CHAPTER 2 DEVELOPMENT OF A SCIENCE TEACHING COMPETENCE MODEL AND E-CONTENT

The principal goal of education is to create men who are capable of doing new things, not simply of repeating what other generations have done.

Jean Piaget

2.1 Rationale for developing the e-content

Though the importance of science is realized, the method of teaching of science is rather crude in most of the schools in India (Ramganesh, 2003). The student-teachers in the rural areas generally do not get an opportunity to think independently and conceptualize the spirit of the subject while practice their teaching due to the lack of innovative methods in the classes. In fact the present state of teaching science in the majority of educational institutions at all levels needs a lot of overhauling. Hence, paramount importance must be given to the fact that the teachers of science should be trained and oriented with constructivist learning environment which consists of problem description and their multi-modal representation as the focus of learning, and the following interdependent components which assist student-teachers to understand and manipulate the difficult concepts in science: a collection of authentic information resources, related cases, cognitive tools to support knowledge construction and technology. e-Content learning encourages open-minded, reflective, critical and active learning. With e-content materials, the student-teacher, the future teacher will understand that he or she is changing from a provider of facts to the one who facilitates a learning environment. It is in this assumption that this investigation attempts to devise an innovative teaching technique through e-content approach with Metacognitive Instructional design for the empowerment of Science Teaching Competence of student-teachers in the colleges of Education in the rural areas.
2.2 Stages of the e-Content
The following are the different steps to be adopted for the development of an e-content:

Selection of the topic

Selection of the topic for the development of e-content has its own significance in any subject in general and science in particular. As far as science subject is concerned, unless a teacher provides opportunity for a student to visualize certain topics in science, the student finds very difficult to master the ideas behind those contents. Science involves explaining abstract concepts and call for visualization of microscopic objects / organisms or gigantic processes like cell division, osmosis, pollination etc. These challenges are met effectively by using graphics, animations and simulations on computers. Hence use of technology in classroom increases productivity so as to facilitate instructional process. In deed technology is used to provide opportunities for students to apply knowledge in real world contents and engage in active participation, exploration and research.

Thus selection of the topic is to be done by keeping the following in your mind:

♦ The topic should be relevant to the audience and it should confirm to the curriculum

♦ It must pave the way to provide multi sensory experience to the students.

♦ Ensure whether the student finds difficulty in understanding and mastering the content.

♦ Ensure the topic is difficult to be explained through chalk and talk method.

♦ Ensure the topic which may require virtual reality

♦ Ensure things pertaining to the content are to be witnessed by the students by not allowing them to assume.

♦ The topic must evoke interest in the learners
In the present study, the investigator besides keeping the above mentioned
guidelines in her mind, she interviewed the experienced teachers of Botany from
select higher secondary schools in the rural areas around Tiruchirappalli about the
selection of topics in botany. Based on their opinion and using her expertise as a
teacher of botany, the topics such as Pollination, Osmosis and Cell division have
been identified for the e-content development. In fact, these topics are hard for a
teacher to make the students master them by chalk & talk method.

**Defining the entry behaviour**

You as a teacher are expected to ascertain your knowledge and skills of ICT
for the development of e-content. It is imperative that you must be equipped with
ICT knowledge and skills. The investigator in the present investigation oriented
the sample of experimental groups on the knowledge and skills of ICT required to
work with the e-learning modules.

**Task analysis**

Task knowledge refers to the individual’s ability to recognize the existence
of many different types of tasks. Understanding the different types of tasks require
different strategies. Knowledge about when and why a specific task requires the
use of a given cognitive strategy is reflective of sophisticated task knowledge
(Pintrich, 2002). The different levels of understanding among the student
population have been duly taken into consideration while developing the e-
content. Every minor step required for easy understanding of the subject is to be
included in the content so as to make even the low achievers attain mastery.
Indeed the topics such as pollination, osmosis and cell division are important and
can be made easy for students by an appropriate instructional design. Attempt has
been taken in the present study to make student-teachers get exposed to a
Metacognitive Instructional design and e-content development for teaching these
topics to their target group.
Script writing and Story board

Script writing is the initial step for the development of e-content. Script should be written in keeping all types of learners in the mind. Relevant information pertaining to the topic should be added. Long sentences should be divided into small chunks. Based on the opinion of the subject experts rewording and rephrasing should be done. From the studies reviewed so far, it is a pioneering effort by the investigator in writing scripts for the development of e-learning modules using the Metacognitive Instructional design as given below.

Figure 2.F.1 Metacognitive Instructional design

![Metacognitive Instructional design](image)

Figure 2.F.1 is a unique design developed by the investigator after careful observation and analysis of different studies reviewed. The observation and analysis of studies reviewed are tabulated as follows:
<table>
<thead>
<tr>
<th>S.NO</th>
<th>Author</th>
<th>Components</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Weinstein and Meyer (1991)</td>
<td><strong>Goal</strong> Goal</td>
<td>Metacognitive control for a learner to achieve specific learning goals and the degree to which the learner organizes, monitors, and modifies those operations to ensure that learning is effective.</td>
</tr>
<tr>
<td></td>
<td>Ertmer &amp; Newby (1996)</td>
<td>Self regulation, self efficacy and Metacognition.</td>
<td>Self regulation and Self efficacy are precursors to achievement goals. Achievement goal orientation is used as an outcome variable of self regulation, self efficacy and Metacognition.</td>
</tr>
<tr>
<td></td>
<td>Schunk, 2001</td>
<td>Goal setting, planning, monitoring &amp; regulating</td>
<td>Self-representation is an integral part of directive-executive function of the human mind. That is, the very process of setting goals, planning his/her attainment, monitoring action goals and the plans, and regulating real or mental action requires a system that can remember and review and therefore know itself.</td>
</tr>
<tr>
<td></td>
<td>Demetriou and Panaoura 2006</td>
<td><strong>Goal</strong> Setting, planning, monitoring &amp; regulating</td>
<td>Self-representation is an integral part of directive-executive function of the human mind. That is, the very process of setting goals, planning his/her attainment, monitoring action goals and the plans, and regulating real or mental action requires a system that can remember and review and therefore know itself.</td>
</tr>
</tbody>
</table>
2. Gagne, 1962 | **Objectives**<br>What is to be achieved? | Need analysis helps to identify the objectives of instruction which will help the trainees achieve the overall purpose.

| Yager (1993) | Instructional skills and competence | Science teacher education programmes should be "based upon objectives, generally expressed in performance terms that delineate a variety of instructional skills and competence."

| 3. Kuhn 1999, 2000 | **Metacognitive Knowledge**<br>Knowledge about one’s skills and intellectual resources.<br>Aptitudes of the learner | Trace the development of Metacognitive thinking that is the ability to reflect on one’s cognitive process. Metacognitive knowing operates on one’s base of declarative knowledge what do I know & how do I know it?

| Thomas and McRobbie 2001 | Knowledge, control and awareness | In science education literature metacognition is a knowledge, control and awareness of learning processes.


<p>| Coburn (2000) | New knowledge based on prior understanding | Constructivism, which maintains that new knowledge, is built upon a learner’s prior understanding, including beliefs and knowledge about science. |</p>
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Metacognitive Functioning</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternberg, (1998)</td>
<td>Metacognitive functioning</td>
<td>Teachers who are aware of their own metacognitive functioning tend to play a more significant role in helping learners develop skills in metacognition.</td>
</tr>
<tr>
<td>Winograd 1990</td>
<td>Regulating one’s knowledge, process, cognitive and affective states</td>
<td>Self-appraisal- peoples personal reflection about their knowledge states, abilities and their affective states concerning their knowledge. Self-management mental process that help to orchestrate aspect of problem solving, regulate one’s knowledge, process, cognitive and affective states.</td>
</tr>
<tr>
<td>McRobbie 2001</td>
<td>Knowledge, control and awareness of learning processes.</td>
<td>In science education literature where metacognition has been defined as knowledge, control and awareness of learning processes.</td>
</tr>
<tr>
<td>Anderson &amp; Schumm 2000</td>
<td>Procedural skill</td>
<td>It is essential to understand prerequisite knowledge that is required for competence in a new domain. The use of examples is a primary mechanism for learners to acquire procedural skill.</td>
</tr>
<tr>
<td>Merrill 1991</td>
<td><strong>Task variable &amp; Time management</strong></td>
<td>Learning should be situated in realistic settings; testing should be integrated with the task and not a separate activity.</td>
</tr>
<tr>
<td>Reference</td>
<td>Strategies for accessing existing information and seeking new knowledge</td>
<td>Presents the concept of an executive function that allows the individual to access knowledge structures in a variety of ways. These strategies for accessing existing information and seeking new knowledge allow for a more effective use of stored knowledge structures.</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Schank et al. (1999)</td>
<td>Goal setting</td>
<td>Learning goals are the skills sets or knowledge that the learner needs to develop in order to be able to perform a role or task.</td>
</tr>
<tr>
<td>Zimmerman et al. 1999</td>
<td>Attention, planning, memory retrieval and detection of performance errors.</td>
<td>Metacognitive activities involve attention activation, checking planning, memory retrieval and detection of performance errors.</td>
</tr>
<tr>
<td>Park et al. 2003</td>
<td>Cognitive strategies</td>
<td>Knowing where and when particular cognitive strategies should be used.</td>
</tr>
<tr>
<td>Schunk &amp; Zimmerman, 2008</td>
<td>Activate, guide, enhance, and sustain learning</td>
<td>Processes students use to activate, guide, enhance, and sustain learning overtime.</td>
</tr>
<tr>
<td>5. Tsui, 2003</td>
<td><strong>Resources</strong>&lt;br&gt;Access to content and Tools</td>
<td>Critical thinking requires teachers to engage students, to ‘assess and scrutinize ‘knowledge’ prior to its consumption.</td>
</tr>
<tr>
<td>6. Yager (1993)</td>
<td><strong>Instructional skill</strong>&lt;br&gt;Planning&lt;br&gt;Self monitoring&lt;br&gt;Organizing</td>
<td>Science teacher education programmes should be based upon objectives, generally expressed in performance terms that delineate a variety of instructional skills and competence.</td>
</tr>
<tr>
<td>Authors / Year</td>
<td>Topic / Description</td>
<td>Summary</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Miyoung Lee and Amy L Baylor (2006)</td>
<td>Cognitive and Metacognitive activities</td>
<td>Ultimate goal of the tool is to support learners Metacognitive activities to facilitate their orientation within web based learning environment with Metacognitive map learners are expected to perform both cognitive Metacognitive activities effectively and efficiently.</td>
</tr>
<tr>
<td>Donovan, Bransford, Pellegrino, 1999</td>
<td>Organizing instructions</td>
<td>Teachers need to be able to make sense of experiences in the classroom and to organize their instructional actions within a coherent framework of teaching &amp; learning.</td>
</tr>
<tr>
<td>Topcu and Ubuz (2008)</td>
<td>Self-awareness, self-control, and self-monitoring</td>
<td>Students to produce efficient participation and deeper levels of thought in discussions, metacognitive strategies that regulate self-awareness, self-control, and self-monitoring are necessary.</td>
</tr>
<tr>
<td>Kramarski et al., 2002</td>
<td>Planning, monitoring, and evaluation</td>
<td>Planning, monitoring, and evaluation enhanced metacognitive knowledge and reflective thinking which enhanced the processes of solving real-life problems.</td>
</tr>
<tr>
<td>Authors</td>
<td>Topic</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Brown and Palincsar, 1989</td>
<td>Self-regulated learning.</td>
<td>Metacognitive scaffolding can be integrated in instructional design, curriculum design, computer based design, or web-based design to develop performance, reasoning, and metacognitive knowledge and facilitate self-regulated learning.</td>
</tr>
<tr>
<td>Carr. et al. 1998</td>
<td>Thinking about thinking</td>
<td>Focus on what the child is thinking Focus on how the child is thinking Focus on child’s thinking about own thinking.</td>
</tr>
<tr>
<td>Lin. 2002</td>
<td>Metacognitive assessment</td>
<td>Created an automatic assessment of metacognitive behavior in integrated learning environment.</td>
</tr>
<tr>
<td>Gregory Schraw 2003</td>
<td>Metacognitive awareness</td>
<td>Promoting Metacognitive awareness through inquiry skills.</td>
</tr>
<tr>
<td>Kramarski &amp; Mevarech, 2003</td>
<td>Self-awareness, self-evaluation and self-regulation</td>
<td>Metacognition and many of its dimensions such as self-representation, self-awareness, self-evaluation and self-regulation have been receiving increased attention in cognitive psychology. Knowledge of cognition is a pre requisite to regulation of cognition.</td>
</tr>
<tr>
<td>Schraw 2006</td>
<td>Setting goals, planning and monitoring</td>
<td>Self-representation is an integral part of directive-executive function of the human mind. That is, the very process of setting goals, planning his/her attainment, monitoring action goals and the plans, and regulating real or mental action requires a</td>
</tr>
<tr>
<td>Demetriou and Panaoura 2006</td>
<td>Monitoring, control &amp; regulation</td>
<td>Metacognition to be the active monitoring, conscious control, and regulation of learning processes.</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7. Gagne et al 1992</td>
<td><strong>Instructional method</strong></td>
<td>The instructional strategy is the ‘plan for assisting the learners with their study efforts for each performance objective.</td>
</tr>
<tr>
<td></td>
<td>Content planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategic planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Josefina Santana 2004</td>
<td>metacognitive strategies</td>
<td>Variety of types of learning strategies, the ones that help the students the most are the metacognitive strategies.</td>
</tr>
<tr>
<td>Bruner (1960)</td>
<td>Fill in the gaps.</td>
<td>Instruction should be designed to facilitate extrapolation and or fill in the gaps.</td>
</tr>
<tr>
<td>Donovan &amp; Bransford, 2005</td>
<td>Goal setting and monitoring</td>
<td>A metacognitive approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.</td>
</tr>
<tr>
<td>Kulik, 2002</td>
<td>Visualization</td>
<td>Simulations that allow students to visualize complex phenomena and/or provide opportunities for practice and experimentation have proven very effective in particular contexts.</td>
</tr>
</tbody>
</table>
| Selva Ranee Subramaniam 2009 | Higher-order thinking skills   | Use of computer-assisted Instruction is another intervention to be looked at in facilitating the teaching of thinking skills. One could expect teachers to face difficulties in employing specific techniques in the
<table>
<thead>
<tr>
<th>Bruner (1966)</th>
<th>New ideas from old knowledge</th>
<th>Learning is an active process in which, students construct new ideas or concepts based upon their current or past knowledge.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Kozma, Chin, Russel &amp; Marx (2000)</td>
<td><strong>Instructional technique</strong> Simulations</td>
<td>In science subjects simulations of processes and experiments allow students to explore concepts in new ways, enabling students to become self-directed learners.</td>
</tr>
<tr>
<td>Umadevi 2008</td>
<td>Inquiry used to process information</td>
<td>Biological science inquiry model useful in teaching students the skill of inquiry in order to process information.</td>
</tr>
<tr>
<td>Catherine McLoughlin Rowan Hollingworth 2001</td>
<td>Simulations</td>
<td>In many science subjects simulations of processes and experiments allow students to explore concepts in new ways, enabling students to become self-directed learners.</td>
</tr>
<tr>
<td>Hartman 2001</td>
<td>Graphic organizer</td>
<td>Graphic organizer techniques can help students analyze text and see how it is structured. Graphic Organizer help to understand concept map.</td>
</tr>
<tr>
<td>Atkinson, 2002</td>
<td>Animations</td>
<td>Pedagogical models with animated characters improve learning.</td>
</tr>
<tr>
<td>Selva Ranee Subramaniam 2009</td>
<td>Meaningful learning demonstration strategy</td>
<td>The priority of the teaching approaches used indicated the teachers’ “thinking about thinking” to ensure meaningful learning. The demonstration strategy as</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>the appropriate choice of teaching strategies and the rationale for adopting demonstration was to save time and to highlight aspects of the demonstration that required attention</td>
<td>Amutha &amp; Ramganesh (2010)</td>
<td>Different Strategies monitoring controlling</td>
</tr>
<tr>
<td>9. Gagne (1965,1977)</td>
<td><strong>Information processing</strong>&lt;br&gt;Advance organizer</td>
<td>Information-processing model of learning could be combined with behaviourist concepts to provide a more complete view of learning tasks.</td>
</tr>
<tr>
<td>Bruce Weil (1978)</td>
<td>Information processing&lt;br&gt;Organizing data generate concepts</td>
<td>Information processing is the way people handle stimuli from environment, organize data, sense problem, generate concepts and solutions to the problems and employ verbal and non verbal symbols.</td>
</tr>
<tr>
<td>King and Rosenshine (1993)</td>
<td>Connecting concepts</td>
<td>When students were metacognitively trained they could make connections between concepts in different areas.</td>
</tr>
<tr>
<td>Reference</td>
<td>Author(s)</td>
<td>Concept/Representation</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Blank (2000)</td>
<td></td>
<td>Connecting experiences</td>
</tr>
<tr>
<td>Harpaz, 2003 Ausubel 1968</td>
<td></td>
<td>Connecting concepts</td>
</tr>
<tr>
<td>10. Veenman et.al. (2006)</td>
<td></td>
<td>Appraisal of the students Assessment</td>
</tr>
<tr>
<td>11. Gagne, 1962</td>
<td></td>
<td>Reinforcement Strengthening with additional material</td>
</tr>
<tr>
<td>12. Bruner, 1973</td>
<td></td>
<td>Revision Gap analysis/ Performance gap</td>
</tr>
<tr>
<td>Weinstein &amp; Meyer, (1991)</td>
<td></td>
<td>Teaching competence</td>
</tr>
<tr>
<td>Trainin &amp; Swanson, 2005</td>
<td></td>
<td>Self-evaluation</td>
</tr>
<tr>
<td>Authors</td>
<td>Type</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Saravanakumar, Mohan 2007 Zimmermann, 1990</td>
<td>Academic goals</td>
<td>Self-regulated learners are distinguished by both awareness of the relationship between strategic regulatory processes and learning outcomes, and the use of these strategies to achieve academic goals.</td>
</tr>
<tr>
<td>Land &amp; Greene (2000)</td>
<td>Metacognitive Evaluation</td>
<td>Define Metacognition as the process of reflecting on, monitoring the effectiveness of the search process and then refining the process when necessary.</td>
</tr>
<tr>
<td>Schraw and Dennison (1994)</td>
<td>Planning, sequencing, self-monitoring and self-evaluating</td>
<td>Metacognitive scaffolding allows individuals to plan, sequence, monitor, and evaluate their learning in a way that directly improves performance.</td>
</tr>
<tr>
<td>Jacobs and Paris, (1987)</td>
<td>Thinking about thinking</td>
<td>Evaluation enhances students to reflect on their solutions or alternatives so as to direct their future steps.</td>
</tr>
<tr>
<td>Kramarski et al., 2002</td>
<td>Thinking about thinking</td>
<td>Planning, monitoring, and evaluation enhanced metacognitive knowledge and reflective thinking which enhanced the processes of solving real-life problems.</td>
</tr>
</tbody>
</table>
Script is to be converted to story board which is the working document for the development of the e-content. The story board gives outline of the material with three-columns. The first column ‘Content’ contains the subject matter of each and every shot of the presentation, the second column ‘Proposed visuals’ explains the type, time sequence and of the visuals on the screen and the third column ‘Audio-Visual Effects’ describes the appropriate Audio-Visual effects to the main video presentation. The following is the example for the story board of the present study.
**Collection and development of the resources**

On the basis of the story board, you are required to explore suitable resources pertaining to the content. You can either develop animation using the software Flash, Swift, Photoshop etc. or download videos or animations from Youtube, Metacafe, Teachertube etc. or download suitable images or text from search engines. You must be prepared with that before you go to next step. In the present study, the video shooting was done in the TOTE (Teacher oriented Televised Education) studio in the Department of Educational Technology, Bharathidasan university. Videos pertaining to the topics such as pollination, osmosis and cell division were downloaded from the websites such as Youtube, Metacafe, Teachertube etc. The images were downloaded from the search engines such as Google, e-tools, exquick etc.

**Sequencing and integrating**

The multimedia components like images, video clips, sounds and texts are sequenced in the story board and various sources for the requirements of the scripts are to be integrated in the proper place so that the information flows continuously and harmoniously that will also ensure effective learning and desired changes in the terminal behaviour. The multimedia components explored from various e-resources were sequenced and integrated with the consultation of experts in the field of Educational Technology and Botany.

**Video Shooting**

After sequencing and integrating, you, the teacher are expected to present the script on the basis of story board. Your presentation will be shot in the studio. The investigator took advantage of TOTE studio of the Department of Educational Technology, Bharathidasan university. As mentioned earlier, the entire scripts were videoed in the TOTE studio. The investigator rehearsed the storyboards in front of the experts for obtaining their opinion. Based on the opinion, gesture, pronunciation, intonation etc of the presenter, were modified.
Editing

The next step is editing. Editing of the video can be done using editing software such as Adobe Premier or Ulead. In the editing process you get an opportunity to delete the unwanted information in the video and sequence the desired multimedia components. Editing should be done carefully because it should not lose its continuity or clarity. The e-learning modules developed were shown to the experts of e-content development and prospective teacher-educators (M.Ed students). Their opinions were recorded by the investigators and taken cognizance during the reediting process of the modules.

Designing Template of the e-content

Now a template of the e-content has to be designed to have components on the basis of the objectives of the content. In that way the template of the e-content has been designed with objectives, Assessment, References, Modules, Pros and cons, Competencies, Development, Glossary, Storyboard, Evaluation, Metacognitive Instructional design and Script. The text embedded in HTML document and video as modules are now given hyperlink and posted in the template. It is to be noted that the modules hyperlinked in the template can be run and better viewed with Internet Explorer version 6 and above.

Tryout

The module of the e-content designed has to be tried before presenting it to the target group. During that time the teachers have an opportunity to review the whole thing. The teacher can modify the programme to suit the time frame and the audience. Tryout gives an opportunity to reedit and resequence the programme and to make last minute addition or deletion to improve the e-content.
2.3 Science Teaching Competence model

Introduction

According to J.P.Kieves the essential characteristic of a model is the proposed structure of the model which is used to investigate the interrelationship between the variables. Research in Education is concerned with the action of many factors, simultaneously or in the casual sequence in a problematic situation. Thus it is essential that research in the field of education should increasingly make use of models in the course of its inquiries. A useful model should fulfill the following requirements:

♦ A model should contain structural relationship rather than associative relationship.
♦ A model should lead to the prediction of consequences that can be verified by observation.
♦ The structure of a model will desirably recall something of the causal mechanisms which are involved in the subject matter being investigated. Thus the model may contribute not only to prediction but also to explanation.
♦ It should become an aid to the imagination in the formulation of new concepts and new relationship and thus be the extension of inquiry.

The purpose of building a model for teaching advanced hypotheses, is to enable the student-teachers to test verify the efficacy. The strength of certain types of models is that they lend themselves more to data collection and testing.

After having gone through the various steps and strategies suggested by various researchers incorporating the essential characteristics of the model on Science Teaching Competence was developed by the investigator. The investigator carefully identified and organized the following components of Science Teaching Competence that have contributed positively on teaching-learning variables such as Task analysis, Instructional objective, Evaluation and reflection for the development of the Science Teaching Competence model:
Amutha’s Model on Science Teaching Competence

**Input**
- Goal
- Objective
- Metacognitive knowledge
- Task Variable & Time Management
- Resources
- Instructional Skill
- Instructional Method
- Instructional Technique
- Information processing
- Appraisal of the Students
- Reinforcement
- Revision
- Metacognitive Evaluation

**Process**
- Need Assessment
- What is to be achieved?
- Procedural Knowledge about one’s skills
- Declarative Intellectual Resources
- Conditional Abilities of the learner
- Identification of tasks complexity
- Adjusting the Pace
- Balancing Intervening Variable
- Access to Content and tools
- Planning
- Self Monitoring
- Organizing
- Delivering
- Content Planning
- Strategic Planning
- Demonstration
- Graphic organizer
- Concept Mapping
- Inquiry
- Advance Organizer
- Assessment
- Strengthening with additional material
- Gap analysis/ Performance Gap
- Reflection-on-action:
  - Analysis of performance
Conceptual models provide a typical strategy to help students learn a concept, task, or process which is frequently used in mathematics and science (Hodgson, 1995; Mayer, 1989, respectively). Model-based learning makes three contributions to science education (Gilbert, 2000). First, the formation and evaluation of mental models is central to developing an understanding of a scientific discipline. Second, the development and experimental testing of models supports authentic science inquiry-based learning. Finally, scientific models are major outcomes and products of scientific inquiry, and understanding the nature of science requires an understanding of these models within a philosophical, scientific and historical context.

**Model generation**

A learner’s mental model is highly individualized and constantly changing as more input and learning take place. Lambert and Walker (1995) stated that a mental model is, “an individual’s existing understanding and interpretation of a given concept, which is formed and reformed on the basis of experiences, beliefs, values, socio-cultural histories, and prior perceptions. A mental model affects how one interprets new concepts and events.” Nersessian (2007) proposed that mental models are “organized units of mental representation of knowledge employed in various cognitive tasks including reasoning, problem solving, and discourse comprehension.” Donald Norman (1988) gave a current definition of mental models: “…the models people have of themselves, others, the environment, or things with which they interact. People form mental models through experience, training and instruction.” Norman also noted, “To gain control over a technical system humans try to build internal mental models of the things with which they are interacting. These models provide predictive and explanatory power for understanding.” Cognitive science researchers and scientists propose that the mind constructs mental models as a result of perception, imagination and knowledge, and the understanding of discourse. Mental models have become known as a
summation of all of a person's thoughts and understandings on a subject. More than just isolated bits of information, a mental model can become a system with which exploratory inputs can be fed and observed for its resultant behavior (Carroll & Olson, 1988.) Mental models are incomplete, unstable, easily confused, and based on superstition instead of scientific fact. Despite these limitations, mental models play a very important role in understanding human cognitive change. Learners construct new knowledge and modify existing knowledge as they experience situations, problems, circumstances, and other events in learning settings (Tzeng & Schwen, 2003). One way to measure this learning is to examine the mental models of learners since they can reflect the type and level of construction that has occurred. Although mental models are different for novices and experts, the models of both continue to change as more knowledge is gained. Authentic project-based learning environments have the potential to provide an environment that allows students to experience learning in situated contexts, and these experiences enrich and change their mental models.

Model Evolution is a teacher-student interaction process through which students restructure their initial ideas to produce successive intermediate models, until, hopefully, reaching the target model for the lesson. The Model Generation Mode is often triggered by the teacher making a request for an explanation of a target phenomenon. Assuming students have not already been given an explanation, they must invent an explanatory model that explains why the phenomenon occurred. Sometimes a student will volunteer an explanation before the teacher requests it. The teacher and the students provide evidence to support an initial hypothesis.

The value of models and modelling to traditional scientific research is well documented (Black 1962). Models are important in scientific research both in formulating hypotheses to be tested and in describing scientific phenomena
In the past decade the value of models and modelling to science education has been increasingly recognized among the science education reform movements (National Science Board Commission on Precollege Education in Mathematics 1983, Giere 1991, NRC 1996, AAAS 1993). At present, models and modeling are considered integral parts of scientific literacy (Gilbert and Boulter 1998, Gilbert, S. 1991, Gilbert, J. 1993, Linn and Muilenberg 1996, Perkins 1986). With the recognized importance of models in science education comes the need for a theory of model-based learning and teaching. However, there is, to date, no coherent theory that outlines the cognitive processes involved in model based learning, nor are there any coherent theories of how model-based teaching should be approached. With the directions of the reviews an initiative of exploration has been attempted by the present study to develop and generate a model on Science Teaching Competence which is assumed to empower the Science Teaching Competence of student-teachers through the e-learning modules with a Metacognitive Instructional design. The student-teacher is expected to develop the following professional competencies through this model in Science Teaching Competence:

Goal setting behaviour

As the goal setting is one of the components of the e-content, it will pave the way to help the user develop skills on how to spell out goals of the taught. It is an effective tool for making progress by ensuring that participants in a group with a common goal are clearly aware of what is expected from them if an objective is to be achieved.

Awareness of one’s own thinking process and teaching strategies

Metacognitive components are integrated in to the instructional design of e-content, the student-teacher will be trained to self-evaluate his/her own thinking process and teaching strategies.
Identification of task complexity

The task variable in the instructional design of e-content is set to enlighten the user to identify difficulty level of the task. More difficult goals require more cognitive strategies and well developed skills. The more difficult the tasks ahead, smaller is the group of people who possess the necessary skills and strategies. From an organizational perspective it is thereby more difficult to successfully attain more difficult goals since resources become more scarce.

Adjusting the pace of instructional process

Adjusting the pace is making everything we do fit into specific durations and schedules. Time management is a very important skill, which can often make or mar academic success. Time management is one of the three key categories of teaching skills that contribute to teachers' ability to organize, remember and apply their knowledge. In that way, time management is identified as the core component of instructional design of the e-content.

Planning, monitoring and evaluating the teaching-learning process

♦ Metacognition is the part of planning, monitoring and evaluating the learning process.
♦ Planning is mind mapping all the activities.
♦ Monitoring is Information processing and checking the path of process.
♦ Evaluation is measuring the learning outcome.
These are the chief thinking processes that could be developed by the user through the e-content.

Selection of appropriate instructional technique

This e-content deals with varieties of strategies which will help the student-teacher realize the importance of providing multi-sensory experience to his/her students. Design of a teaching process for acquisition, recording, organization,
retrieval, display, and dissemination of information and training aids and materials must suit the students’ needs.

**Designing formative assessment of students**

This e-content is designed with the appropriate formative assessment. Formative assessment is a self-reflective process that intends to promote student attainment. Cowie and Bell (1999) define it as the bidirectional process between teacher and student to enhance, recognize and respond to the learning. Black and Wiliam (1998) consider an assessment ‘formative’ when the feedback from learning activities is actually used to adapt the teaching to meet the learner's needs. Nicol and Macfarlane-Dick (2006) have re-interpreted research on formative assessment and feedback and have shown how these processes can help students take control of their own learning (self regulated learning).

**Understanding performance gap**

A student teacher can be trained to revise or monitor his/her teaching activities by the e-content where he/she can analyze the performance and overhaul the gap in understanding if any.

**Reflection -on –action**

Thinking about the service performed and how it impacted the community. Considering what worked well and what could be changed to make the project better. This e-content is carefully developed with a Metacognitive Instructional design which insists on the evaluation of action after the teaching is over. This competence is very important for identifying any gap in student-teacher understands which will ultimately fine tune his/her professional preparation.

Competence refers to appropriate prior knowledge, skills, attitudes and abilities in a given context that has just developed with time and need in order to effecti0vely and efficiently accomplishes a task and that has to be evaluated. In
other way, it is defined as appropriate prior knowledge, skills, attitudes, and abilities in a given context that adjust and develop with time and needs in order to effectively and efficiently accomplish a task and that is measured against a minimum standard.

To be competent teacher B.Ed trainees should use the knowledge along with the application in their teaching. There are five important competencies which are essentially required for an effective teacher Viz. Subject matter knowledge, Communication skill, Instructional practice, Evaluation and Problem solving. The development of a model on Science Teaching Competence is first of its kind because it teaches the student-teachers how to teach the concepts effectively by using Metacognitive Instructional design. This innovative model plays a pivotal role in teaching of science. The following example details how to write a script and storyboard for a topic of science for a student-teacher of science.

2.4 Script for teaching Pollination

Goal
To make the student teachers understand how to teach Pollination, the science of fruit formation through efficient means.
To help student teachers concretize the instructional design for pollination.

Objectives
After completion of this module the student-teacher of science will be able to:

♦ search and download the appropriate resources such as images, animation, text, video etc. pertinent to the process of pollination.
♦ learn to integrate the resources apparently in the design of instruction
♦ select suitable instructional methods to teach the different process of Pollination.
learn to use Metacognition in the teaching process of Pollination wherever necessary.

make student teachers to be confident in putting across the process of pollination.

make the student teachers visualize and internalize the factors involving in fertilization through pollination.

make the student teachers teach easily the different modes of pollination.

Dear student teachers now you are going to learn how to teach pollination. Here the teacher should help students connect the new information to what they already know.

**Metacognitive Declarative Knowledge**

To bring about the readiness of the students the following questions may be asked to elicit their response.

Do you know how organisms reproduce?

Do you know how organisms perpetuate?

You can also ask students to spell out all the parts of the flower.

After eliciting the response for the above mentioned question define the concept pollination as you go through now.

The process of transfer and deposition of pollen grains from the anther to the stigmatic surface of the flower is called pollination.

While defining the definition of pollination, give stress to certain terminologies such as pollen grain, anther and stigma.

Shall we now learn to teach the different types of pollination?

Self pollination:

It is the process of transfer of pollen grains from the anther to the stigma of either the same flower or another flower borne on the same plant.

Now the students will be able to visualize the process of self pollination.
Cross pollination:
It involves the transfer of pollen grains from flowers of one plant to the stigma of the flower of another plant. Don’t you feel students will be able to visualize it?
Now ask the students to differentiate self pollination and cross pollination.
Now make the students recall the definition of pollination.
To ascertain whether the students internalize the concept pollination, elicits response for the following question.
Why do the plants pollinate? (Procedural knowledge)

**Metacognitive task variable**
Ensure the students could spell out male and female reproductive organs of the flower.
Do all plants have male and female reproductive organs?
Do all the plants pollinate?

**Time management**
Content planning
Ensure whether you can teach the concept of pollination in 40 minutes.

**Resources**
When we make use of all the following resources students will be able to concretize the concept pollination.
Different types of flowers, images related to the types and modes of pollination.
Male and Female plant –Papaya

**Instructional skill**
You have to internalize whether you are going in a right way according to the time.
Keep monitoring yourself whether you are going in the right direction.
**Instructional methods**
Certain concept like pollination can be explained effectively with learning multimedia components. Shall we see how the pollination takes place through multimedia components?
Picture of L.S of flower, anther, stamen, style, stigma, and ovary should be shown. Try to help students to witness a magnified pollen grain so that they can see the size and shape of the pollen grain.

**Instructional Model for information processing**
You can also think of graphic organizer on pollination which will make students remember easily.

**Graphic organizer**

**Figure 2.F.3 Graphic organizer**

![Pollination Diagram]

Modes of pollination can be explained with the help of animation for better understanding as some of the modes cannot be seen through naked eye.

Anemophily (Wind)
It is a mode of pollination or transfer of pollen grains from anther to stigma through the wind. The flowers pollinated through the wind are called anemophilous.
The flowers have following adaptations in anemophilous pollination.
Flowers are small, colourless, odourless and nectorless, well exposed in the air, calyx and corolla are either absent or reduced.
Pollen grains are small, light, dry, dusty and winged.
Stigmas are large well exposed, hairy, shiny, sticky, feathery or branched.
Assess the students periodically by asking questions like this.
How do the pollen grains attach to the stigma in animophilous plants?
Now students will understand why anemophily is possible only in these type of plants.
Dear trainees educate the students that the above characteristics of the flowers will not help to attract insects for aiding entamophilic pollination.
Before the introduction of the next mode of pollination Hydrophily, help your students learn the meaning of hydro so that they cannot misunderstand.
Hydrophily occurs only in a few aquatic plants. There are two types. One is hydrophily and another is epiphily.
Hydrophilic pollination occurs below the surface of water and the pollen grains are water borne.
When does the hydrophilic pollination take place?
In Ceratophyllum the male flowers bear 32 – 45 stamens. The mature anther breaks at the base and rise to the surface of water and dehisce there. The liberated pollens germinate and sink in water, while sinking they come in contact with stigma of female flowers to effect pollination.
In Zostera marina pollen grains elongated like a needle without exine. They float below the surface of water. When they reach the stigma they coil around it and germinate. Since both the modes are alike to avoid confusion between hydrophily and epiphily differentiate these two.
Before Entomophily is discussed ascertain the knowledge of students by asking the following questions.
Do you have garden at home?
Have you watched any insects in the garden?
Entomophily
Now all the insects should be witnessed by the students so that they can remember entomophily easily.
It is a type of pollination mediated by the insects. The important pollinating insects are bees, butterflies, moths, wasps, beetles etc.
The insects visit the flowers for nectar, edible pollen or shelter. Bees have pollen sacs or pollen baskets for collecting pollen.
Now the important characteristics of insect pollinated flower have to be discussed.
Now you assess the students by asking them the following questions.
What is the agent of entomophilic pollination?
How do the bees carry pollen grains?
Do the insects get its food from the flower?
Usually flowers are large in size. If it is small they are grouped into inflorescence.
Brightly coloured
Have specific odour
Possesses nectar or edible pollen
Produce fewer pollen grains
Anthers and stigmas commonly inserted
Stigmas are unbranched may be flat or lobed
Dear student teachers ornithophily involves the contribution of birds for the pollination.
It is obvious showing this type of video programmes will help the students to understand the concepts with clarity.
Ornithophily
Some of the birds which are ornithophily are Sunbird, Humming bird, Crow, Bulbul, Parrot and Mynah. Number of plants is pollinated through birds. These birds usually visit flowers such as Bombax (Red silk cotton), Erythrina (Coral
chain), Callistemon (Bottle brush), Bignonia and Agave. Ornithophilous flowers have following characteristics.

Who is the contributor of ornithophily?

Flowers are large in size
Have tubular or funnel shaped corollas
Brightly coloured flowers
Produce abundant watery nectar

**Reinforcement**

Ensure the mastery over the process of the pollination, among the students by asking certain relevant questions. To enhance the retention capacity of the students attention should be focused on the key terms of the topic. Due attention need to be given for making the students to understand the important terms pertaining to pollination.

**Appraisal of the students**

Following things need to be ascertained by the student teachers.

Confidence in teaching the content on pollination
Able to visualize the different process of pollination
To teach different modes of pollination at ease.

**Learning outcome**

You are required to ascertain the following.

Can I use Metacognition during the process of teaching pollination?
Were I able to visualize the concept of pollination to the students?
Were I able to develop a design of Instruction for pollination?
Were I able to help the students the different terminologies pertaining to pollination?
Can I think of developing e-content?
Revision as required
Update the strategies. If certain objectives are not achieved go through the process once again.

Meatcognitive Evaluation
You are also required to reflect on the action you have made.
How well did I teach the process of pollination?
Did I make students concretize the concept pollination?
What could I have done differently to teach the concept pollination?
Could I use this line of thinking for teaching some other concept in Botany?

2.5 Story Board for teaching Pollination
Story board is a script with visuals which actualizes the development of e-content. In other words, it is called Action Script. Indeed a story board helps content developers in editing.
2.T.2 STORY BOARD FOR TEACHING POLLINATION

<table>
<thead>
<tr>
<th>Text</th>
<th>Instruction</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dear student teachers now you are going to learn how to teach pollination. Here the teacher should help students to connect the new information to what they already know.</td>
<td><img src="image1.png" alt="Video" /></td>
<td>Video</td>
</tr>
<tr>
<td>To bring about the readiness of the students the following questions may be asked to elicit their response. Do you know how organisms reproduce? Do you know how organisms perpetuate? You can also ask students to spell out all the floral parts. After eliciting the response for the above mentioned question define the concept pollination as you go through now.</td>
<td><img src="image2.png" alt="Slide" /></td>
<td>Slide</td>
</tr>
</tbody>
</table>
The process of transfer and deposition of pollen grains from the anther to the stigmatic surface of the flower is called pollination.

While defining the definition of pollination give stress to certain terminologies such as pollen grain, anther and stigma. Shall we now learn to teach the different types of pollination?
<table>
<thead>
<tr>
<th>Self pollination</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is the process of transfer of pollen grains from the anther to the stigma of either the same flower or another flower borne on the same plant.</td>
</tr>
</tbody>
</table>

Now the students will be able to visualize the process of self pollination.
Cross pollination
It involves the transfer of pollen grains from flowers of one plant to the stigma of the flower of another plant.

Don’t you feel students will be able to visualize it?

Now ask the students to differentiate self pollination with cross pollination.

Now make the students recall the definition of pollination.
To ascertain whether the students internalize the concept pollination elicit response for the following question.

Why do the plants pollinate?

<table>
<thead>
<tr>
<th>Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why do the Plants pollinate?</td>
</tr>
</tbody>
</table>

Ensure the students could spell out male and female reproductive organs of the flower.

Do all plants have male and female reproductive organs?
Do all plants pollinate?

Ensure whether you can teach the concept of pollination in 40 minutes.

When we make use of all the following resources students will be able to concretize the concept pollination.

<table>
<thead>
<tr>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image of a teacher</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do all plants have male and female reproductive organs? Do all plants pollinate?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image of a teacher</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image of a teacher</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why do the Plants pollinate?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image of a teacher</td>
</tr>
</tbody>
</table>
You have to internalize whether you are going in a right way according to the time. Keep monitoring yourself whether you are going in the right direction.

Certain concept like pollination can be explained effectively with learning multimedia components. Shall we see how the pollination takes place through multimedia components?

Try to help students to witness a magnified pollen grain so that they can see the size and shape of the pollen grain.
You can also think of graphic organizer on pollination which will make students remember easily.

Modes of pollination can be explained with the help of animation for better understanding as some of the modes cannot be seen through naked eye.

Dear trainees pronounce the following characteristics of the plants to the students as any insect shall not be attracted towards this characteristics.

Dear student teachers the following characteristics shall not be applicable to insect mediated pollination category.

Now students will understand why anemophily is possible only in these types of plants.

| Slide |
| Video |
It is a mode of pollination or transfer of pollen grains from anther to stigma through the wind. The flowers pollinated through the wind are called anemophilous.

The flowers have following adaptations.

Flowers are small, colourless, odourless and nectarless well exposed in the air. Calyx and corolla are either absent or reduced.

Pollen grains are small, light, dry, dusty and winged.
<table>
<thead>
<tr>
<th>Stigmas are large well exposed, hairy, feathery or branched.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the introduction of the next mode of pollination Hydrophily help your students learn the meaning of hydro so that they cannot misunderstand.</td>
</tr>
<tr>
<td>Hydrophily occurs only in a few aquatic plants. It is of two types. One is hydrophily and another is epiphydrophily.</td>
</tr>
<tr>
<td>Hydrophily pollination occurs below the surface of water and the pollen grains are water borne.</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>In ceratophyllum the male flowers bear 32 – 45 stamens. The mature anther break at the base and rise to the surface of water and dehisce there. The liberated pollens germinate and sink in water, while sinking they come in contact with stigma of female flowers to effect pollination.</td>
</tr>
</tbody>
</table>
In Zostera marina pollen grains elongated like a needle without exine. They float below the surface of water. When they reach the stigma they coil around it and germinate. Since both the modes are alike to avoid confusion between hydrophily and epiphyll differentiate these two.

Before Entomophily is discussed ascertain the knowledge of students by asking the following questions.
Do you have garden at home?
Have you watched any insects in the garden?
Now all the insects should be witnessed by the students so that they can remember entomophily easily.
<table>
<thead>
<tr>
<th>It is a type of pollination mediated by the insects. The important pollinating insects are bees, butterflies, moths, wasps, beetles etc.</th>
<th>Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>The insects visit the flowers for nectar, edible pollen or shelter. Bees have pollen sacs or pollen baskets for collecting pollen.</td>
<td>Image</td>
</tr>
</tbody>
</table>
Now the important characteristics of insect pollinated flower have to be discussed.

Now you assess the students by asking them the following questions.

Who is the agent of entomoplilic pollination?  
How do the bees carry pollen grains?  
Do the insects get its food from the flower?
Flowers of entomophilic pollination have following characters.
Usually flowers are large in size.

If it is small they are grouped into inflorescence.
Brightly coloured

Have specific odour

Possesses nectar or edible pollen
Produce fewer pollen grains
Anthers and stigmas commonly inserted
Stigmas are un branched may be flat or lobed
Dear student teachers ornithophily involves the contribution of birds for the pollination. It is obvious showing this type of video programmes will help the students to understand the concepts with clarity.

Some of the birds which are ornithophily are Sunbird, Humming bird, Crow, Bulbul, Parrot and Mynah.
Number of plants are pollinated through birds. These birds usually visit flowers such as Bombax (Red silk cotton), Erythrina (Coral tree), Callistemon (Bottle brush), Bignonia, Agave. Ornithophilous flowers have following characteristics.
<table>
<thead>
<tr>
<th>Flowers are large in size</th>
<th>Have tubular or funnel shaped corollas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightly coloured flowers</td>
<td></td>
</tr>
<tr>
<td>Produce abundant watery nectar</td>
<td></td>
</tr>
</tbody>
</table>
Ensure the mastery over the process of the pollination. Among the students by asking certain relevant questions. To enhance the retention capacity of the students’ attention should be focused on the key terms of the topic. Due attention need to be taken for making the students to understand the important terms pertaining to pollination.

Following things need to be ascertained by the student teachers.
Confidence in teaching the content on pollination.
Able to visualize the different process of pollination.
To teach different modes of pollination at ease.
You are required to ascertain the following:

Can I use Metacognition during the process of teaching pollination?

Were I able to visualize the concept of pollination to the students?

Were I able to develop a design of Instruction for pollination?

Were I able to help the students the different terminologies pertaining to pollination?

Can I think of developing e-content?
<table>
<thead>
<tr>
<th>Question</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Update the strategies if certain objectives are not achieved go through the process once again.</td>
<td>Video</td>
</tr>
<tr>
<td>You are also required to reflect on the action you have made.</td>
<td>Slide</td>
</tr>
<tr>
<td>How well did I teach the process of pollination?</td>
<td>Slide</td>
</tr>
<tr>
<td>Did I make students concretize the concept pollination?</td>
<td>Slide</td>
</tr>
<tr>
<td>What could I have done differently to teach the concept pollination?</td>
<td>Slide</td>
</tr>
<tr>
<td>Could I use this line of thinking for teaching some other concept in botany?</td>
<td>Slide</td>
</tr>
</tbody>
</table>
2.6 Conclusion

The development of the models was the result of the joint effort between the teacher and the students. It was not the product of a sudden insight but a slower step-by-step, model evolution process. Even though the teacher’s goals were primarily content-driven in this case, these lessons also speak to many process goals. In fact, the students appeared engaged in a number of processes that correspond to science process goals: generating a model, evaluating a model by disconfirming or modifying model elements, modifying a model, and progressing to a deeper level of explanation. The diagrammatic notation developed is capable of showing each of these processes and the contributions made to them from both the teacher and students. It is believed that this framework provides a set of lenses that complements other cognitive and sociological frameworks for analyzing classroom discussions.