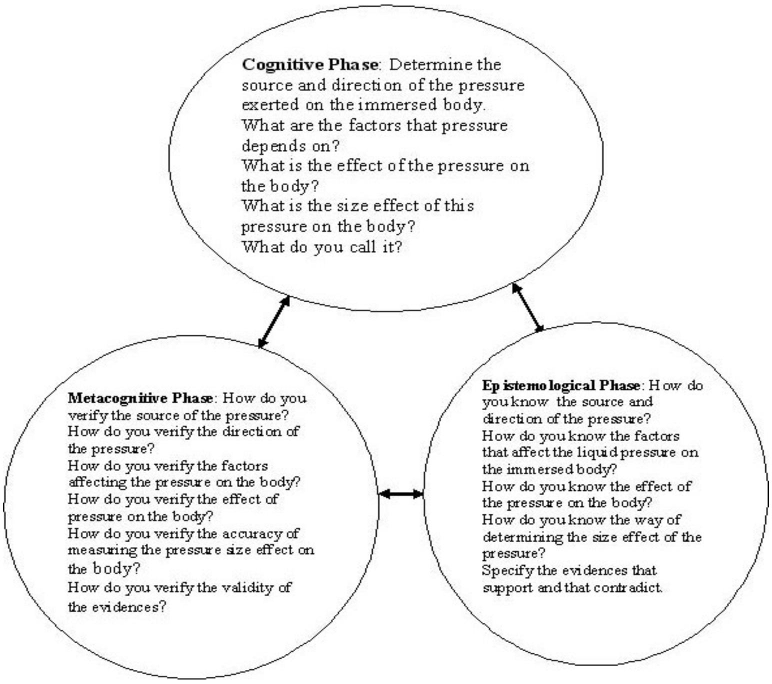
2- Further research should be conducted on additional samples from other content areas, to determine more clearly the effectiveness of the SCCM model in developing other types of thinking skills, like metacognitve, critical and innovative skills.

Appendix-A:

Teaching the Bulk Strain Concept Using the (SCCM):

Activity: If a heavy body is immersed in a liquid, then the liquid will exert a pressure on the surface of the boy, what is the bulk strain of the body?

According to the (SCCM) teaching method, each phase will contain many questions raised either by students or by the teacher (Facilitator) as in the following systemic:



Systemic of the Bulk Strain Concept Teaching Using the (SCCM)

Appendix-B:

Examples of translated items of STS (The initial version of the scale used in this study was Arabic version):

1. A building has fallen in one of the neighborhoods in a big city which causes panic for its residents and makes them leave it. This indicates that the **main** problem is :

A. What is the reason of the falling down?
B. What are the reasons of the residents panic?
C. How can we avoid the falling of the building in the neighborhoods?

2- A company has claimed that it produces a tooth paste that is capable of protecting teeth from cavities. It is possible to test the claim of the company by watching out the effect of the new paste for an enough period with:

A. A group of children chosen randomly.
B. A group of children whose teeth are cavity - free.
C. A group of children who have dental cavity.

3- A dentist used a tooth filling for one of his clients, and the client complained from the feeling of the pain of the tooth filling every time he has hot food. This can be explained with the following:

A. The client's teeth are damaged and cannot be treated.
B. Hot food causes pain in the filling.
C. The coefficient of expansion of the fillings is less than that of the tooth.

4- A building has fallen down in one of the neighborhoods in a big city. This indicates:

A. The necessity of not dealing with the company that built the building.
B. The land is not appropriate for the building.
C. The building was not built following correct scientific and structural bases.

5. One of the reports issued by the seismic observation center indicates the difficulty of predicting an earthquake in a definite area because there are no indicators about its occurrence. This report implies a generalization of:

A. Impossibility of an earthquake in that area.
B. Difficulty of predicting an earthquake within the available capacities.
C. **Possibility of predicating an earthquake if some indicators are available.**

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