5E Model in Science Classroom
A Shift towards Constructivism

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Abstract

Learning by doing is the essence of science and for science classroom, constructivism seems promising learning philosophy. Constructivism is the buzz word of learner-centred education, today we find textbooks structured on the philosophy of constructivism. Unfortunately, the type of pedagogical approach students facing in science classrooms is still old fashioned, behaviouristic one. Science teacher is an important person in structuring and guiding students' understanding of living in the changing world. They play the role of facilitator and help students to bridge between nature of science and inquiry practices. They also need to learn new ways of pedagogical sciences to promote scientific literacy based on inquiry-oriented classroom. For practising constructivist methods in science classrooms, there is need to restructure the curriculum of teacher education and to orient pre-service and in-service teachers towards using these constructivist strategies in classroom. In our country still prospective science teachers are practising their teaching based on contemporary teaching models of Herbart, Bloom indirectly emphasising behaviourism. These teachers use the oldest and the most traditional approach, deductive reasoning that focuses on the content of the science organised from general concepts to particular concepts, with less emphasis on the development of skills. Teachers need to change their lesson plan format from behaviourist to constructivist one. Several studies have shown that instructions based on 5E model has positive impact on academic achievement and attitude towards learning among students. In the light of these, in the present paper, the authors attempt to enlighten the 5E model based on constructivism and tries to comprehend its usage in our science classrooms for better understanding of scientific concepts.

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Introduction

Today school science curricula are commonly placed on a continuum from 'textbook-centred' to 'teacher-centred' and the textbook is the vehicle that drives the teaching. The present science textbooks are restructured on the guidelines of constructivism philosophy. Constructivist teaching offers a bold departure from traditional objectivist classroom strategies. The goal is to make the learner play an active role in assimilating knowledge onto his/her existing mental framework. The ability of students to apply their school-learned knowledge to the real world is valued over memorising bits and pieces of knowledge that may seem unrelated to them. The constructivist approach requires the teacher to relinquish his/her role as sole information-dispenser and instead, to continually analyse his/her curriculum planning and instructional methodologies. Clearly, the constructivist approach opens new avenues for learning as well as challenges for the teacher trying to implement it.

Research in science education indicates that an effective method of teaching includes the use of constructivist learning theory to promote student learning. Constructivist theory allows students to construct their own knowledge about a concept by integrating their prior knowledge views with new information that is being presented. Through this method of instruction, student learning is inquiry-based, as students are more actively engaged in doing science, they are more motivated to learn and they develop higher-order thinking skills. The main objective of this instructional application is to improve student knowledge outcomes through the creation of a more effective learning community which may more accurately reflect real-life employment settings. Student-based instructional models have been linked to greater learning gains (Blumberg, 2008), greater student autonomy (Bruton, 2005), and greater student opportunities for leadership (Gressick and Derry, 2008). The 5E Model/5E Learning Cycle is an inquiry approach originating with the Science Curriculum Improvement Study. Robert Karplus and his colleagues based the learning cycle format on Piaget's cognitive development principles. Students "learn through their own involvement and action…the goal is to allow students apply previous knowledge, develop interests, and initiate and maintain a curiosity toward the materials at hand" (Trowbridge and Bybee, 1990).

The findings of several studies suggest that the Biological Science Curriculum Study (BSCS) 5E Instructional Model is effective than alternative teaching methods in helping students reach important learning outcomes in science. For example, several comparative studies suggest that the BSCS 5E Instructional Model is more effective than alternative approaches at helping students master science subject matter (for example, Akar, 2005; Coulson, 2002). Coulson (2002) also explored how varying levels of fidelity to the BSCS 5E model affected student learning. Coulson found that students whose teachers taught with medium or high levels of fidelity to the BSCS 5E Instructional Model experienced learning gains that were nearly double when compared to students whose teachers did not use the model or used it with low levels of fidelity. However, some studies indicated that the BSCS 5E Instructional Model had a positive effect on scientific reasoning (Boddy, 2003) and on interest and attitudes toward science (Akar, 2005; Boddy, 2003; Tinnin, 2001). One study reported a decrease in understanding of the nature of science among middle school students who used field-test curriculum materials based on the BSCS 5E Instructional Model (Meichtry, 1991). Given the novel and unfinished nature of the field-test curriculum materials, these results should probably be considered in the light of Coulson's (2002) findings about the impact of fidelity of use on learning gains, described previously.

Marek, Eubanks and Gallaher (1990) examined the relationship that exits between high school science teachers' understanding of the Piagetian developmental model of intelligence, its inherent teaching procedure – the 5E Learning Cycle – and classroom teaching practices. The teachers who exhibited a sound understanding of the Piagetian model of intelligence and the learning cycle were able to successfully integrate their students' laboratory experiences with class discussions to construct science concepts. Caprio (1994) published a study that compared a class in which the traditional (lecture) methodology was used with 5E Learning Cycle method. The exam grades were much higher for the class that used constructivist methodology. In addition to the test scores, the experimental group had a high energy level and gave positive feedback on the course. It also enhances teachers' classroom behaviors. Bevenino, Dengel and Adams (1999) have explored 5E Learning Cycle approach and concluded that 5E Learning Cycle approach encourage students to develop their own frames of thought and it is effective in the classroom. Balci, and Tekkaya (2003) investigated the effects of the 5E Learning Cycle, conceptual change texts, and traditional instructions on 8th grade students' understanding of photosynthesis and respiration in plants. The results showed statistically significant difference between the experimental and control groups in the favour of experimental groups after treatment. However, no statistically significant difference between two experimental groups (5E versus conceptual change text instruction) was found. Castori, Davis; (2006) looked at the relationship between the use of teaching strategies consistent with the Constructivist Learning Model (CLM) in secondary science classrooms and the attitudes of students toward science and found a significant increase in positive student's attitudes toward science. Orgill and Thomas (2007) described the use of analogies for each of the steps of the 5E model. They argued analogies motivate and help students visualise abstract concepts by comparing a familiar concept or the analog with a new concept referred to as the target. Cardak, Dikmenli and Saritas (2008) studied about the Effect of 5E instructional model in student success in primary school 6th year circulatory system topic and a significant difference between post test score of control and experimental group has been found. Pirasa, Tirgil and Tekbiyik (2008) studied about the effect of learning environment with 5E Model and Dynamic Geometry Software Cabri on Learning Levels. It is concluded that, activities developed for Cabri as to 5E model, affect students' learning positively and improve their thinking abilities.

What is 5E Model?

In 1997 (BSCS) Biological Science Curriculum Study (Colorado), a team whose Principal Investigator is Roger Bybee, received a grant from IBM to conduct a design study that would produce specifications for a new science and health curriculum for elementary schools. Among the innovations that resulted from this design study was the BSCS 5E Instructional Model for constructivism, called the 'Five Es'. The BSCS model has five phases: engagement, exploration, explanation, elaboration, and evaluation. *Engagement*: The activities in this section captures the students' attention, stimulates their thinking, and helps them access prior knowledge. *Exploration*: Students are given time to think, plan, investigate, and organise collected information. Explanation: Students are now involved in an analysis of their explorations. Their understanding is clarified and modified because of reflective activities. *Elaboration*: This section gives students the opportunity to expand and solidify their understanding of the concept and/or apply it to a real world situation. *Evaluation*: Evaluation occurs throughout the lesson. The teacher should observe students' knowledge and skills along with their application of new concepts and a change in thinking. Designed primarily by science educators for secondary science teaching, the 5E model has a classic constructivist structure.

In 5E Model initial phase is designed to engage the learner's prior knowledge and final phase, to evaluate the student's understanding. 5E Instructional Model, or the 5Es, consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills (see Figure 1).

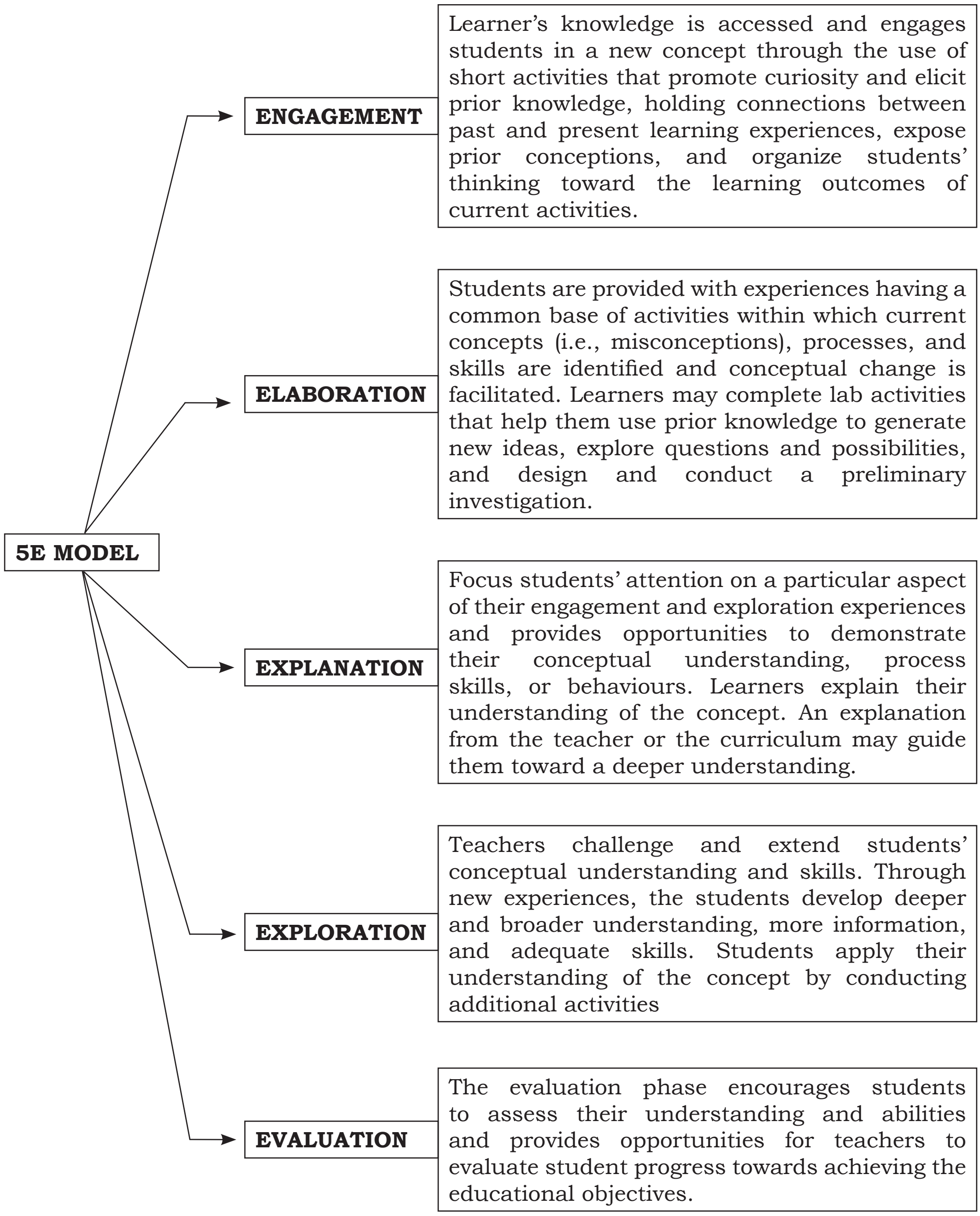

Figure 1: *Outline of BSCS 5E Model (Source: Bybee et, al. 2006)*

The model use the work of Jean Piaget (Piaget and Inhelder, 1969; Piaget, 1975) and subsequent research consistent with the Piagetian theory, specifically the focus of cognitive sciences and the work on misconceptions, the difference between novice and expert explanations of phenomena, and naive versus canonical theories.

Briefly, the theory underlying BSCS 5Es views learning as dynamic and interactive. Individuals redefine, reorganise elaborate, and change their initial concepts through interaction with their environment, other individuals, or both. The learner 'interprets' objects and phenomena and internalises the interpretation in terms of the current experience encountered. To change and improve conceptions, it is necessary to challenge the students' current conceptions and showing them to be incomplete or inadequate. If a current conception is challenged, there must be opportunity, in the form of time and experiences, to develop a more accurate conception. In sum, the students' construction of knowledge can be assisted by using sequences of lessons designed to challenge current conceptions and provide time and opportunities for reconstruction to occur.

In summary, the BSCS 5E Instructional Model, is grounded in sound educational theory, has a growing base of research to support its effectiveness, and has had a significant impact on science education. While encouraging, these conclusions indicate that it is important to conduct research on the effectiveness of the model, including when and how it is used, and continue to refine the model based on direct research and related research on learning. To ensure that the materials have the greatest chance of being implemented in the way they were intended and to honour the integrity of the 5Es, BSCS developed two charts that explicitly show the salient characteristics of each stage of the 5Es (see Tables 1 and 2).

Table 1
The BSCS 5E Instructional Model: What the Student Does
(Source: Bybee *et al.* 2006)

Stage of the Instructional Model	*The BSCS 5E Instructional Model: What the Student Does*	
	That Is Consistent with This Model	*That Is Inconsistent with This Model*
Engagement	• Asks questions such as, "Why did this happen?" "What do I already know about this?" "What can I find out about this?" • Shows interest in the topic	• Asks for the "right" answer • Offers the "right" answer • Seeks one solution

Exploration	• Thinks freely, within the limits of the activity • Tests predictions and hypotheses • Forms new predictions and hypotheses • Tries alternatives and discusses them with others • Suspends judgment • Records observations and ideas • Asks related questions	• Lets others do the thinking and exploring (passive involvement) • "Plays around" indiscriminately with no goal in mind • Stops with one solution
Explanation	• Explains possible solutions or answers to others • Listens critically to others' explanations • Questions others' explanations • Listens to and tries to comprehend explanations that the teacher offers • Refers to previous activities • Uses recorded observations in explanations • Assesses own understanding	• Proposes explanations from 'thin air' with no relationship to previous experiences • Brings up irrelevant experiences and examples • Accepts explanations without justification • Does not attend to other plausible explanations
Elaboration	• Applies new labels, definitions, explanations, and skills in new but similar situations • Uses previous information to ask questions, propose solutions, make decisions, and design experiments • Draws reasonable conclusions from evidence • Records observations and explanations • Checks for understanding among peers	• Plays around with no goal in mind • Ignores previous information or evidence • Draws conclusions from thin air • In discussion, uses only those labels that the teacher provided
Evaluation	• Answers open-ended questions by using observations, evidence, and previously accepted explanations • Demonstrates an understanding or knowledge of the concept or skill • Evaluates his or her own progress and knowledge	• Draws conclusions, not using evidence or previously accepted explanations • Offers only yes-or-no answers and memorised definitions or explanations as answers • Fails to express satisfactory explanations in his or her own words

Table 2.
The BSCS 5E Instructional Model: What the Teacher Does
(Source: Bybee *et al.* 2006)

Stage of the Instructional Model	*The BSCS 5E Instructional Model: What the Teacher Does*	
	That Is Consistent with This Model	*That Is Inconsistent with This Model*
Engagement	• Creates interest • Generates curiosity • Raises questions • Elicits responses that uncover what the students know or think about the concept or topic	• Explains concepts • Provides definitions and answers • States conclusions • Provides closure • Lectures
Exploration	• Encourages the students to work together without direct instruction from the teacher • Observes and listens to the students as they interact • Asks probing questions to redirect the students' investigations when necessary • Provides time for the students to puzzle through problems • Acts as a consultant for students • Creates a 'need to know' setting	• Provides answers • Tells or explains how to work through the problem • Provides closure • Directly tells the students that they are wrong • Gives information or facts that solve the problem • Leads the students step by step to a solution
Explanation	• Encourages the students to explain concepts and definitions in their own words • Asks for justification (evidence) and clarification from students • Formally clarifies definitions, explanations, and new labels when needed • Uses students' previous experiences as the basis for explaining concepts • Assesses students' growing understanding	• Accepts explanations that have no justification • Neglects to solicit the students' explanations • Introduces unrelated concepts or skills

Elaboration	• Expects the students to use formal labels, definitions and explanations provided previously • Encourages the students to apply or extend the concepts and skills in new situations • Reminds the students of alternate explanations • Refers the students to existing data and evidence and asks, "What do you already know?" "Why do you think …?"	• Provides definitive answers • Directly tells the students that they are wrong • Lectures • Leads students step by step to a solution • Explains
Evaluation	• Observes the students as they apply new concepts and skills • Assesses students' knowledge and skills • Looks for evidence that the students have changed their thinking or behaviours • Allows students to assess their own learning and group-process skills • Asks open-ended questions such as, "Why do you think …?" "What evidence do you have?" "What do you know about x?" "How would you explain x?"	• Draws conclusions, not using evidence Tests vocabulary words, terms, and isolated facts • Introduces new ideas or concepts • Creates ambiguity • Promotes open-ended discussion unrelated words

How to Prepare a Lesson based on 5E Model

In order to use the model in science classroom the teacher need to prepare a lesson plan based on it. For this, following things need to be kept in mind for planning activities at each phase.

Engagement

- Describe how the teacher will capture students' interest.
- What kind of questions should the students ask themselves after the engagement?

Exploration

- Describe what hands-on/minds-on activities students will be doing.
- List 'big idea' conceptual questions the teacher will use to encourage and/or focus students' exploration.

Explanation

- Student explanations should precede introduction of terms or explanations by the teacher. What questions or techniques will the teacher use to help students connect their exploration to the concept under examination?

- List higher order thinking questions which teachers will use to solicit *student* explanations and help them to justify their explanations.

Elaboration

- Describe how students will develop a more sophisticated understanding of the concept.
- What vocabulary will be introduced and how will it connect to students' observations?
- How is this knowledge applied in our daily lives?

Evaluation

- How will students demonstrate that they have achieved the lesson objective?
- This should be embedded throughout the lesson as well as at the end of the lesson.

Conclusion

The BSCS 5E Instructional Model is grounded in sound educational theory, has a growing base of research to support its effectiveness, and has had a significant impact on science education. Although encouraging, these conclusions indicate the need to conduct research on the effectiveness of the model, including when and how it is used, and continue to refine the model based on direct research and related research on learning. The research base around the BSCS 5E Instructional Model should be elaborated on through additional studies that compare its effect on mastery of subject matter, scientific reasoning, and interest and attitudes with other modes of instruction. The five phases of the BSCS 5E Instructional Model are designed to facilitate the process of conceptual change. The use of this model brings coherence to different teaching strategies, provides connections among educational activities, and helps science teachers make decisions about interactions with students.

There is need to introduce the concept of this model and other constructivist strategies in teacher education curriculum so that we can produce competent constructivist teachers to meet the challenging demands of present day.

Example: (Classroom Process Plan Based on 5E Model)
Topic - Diffusion (Grade IX)

ENGAGE
In this phase the teacher will ask some thought-provoking questions in order to capture students' interest and to increase their level of curiosity towards the topic.

1. Placing three balls in triangular pattern the teacher will ask- What do you find in between these balls?
2. Placing a chalk piece in the spaces between balls the teacher will ask – where is this chalk piece placed?
3. How salt gets dissolved in water?
4. What do we call a phenomenon where particles of two matters mix with each other?
5. Among solid and liquid states which state has larger spaces among particles?

6. Among solid and liquid states which has higher rate of diffusion?
7. What is the relation between temperature and rate of diffusion?

Do we have to search answers to these questions?

EXPLORATION

In this phase students will perform some activities and try to find out the answers of questions asked in the previous phase. Students will be divided into four groups and each group has to go to a workstation which is preplanned. At each workstation students will find a format of activity to be performed and its required materials. Students will perform that activity and try to find out different scientific facts involved in the activity. After working on a workstation each group will interchange their workstation.

Workstation I

Materials Required

Chalk, scale, few students, etc.

Format of Activity

a. Make three squares of one metre square on the floor.
b. Ask six students to stand in the first square holding their hands. Make sure no student comes out of the boundaries.
c. Similarly ask four students to stand inside the second square and two students inside the third square.
d. Ask students of all squares to move in their square without crossing the boundaries.
e. Write down whatever you have observed.

Workstation II

Materials Required

Chalk, scale, four caps tagged salt, eight caps tagged water, twelve students etc.

Format of Activity

a. Make one square of 4 m^2 on floor.
b. Ask eight students to stand inside the square after wearing caps tagged water.
c. Now ask four students to put on caps tagged salt and ask them to go inside the square.
d. Observe carefully and note down the conclusions.

Workstation III

Materials Required

Scentsticks, match box etc.

Format of Activity

a. Place scent stick in the corner of the classroom.
b. Ask a student to smell its fragrance.
c. Now with a matchstick light it up and ask students to smell its fragrance.
d. Observe carefully and pen down the conclusions.

Workstation IV

Materials Required

A glass of warm water, a glass of cold water, crystals of potassium permanganate.

Format of Activity

a. Put a crystal of potassium permanganate in both glasses of warm water and cold water. Do not disturb the glass.

b. Let the crystal settle on the bottom of the glass.
c. Observe carefully and pen down the conclusions.

EXPLANATION

In this phase, students, on the basis of observation, will try to explain different concepts under consideration.

a. Each group will discuss their results.
b. After this students will watch a power point presentation based on diffusion so that they can relate their experience with the scientific concepts.
c. After watching presentations students will again discuss about their findings.

ELABORATION

In this phase students will have in depth knowledge about the concepts and use scientific dictionary to explain.

In this phase students will be divided in to two groups. Each group will be given a pre-planned topic. The students will have to derive conclusions on the topics after inter and intra-group discussions.

Topic – 1

You can inhale the smell of hot meal from a considerable distance while to inhale the smell of cold meal we have to go nearer. Why?

Topic – 1

How does the whole water in a glass turns colourful when we drop a single drop of colour in that?

EVALUATION

In this phase, the students will demonstrate that they have well acquired the objectives of the lesson by answering the questions and the teacher will also make sure of the same.

1. Explain the process of diffusion with a live example?
2. Why the rate of diffusion increases with temperature? Discuss the topic in the classroom and present the conclusions.

How aquatic animals get oxygen in water for respiration?

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