

## DESIGNING GENETICS INSTRUCTION FOR A SOCRATIC APPROACH

**Sharifah Norhaidah Syed Idros**

*School of Educational Studies*

*University Sains Malaysia*

*Penang*

*Science is at heart a rational activity. Reasoning, being an important component of critical thinking has been successfully taught using Socratic methods. As an approach, the instructor or designer of instruction models an inquiring and probing mind focusing on providing questions and not answers. The main aim has been to allow learners to construct and evaluate their own reasoning or judgements explicitly, thereby making it consistent with current constructivist approaches to teaching and learning. Mendelian genetics has long been identified as an important subject but it is perceived as difficult because it requires students to operate at a higher level of scientific reasoning as well as to have mastery of theoretical genetic concepts. Success in concept acquisition and problem solving depends on many variables. Higher order questions were formulated and integrated into the instructional module for instruction on Mendel's first and second laws. This form of cognitive scaffolding was embedded in the learning cycle model of instruction. This paper discusses a study done on 262 students undergoing a matriculation programme of the Ministry of Education, Malaysia looking into the elements of higher order questions and their benefits on their performance on problem solving in Mendelian genetics at the preuniversity level.*

## INTRODUCTION

*Can it be, Ischomachus, that asking questions is teaching? I am just beginning to see what is behind all your questions. You lead me on by means of things I know, point to things that resemble them, and persuade me that I know things that I thought I had no knowledge of.*

— Socrates

Science, being basically a dynamic activity has been wrongfully presented as a basket of facts by classroom teachers and what have been presented in text books thereby giving the impression that scientific findings are absolute (Duschl, 1990; Gallagher, 1991). The failure to portray the nature of science as being merely tentative has brought about learning mainly by rote and the expectation that there is only one correct answer to any question. No wonder then, there are lamentations that science students are passive, disinclined to ask questions, do not use reasoning, if science seems no more than a process of indoctrination.

Capacity to reason at the formal level is needed to be able to succeed at science, what more to be able to teach effectively (Lawson & Snitgen, 1982). However the failure of students at the tertiary level to reason effectively has been widely reported (Lawson, Nordland & De Vito, 1975; Gipson, Abraham & Renner, 1989; Sharifah, 1999; Sharifah & Merza, 2000). In the context of this paper, being able to reason formally includes the ability to display combinatorial thinking, proportional thinking, correlational and probabilistic as well as the identification and control of variables collectively known as hypothetical-deductive reasoning. Lawson (1995) has reported that even though biology has been perceived to be relatively easy it nonetheless requires learners to exhibit formal reasoning in order to be successful.

## LEARNING DIFFICULTIES IN GENETICS

Extensive research has been done on learning difficulties in genetics such as on misconceptions (Hackling & Treagust, 1984), sources of misconceptions (Stewart & Van Kirk, 1990; Stewart & Dale, 1989; Stewart, 1983), expert and novice problem solving (Smith & Good, 1984) and formal reasoning (Longden, 1982, Radford & Bird-Stewart, 1982; Lawson & Thompson, 1988; Lawson & Weser, 1990; Lawson & Worsnop, 1992).

The main barrier to most learners in acquiring correct concepts in genetics has a great deal to do with the fact that most of genetics concepts are theoretical concepts which are abstract and not descriptive ones (Lawson, 1995). The concept of 'gene' is itself a theoretical concept and needs to be understood in terms of other concepts such as heredity, the combination of genes needed to bring about a certain phenotype as well as the theory that explains phenotype and genotype.

Weak mathematical procedures have also contributed towards learning difficulties especially during problem-solving activities. The concept of probability which is abstract has been found to impede learning for learners are inclined to think that the phenotypic ratio of 3:1 and 9:3:3:1 in mono and dihybrid crossings are true even when 'progeny' numbers are small (Hackling & Treagust, 1984). Kinnear (1983) reported that learners perceive the ratio concept might give rise to absolute numbers and not in terms of probability. This gives rise to the assumption that learners do not comprehend the role of chance events in heredity. In conclusion Gipson, Abraham and Renner (1989) summed up that learners must be able to operate at the hypothetical-deductive/ formal level of reasoning in order to succeed in Mendelian genetics.

Sharifah (1999) reported that 38.19% (N= 560) of students undergoing a matriculation programme at University Science Malaysia cited genetics as the most difficult component of biology.

Further analysis on their scientific reasoning performance revealed that only 16.67% of them were operating at the hypothetical-deductive level needed to successfully understand genetics concepts considered abstract (Gipson, Abraham & Renner, 1989).

## **LETHARGY IN LEARNING AND INSTRUCTION**

The current practices in teaching and learning have not succeeded in preparing learners who can apply their knowledge towards solving problems or constructing arguments and explanations regarding natural phenomena (Roth, 1990). While Gagne (1985) did place the activity of problem solving as the terminal objective on his learning hierarchy these kind of efforts did not situate the reasoning activity into the instruction proper and as such only hope that students are able to attain this objective by themselves. Learning and instruction in Malaysian schools have long taken the didactic approach due to the heavy burden that teachers hold in the course of carrying out their responsibilities (Ahmad Roslan, 1997). Paul (1990) held the view that didactic teaching acts as a barrier for students to think critically. Didactic teaching is characterized by among other things, that, (1) the teacher lectures and uses drill and practice, (2) the learner that memorizes and regurgitates back the information, (3) time is not allocated to stimulate the process of questioning and (4) the learner is neither encouraged to challenge nor to suspect information received. All aspects of a didactic approach to teaching are used to enhance the quality of imparting knowledge but little or none towards the development of thinking and analysis.

Against a background of lacklustre scientific reasoning prowess coupled with a dominantly didactic practice of teaching, difficulties in learning genetics would appear to be a challenge for many Malaysian science educators.

## **BENEFITS OF QUESTIONING IN INQUIRY**

Inquiry methods are used to prompt concerted efforts towards a specific problem which includes the retrieval of relevant concepts, skills as well as the execution of generating, analyzing and interpretation of data (Flick, 1998). Flick (1998) further reported that classroom-based reasoning situations do not afford the time, focus and cues for employing critical thinking and proposed that cognitive scaffolding is necessary to support student thinking processes thereby benefiting from an inquiry based lesson. By scaffolding is meant any support given by teachers to complete a task or solve a problem or even to meet goals which are not likely to be achieved by students on their own (Collins, Brown & Holum, 1991). In addition, Martinello (1998) stated that questioning remains the pulse in a lesson to all inquiry approaches.

Questioning strategies have been widely used in inquiry learning that involves discussions, or discourses (Flick, 1998; Tabak & Reiser, 1999; Sandoval, Daniszewski, Spillane & Reiser, 1999; Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone 2000). Westbrook (1997) reported that even though discussions is essential in inquiry-oriented instruction, discussions are often missing. Furthermore, questioning by both teachers and students can draw out discrepancies and patterns among the data as well as stimulate new ideas. Open verbal interactions as aforementioned are able to create dissonance in the social and conceptual environment of the classroom hence setting the stage for students' construction and reconstruction of science concepts. In teacher-student discussions, the teacher is now able to probe and affirm correct concepts and hypotheses thus preventing students from abandoning a sound investigation path. In addition, structured discussions enable the teacher to guide students to give focus to main principles and to avoid pursuing a fruitless line of solution (Lewis, Stern & Linn, 1993).

## **DESIGNING FOR A SOCRATIC APPROACH (COGNITIVE SCAFFOLDING)**

Socratic teaching remains the most powerful technique for fostering critical and analytical thinking where the questioner represents an equivalent of the inner critical voice that scrutinizes and challenge preexisting assumptions and beliefs. Its main technique is to force the learner to think in a disciplined and intellectually responsible manner as the class or discussion advances. Malaysian learners encultured in an objectivist learning experience due to pressures of public examinations approach their learning experience with basically surface strategies and motives which lean heavily on rote learning (Mardiana & Sharifah, 2003). While such strategies may work towards getting good grades in school-based examinations they do not equip the learners to the more liberal style of education at the tertiary level as is evident in past studies (Sharifah, 1999; Sharifah & Merza, 2000). In the planning and designing for an effective instruction in Mendelian genetics, higher order questions as Socratic questioning were used as a form of cognitive scaffolding to bring attention to important elements that might have otherwise been marginalized. Higher order questions were formulated according to the Grasser, Person, & Huber (1992) (see Figure 1) schema and integrated into the instructional module for instruction on Mendel's first and second laws. This form of cognitive scaffolding was embedded in the learning cycle model of instruction.

Since the content of Mendelian genetics is steeped in hypothetical-deductive thinking, questions were formulated at various points of instruction in order to tease out and prolong dialogue so that abstract concepts are examined more closely and cherished beliefs challenged in the open (examples of questions are shown in Appendix A). The kinds of questions were those among others intended to stimulate hypothetical deductive thinking such as combinatorial thinking, proportional thinking, correlational and

probabilistic thinking as well as the identification and control of variables. Formulation of questions was also guided by the background knowledge of common misconceptions in the learning of genetics found in the literature. Since Malaysian school children are not accustomed to giving viewpoints which they feel might not be congruent with the rest of the class or those of their teacher's, and in doing so exposing their vulnerability, the instructional setting is now in the form of small group interactions with the teacher. The formation of small group discussions among members and the offering of a negotiated consensus as the group's views were successful in overcoming the usual passiveness as well as it supported and sustained the continued dialogue.

## **METHODOLOGY**

### **Sample**

The subjects were pre-university students undergoing a science matriculation programme at two different matriculation colleges. Random sampling was employed among the five colleges seeing that placement was already done randomly by the Ministry of Education. Random sampling was also carried out among the classes to select one intact class from each of the colleges involved. 92 students (from one intact class) were selected for treatment with cognitive scaffolding while 125 students (from one intact class) were selected for those undergoing treatment without cognitive scaffolding. Students from each class were further identified as high-achieving and low-achieving based on their cumulative aggregate of biology and mathematics grades from their first semester matriculation examinations. High achievers were those who scored grades 'A' and 'B' in both subjects while low achievers were those who scored grades 'C', 'D' and 'F'. Since grading of examination papers for matriculation program are done centrally, this ensured that the sample at any of the colleges can be considered equivalent.

## **INSTRUMENTS**

Two different teacher modules were developed: a module of instruction in Mendelian genetics using the learning cycle with cognitive scaffolding (higher-order questions) and module of instruction in Mendelian genetics using the learning cycle but with no cognitive scaffolding embedded. The learning cycle was the instructional model used to design and deliver the instruction in Mendelian genetics. By this, is meant that the instruction will lead the learning process through three phases namely (1) Exploration (2) Introduction of terms and (3) Application, beginning with an introduction of an unexplained phenomenon (phase of cognitive dissonance), generation of hypotheses to be tested by the use of deduction. The two modules would be similar in every aspect with the exception that the module scaffolded with higher-order questions had questions the teacher had to ask students in order to bring attention to important elements in the domain.

Since the literature has documented that success in Mendelian genetics placed an essential requirement at higher-order thinking or hypothetical-deductive reasoning made up of combinatorial thinking, proportional thinking, correlational and probabilistic as well as the identification and control of variables (Lawson, 1995), these questions were formulated to activate thinking at these levels (see Appendix A).

The Graesser-Person-Huber schema (1992) was used to design the questions, the majority of which came from categories 11 till 18 of the schema depicting a higher-order level.



Question category	Abstract specification	Example
Short answer	Is a fact true? Did an event occur?	Is the answer 5?
1 Verification	Is X or Y the case? Is X, Y, or Z	Is gender or
2 Disjunctive	the case?	female the variable?
3 Concept completion	Who? What? What is the referent of a noun argument slot?	Who ran this experiment?
4 Feature specification	What qualitative attributes does entity X have?	What are the properties of a bar graph?
5 Quantification	What is the value of a quantitative variable? How many?	How many degrees of freedom are on this variable?
Long answer		
6 Definition	What does X mean?	What is a t test?
7 Example	What is an example label or instance of the category?	What is an example of a factorial design?
8 Comparison	How is the X similar to Y? How is X different from Y?	What is the difference between a t- test and chi-square test?
9 Interpretation	What concept or claim can be inferred from a static or active pattern of data?	What is happening in this graph?
10 Causal antecedent	What state or event causally led to an event or state?	How did this experiment fail?
11 Causal consequence	What are the consequences of an event or state?	What happens when this level decreases?

---

12	Goal orientation	What are the motives or goals behind an agent's action?	Why did you put decision latency on the y-axis?
13	Instrumental/ procedural	What instrument or plan allows an agent to accomplish a goal?	How do you present the stimulus on each trial?
14	Enablement	What object or resource allows an agent to perform an action?	What device allows you to measure stress?
15	Expectational	Why did some expected event not occur?	Why isn't there an interaction?
16	Judgemental	What value does the answerer place on an idea or advice?	What do you think of this operational definition?
17	Assertion	The speaker makes a statement indicating he lacks knowledge or does not understand an idea.	I don't understand main effects.
18	Request/ Directive	The speaker wants the listener to perform an action.	Would you add those numbers together?

---

*Figure 1: Question Categories in Graesser's, Person's, and Huber's (1992) Scheme*

## POST TEST ON MENDELIAN GENETICS

This was a paper-and-pen test administered to students a day after the treatment ended and was not administered before the treatment. This instrument tested students' problem solving abilities in both mono and dihybrid crossings based on the syllabus for matriculation programme and for the *Sijil Tinggi Pelajaran Malaysia* (STPM) examination. There were seven main questions comprising of 17 smaller parts to the problems, which had to be completed in a set time. This test had a reliability Cronbach a coefficient of 0.7096.

**RESULTS**

Table 1  
*T-test for groups with questions (cognitive scaffolding) and without*

Treatment	N	Mean	df	t	Sig (2-tailed)
Learning Cycle with questions	92	75.478			
Learning Cycle without questions	125	58.072	204.2	8.427	0.000

Significant at 0.05

The results show that all students who underwent the instruction using the learning cycle with higher-order questions embedded scored a mean of 75.48 which is a grade A compared to those without the questions who managed only 58.07 which is a grade C. This difference is statistically significant.

Table 2  
*T-test for high achieving groups with questions (cognitive scaffolding) and without*

Treatment/High achievers	N	Mean	df	t	Sig (2-tailed)
Learning Cycle with questions	67	78.716			
Learning Cycle without questions	109	59.339	173.57	10.357	0.000

Significant at 0.05

Again, the results show that the high achieving students who obtained questions scored significantly higher (mean of 78.716) than those without (mean of 59.339) been given the questions.

Table 3  
*T-test for low achieving groups with questions (cognitive scaffolding) and without*

Treatment/ Low achievers	N	Mean	df	t	Sig (2-tailed)
Learning Cycle with questions	25	66.800			
Learning Cycle without questions	16	49.437	35.808	2.866	0.007

Significant at 0.05

The results again show that the higher-order thinking questions embedded within a learning cycle mode of instruction benefited even the low achieving students for the difference in means between the treatment and control group was found to be statistically significant. The mean for group with higher-order thinking questions was 66.8 (grade B) while those without the higher-order thinking questions scored only 49.44, an average of a strong D.

## DISCUSSION

The findings have shown that cognitive scaffolding in the form of higher-order thinking questions were able to benefit students greatly in their problem solving activities in Mendelian genetics. The questions were formulated especially to prompt thinking skills in areas such as correlational thinking, probability, proportional thinking, combinatorial thinking and the identification and control of variables all considered essential for a sound understanding of genetics concepts. Irrespective of whether the students were earlier identified as high or low achievers, they gained from the experience that allowed for discussions, negotiations and verbalizing their thinking. Questioning has provided a learning environment that ensured students take an active part in reasoning.

The constructivist learning environment of the learning cycle involves sequencing the phases so that students are brought into a

situation of cognitive disequilibrium where they are unable to explain a scientific phenomenon or concept using the usual methods. Small group discussions were encouraged to trigger arguments. Students were encouraged to arrive at a consensus with regards to their useful and tangible explanations. Thereby teachers played the role of a facilitator first leading students into a cognitive conflict where accommodation of new inputs occur in the existing schema or there was a restructuring of the knowledge structure. Further questions guided their reasoning process such that an imminent explanation is not an impossibility. Teachers have also been sufficiently trained to not visibly agree or reject explanations by students so as to allow the process of reasoning from continuing.

The strategies taken to scaffold students when constructing explanations allow them to evaluate the quality as well as the development of their explanations (Sandoval & Reiser, 1997). In addition when engaged in their own learning process outside of the formal classroom, students are more inclined to emulate the style and type of questions that they had witnessed teachers ask.

Indirectly, this kind of approach can shape a style of learning that is efficient and at the same time providing guidance for the active participation of students in inquiry (Sandoval et al., 1999) as is evident in this study.

## **CONCLUSIONS**

Cavallo (1996) had earlier stated that success in genetics problem solving depended on both higher-order thinking skills as well as students orientation towards meaningful learning. In addition, Stewart and Hafner (1994) reported that failure in this activity was not only because students had poor reasoning skills but because they were reasoning within a knowledge base that was insufficient. Higher-order questions embedded in the learning cycle managed to connect the varied subconcepts in genetics meaningfully making

the acquisition of genetics concepts possible thereby even allowing the low-achieving students to benefit profitably from instruction that need cognitive scaffolding embedded in it.

## REFERENCES

- Ahmad Roslan Johari, (1997). Prestasi pelajar Melayu dalam sains dan teknologi: Pengalaman Bahagian Pelajaran Menengah MARA. *Kertas kerja dibentangkan di Persidangan Pendidikan Sains dan Teknologi*, Kuala Lumpur pada 15-16 Disember, 1997.
- Cavallo, A. M. L. (1996). Meaningful learning, reasoning ability and students' understanding and problem solving of topics in genetics. *Journal of Research in Science Teaching*, 33(6), 625-656.
- Collins, A.M., Brown, J. S. & Holum, A. (1991). Cognitive apprenticeship: making thinking visible. *American Educator*, Winter 1991.
- Duschl, R.A. (1990). *Restructuring science education*. New York: Teachers College, Columbia University.
- Flick, L.B. (1998). *Integrating elements of inquiry into the flow of middle level teaching*. Paper presented at Annual Meeting of the National Association for Research in Science Teaching, San Diego, Cal.
- Gagne, R.M. (1985). *The conditions of learning (4<sup>th</sup> ed.)*. New York: Holt, Rinehart, & Winston.
- Gipson, M.H., Abraham, M.R. & Renner, J.W. (1989). Relationships between formal-operational thought and conceptual difficulties in genetics problem solving. *Journal of Research In Science Teaching*, 26(9), 811-822.
- Hackling, M.W. & Treagust, D. (1984). Research data necessary for meaningful review of grade ten school genetics curricula. *Journal of Research In Science Teaching*, 21(2), 197-209.
- Kinnear, J. (1983). Identification of misconceptions in genetics and the use of computer simulations in their corrections. *Proc. Int. Seminar: Misconceptions in Science and Mathematics*. Ithaca, NY: Cornell University.

- Lawson, A.E. (1995). *Science teaching and the development of thinking*. Wadsworth Publishing Company, Belmont, California.
- Lawson, A.E. & Snitgen, D.A. (1982). Teaching formal reasoning in a college biology course for preservice teachers. *Journal of Research in Science Teaching*, 19(3), 233-248.
- Lawson, A.E., Nordland, F.H., & De Vito, A. (1975). Relationships of formal reasoning to achievement, aptitudes, and attitudes in preservice teachers. *Journal of Research in Science Teaching*, 12(4), 423-431.
- Lawson, A.E. & Thompson, L.D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. *Journal of Research in Science Teaching*, 25(9), 733-746.
- Lawson, A.E. & Weser, J. (1990). The rejection of nonscientific beliefs as a function of instruction and reasoning ability. *Journal of Research in Science Teaching*, 27 (6), 589-606.
- Lawson, A.E. & Worsnop, W.A. (1992). Learning about evolution and rejecting a belief in special creation: Effects of reflective reasoning skill, prior knowledge, prior belief and religious commitment. *Journal of Research in Science Teaching*, 29, 143-166.
- Gallagher, J. J. (1991). Prospective and Practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, 75(1), 121-133.
- Graesser, A.C., Person, N.K. & Huber, J.D. (1992). Mechanisms that generate questions. In T.E. Lauer, E. Peacock & A.C. Graesser (Eds.), *Questions and information systems* (pp167-187). Hillsdale, NJ: Erlbaum.
- Graesser, A.C. & Person, N. K. (1994). Question asking during tutoring. *American Educational Research Journal*, 31(1), 104-137.
- Lewis, E.L., Stern, J.L., & Linn, M.C. (1993). The effect of computer simulations on introductory thermodynamics understanding. *Educational Technology*, 33(1), 45-58
- Longden, B. (1982). Genetics - are there inherent learning difficulties? *Journal of Biological Education*, 16(2), 135-140.

- Mardiana Abd. Rahim & Sharifah Norhaidah Idros (2003). Perhubungan Pendekatan Pembelajaran dengan Pencapaian Dalam Genetik Mendel. Paper presented at *Persidangan Biologi Kebangsaan 2003*, Hotel Royal Casuarina Ipoh, 14-16 Disember, 2003.
- Martinello, M.L. (1998). Learning to question for inquiry. *The Educational Forum*, Vol. 62, Winter 1998.
- Paul, R.W. (1990). Critical and reflective thinking: A philosophical perspective. In B.F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction*. Hillsdale: NJ: Lawrence Erlbaum Associates.
- Radford, A. & Bird-Stewart, J.A. (1982). Teaching genetics in schools. *Journal of Biological Education*, 16(3), 177-180.
- Reiser, B.J., Tabak, I., Sandoval, W. A., Smith, B.K., Steinmuller, F. & Leone, A. J. (2000). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms
- Roth, K.J. (1990). Developing meaningful conceptual understanding in science. In B.F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction*. Hillsdale, NJ: Erlbaum.
- Sandoval, W.A., & Reiser, B.J. (1997). *Evolving explanations in high school biology*. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.
- Sandoval, W.A., Daniszewski, K., Spillane, J.P. & Reiser, B.J. (1999). *Teachers' discourse strategies for supporting learning through inquiry*. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.
- Sharifah Norhaidah Idros (1999). Enhancing scientific reasoning in a biology course. In Proceedings of 'Konvensyen Persatuan Teknologi Pendidikan ke-12' pp.34-43.
- Sharifah Norhaidah Idros & Merza Abbas (2000). Scientific reasoning and epistemological beliefs: Synergy or lethargy? Paper presented at *Simposains 2000*, Shah Alam, 2-5 Oktober, 2000.
- Smith, M. U. & Good, R. (1984). Problem solving and classical genetics: Successful versus unsuccessful performance. *Journal of Research in Science Teaching*, 21(9), 895-912.



- Stewart, J.H. & Van Kirk, J. (1990). Understanding and problem solving in classical genetics. *International Journal of Science Education*, 12(5), 575-588.
- Stewart, J.H. (1983). Student problem solving in high school genetics. *Science Education*, 67(4), 523-540.
- Stewart, J., & Dale, M. (1989). High school students' understanding of chromosome / gene behaviour during meiosis. *Science Education*, 73(4), 501-521.
- Stewart, J., & Hafner, R. (1994). Research on problem-solving: Genetics. In D.L. Gabel (Ed.), *Handbook of Research on Science Teaching and Learning*. Macmillan Publishing Company, New York.
- Tabak, I. & Reiser, B.J. (1999). Steering the course of dialogue in inquiry-based science classroom. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.
- Tabak, I., Sandoval, W.A., Smith, B.S., Agganis, A., Baumgartner, E. & Reiser, B.J. (1995). Supporting Collaborative Guided Inquiry in a Learning Environment for Biology dalam *Proceedings of the Computer Support for Collaborative Learning '95 Conference*. [http://www.letus.org/bguile/Papers/Bguile\\_papers.html](http://www.letus.org/bguile/Papers/Bguile_papers.html)
- Westbrook, S.L. (1997). The lab's done ... Now what? Paper presented at Annual Meeting of the National Association for Research in Science Teaching, San Diego, Cal.

## APPENDIX A

(Some examples of Higher-Order Questions Used In the Learning Cycle Mode of Instruction found in the Teacher Module – figures in parentheses denote level in Graesson-Huber Scheme)

### PHASE 1: EXPLORATION

- A Teacher uses a concrete concept by way of demonstration, examples and actions.

Start with a simple demonstration and challenge students to ask questions or to predict the outcome of an experiment.

1. Introduce a new topic, Mendelian Genetics

Show to the class, a picture of a litter of kittens/puppies and ask the question,

Question

- (a) What are the differences that you can see in this litter? (#8)  
(b) What are the similarities that you can see in this litter? (#8)

2. To introduce the concept of phenotypic ration of 3:1 in a concrete form.

Distribute to the students a corn that is the outcome of a monohybrid cross.  
(corn that possesses yellow and purple seeds in the ratio 3:1)

3. To sharpen the observational skills in order to facilitate the generation of a new hypothesis.

This part is aimed at showing students that certain patterns occur in a phenomena. In this matter, students must be guided to see that the recessive allele is suppressed in the F1 generation and the phenotypic ratio in F2 generation is 3:1.

Show to students pictures of the outcome of Mendel's various experiments as well as the figures.

(Use the transparencies provided)

- picture of cotyledon (smooth/wrinkled, yellow/green)
- picture of pea pod (inflated/constricted; yellow/green)
- height of pea plant (tall/dwarf)
- position of flowers (axial/apical)
- color of flower (purple/white)

Question: (a) Observe the pattern of inheritance for all cases. What are the similarities that you can see in the F1 generation? (#9)

(b) In the F2 generation? (#16)

(c) In your opinion, what could have happened that has brought about such results? (#15)

(d) Try to give an explanation for the results of F1? (#16)

\*\* Teacher is advised to give freedom for students to offer their suggestions even though some may not be plausible.

Small-group discussions are best – give students the freedom to interact with one another. This opportunity is good for students to become more aware of their own style of reasoning and also to learn from others, more strategic ways of reasoning. At this stage, teacher is advised neither to agree nor disagree but instead to encourage brainstorming of ideas.

Students are assumed to be not very capable of reasoning out this part based on usual ways of thinking. Their efforts to offer explanations for the mechanism of monohybrid inheritance will prepare them to think of alternative explanations and to be prepared to accept new scientific concepts.

## **PHASE 2: INTRODUCTION OF TERMS (only part of actual module)**

- B. Teacher will introduce new terms that will be used to make connections with matters faced in the first phase.

A short lecture will be delivered alongside questioning students regarding why certain events occur. It is not realistic to hope that students can offer an accurate explanation underlying the rationale behind Mendel's experiments to describe the monohybrid inheritance. The main aim of teacher here would be to guide students through the same thinking processes as Mendel himself would have done when he was planning and carrying out his experiments.

1. Relevant terms that need to be clarified during teacher-student discourse.

(i) Pure-breeding

Mendel used only pure-breeding pea plants in his experiments.

The different ways and reasons that Mendel used pure-breeding pea plants requires a variety of scientific thinking. Teacher can ask these questions:

Question:

- (a) Why is it necessary to use only pure-breeding pea plants? (correlational thinking) (#12)
- (b) Why the need to use self-fertilization for certain characteristics at any one time? (combinatorial thinking) (#12)
- (c) Why did Mendel allowed self-fertilization processes to run for several years and not for a shorter period like a few months? (correlational thinking) (#12)

- (d) Why is it important to have extensive data?  
(probabilistic thinking) (#14)
- (e) What are the ways that Mendel used to generate his hypothesis? (#13)
- (f) Why did Mendel use mathematical analysis in order to generate his hypothesis?  
(proportional thinking) (#14)
- (ii) Monohybrid  
Question:
  - (a) What is meant by the term 'mono'? (#6)
- (iii) Allele  
Question:
  - (a) Is a gene and an allele the same thing? (#2)
- (iv) Chromosome separation  
Question:
  - (a) In your opinion, is this event in any way connected to meiosis? (#16)
  - (b) Try to identify at which stage of meiosis did this event occur? (#13)
- (v) Probability  
Question:
  - (a) What is the meaning when we say a certain event has a high probability of it happening? (#15)
  - (b) How does a probabilistic event differ from a certain event? (#8)
  - (c) What is the probability that snow will fall on the Sahara? (#11)

- (d) What is the probability that the sun will rise in the morning? (#11)
- (e) What is the probability that in the event a coin is tossed, it will fall with its face facing upwards? (#11).

(vi) Random combination

Question:

- (a) In your view, is this event connected to any of the phases of meiosis? (#16)
- (b) Try to identify which meiotic division does this event take place? (#13)

(vii) Genotype

(viii) Phenotype

Question:

- (a) What is the difference between genotype and phenotype? (#8)
- (b) How can you remember in a meaningful manner the difference between the two? (#14)

(ix) Homozygote

(x) Heterozygote

Question:

- (a) What is the difference between homozygote and heterozygote? (#8)
- (b) How can you remember in a meaningful manner the difference between the two? (#14)