

## **Problem Solving of Secondary School Genetics and Holistic Strategy to Develop it.**

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### **Abstract :**

Genetics, an integral component of biological sciences, is important because it serves as a foundation for understanding inheritance, diversity, and evolution. It is difficult topic at secondary school and undergraduate levels.

Problem-solving in genetics is difficult because it requires strategic integration of complex knowledge including concepts, procedures, and models. This study investigates the problem-solving behaviors of secondary school students (N = 80) when solving 7 genetics problems. By using a questionnaire, genetics problem-solving performance test developed by the researchers and holistic strategy (key concepts of genetics and relationships, diagrams, and intensive exercises). The results revealed differences between pre-post tests of experimental group in favour of post-test and the holistic strategy was important to develop problem-solving behaviors.

### **Introduction :**

According to the current information explosion during the past decade, it has been impossible to teach a student the knowledge needed in order to be an effective citizen; and even if this were possible, that knowledge will become out dated very quickly. Though the knowledgeable teacher is an adequate position to choose what information is important for the students to know. After they leave

their classrooms, in fact, students need to understand and apply knowledge which has not even been discovered, solve problems which have not yet been identified. Education in general, and science education in particular should focus on problem-solving and related skills for enhancing development of students.

Problem solving in any science education domain is a very complex process involving problem recognition, defining the problem, generating possible strategies to solve the problem, implementing a strategy, and evaluating to see if the problem has been successfully resolved. The overall process involves the integration of procedural knowledge of how to execute a problem solution and prior conceptual knowledge of concepts, laws, and theories which provide meanings or contexts to the procedures. (Stewart, 1982).

Genetics, an integral component of biological sciences is important. It serves as a foundation for understanding inheritance, diversity, and evolution. According to the related literature of problem-solving of secondary school students, genetics is difficult topic to learn because it requires strategic integration of complex knowledge including concepts, procedures, and models (Stewart, 1982; Stewart, 1988; Thomson & Stewart, 1994).

In genetics, as a field of science education, three dominant traditions have influenced research on learning problem solving. Piagetian researchers such as : (Walker, Hendrix, and Mertens, 1980; Smith and Good, 1984; Gipson & Abraham, 1985; Hacking,

1986; Simmons & Lunnetta, 1993) argue that the developmental stage of a student can be used to account for his or her success or failure in genetics problem-solving. They indicated that the Mendelian genetics concepts presented in biology requires formal intellectual operations of students. These researchers proposed that combinatorial reasoning, propositional logic and the use of probabilistic reasoning are all necessary to the understanding of many basic principles of genetics.

The Ausubel tradition researchers focus on the influence of existing knowledge on learning; the means of assessing student knowledge acquisition has been to have them solve problems in paper - and - pencil and clinical interview situation (Stewart, 1982; Thomson and Stewart, 1985; Cho and Nordland, 1985; and Finkel, 1996). They have emphasized the important influences that relevant knowledge has on problem-solving.

Research in each of these traditions had produced interesting results, but it has not examined the relationship between student's conceptual knowledge and problem-solving strategies.

The third tradition is called the cognitive science tradition (Hayes, 1981; and Stewart, 1988) which emphasizes the interrelationships between the conceptual knowledge possessed by problem solvers and their knowledge of procedures they use to solve problems. They have described general procedures (means-ends - analysis, planning, hillclimbing, working backward) which can be used in genetics problem-solving.

According to the study of misconceptions of genetics problems and problem-solving. Many researchers revealed that student's limited knowledge of meiosis has resulted in procedural errors when solving routine genetics problems. Furthermore, some students who used algorithms to obtain correct answers could not justify their procedural steps in terms of related conceptual knowledge (*Hackling ; and Treagust, 1984; Kinnear, 1986; and Hackling and Lawrence, 1988*).

*Cho, Kahle; and Nordland, (1985)*, added that due to the probabilistic nature of allelic segregation and gene assortment and to the effect of chromosomal behavior on allelic segregation and gene assortment, probability in genetics must be understood in relation to chromosomal behavior. A lack of understanding probability in the context of chromosomal behavior results in failure to select proper gametes for genetic crosses.

Another source of difficulty of genetics problems is the widespread use of proposed diagrams and the lack of understanding mathematics involved. *Thomson, (1994)*; argued that problem-solving strategies used by the geneticists to solve realistic transmission genetics problems were independent of the degree of problem difficulty and contrast significantly with textbook problem types.

For the successful application of problem-solving skills in a discipline-specific context, learners must have a mastery of knowledge base and of the investigatory armory of that domain, as

well as possessing general problem-solving knowledge. (*Kinnear, 1986*).

#### The Problem :

This study attempts to investigate the problem-solving behaviors that students employ during solving genetics problems; and develop a teaching strategy for remediating these problems of students.

Specifically, this study tried to answer to the following questions;

- 1- What problem-solving behaviors do students employ when investigating secondary school genetics problems ?
- 2- What is the effect of a suggested teaching strategy for developing problem-solving behaviors of genetics ?
- 3- What are the distinct strategies which students use when solving genetics problems ?

#### The significance of the study :

The significance of this study can be expressed in the following main points :

- 1- An investigation of student problem solving behaviors when faced genetics problems has been useful guide for instructors to develop instructional material in genetics and other domains of science education.
- 2- The study gives an information of meaningful revision which can be designed to take account of student's preconceptions; and to

avoid the common misconceptions resulting from the usable pattern of instruction.

- 3- An analysis of procedural knowledge or strategies of how students execute a problem solution of genetics provide meaning or context to the procedures necessary for meaningful solution of any problem of science domain.
- 4- The use of instructional strategy deals with developing problem solving in genetics is a useful guide for other researchers of science teaching .

#### Related Literature :

The procedural knowledge (or strategy) is represented as a set of steps. Since the class of problems includes monohybrid through n-hybrid problems, the correct solution may involve more than one cycle through some of the steps (*Stewart, 1982*).

*Cho, Kahle; and Nordland (1985)*, have been identified the major sources of misconceptions and learning problems of genetics as:

- A- Conceptual organization, particular sequencing of topics in texts.
- B- Conceptual relationships,
  - 1- General relationship of meiosis with genetics due to misunderstanding of the following relationships : Chromosomal separation - DNA replication- Alleleic pair - trait expression Chromosomal movement - Trait transmission.

- 2- Specific relationships among the following basic concepts : allele, gene, DNA, chromosome trait, gamete, zygote.

C- Use of terms,

D- Mathematical elements.

*Finkel, (1994, 1996)*, dealt with the ways which students collaborate to construct, use, and revise conceptual and strategic knowledge as they solve genetics problems. He concludes that students used three types of knowledge during model revision : knowledge of genetics, knowledge of the process of model revision; and knowledge of their own problem-solving strategies.

In order to solve genetics problems, there are two main types of thinking : one that requires the solver to reason from causes (know information on inheritance patterns) to effects, (e.g., the prediction of offspring genotype or phenotype data); and that which requires the solver to reason from effects (phenotype data from crosses); to causes (determining a geno-type explanation for the phenotype data). Paralleling these two types of reasoning there are two types of problems, that require only cause to effect reasoning and those that require effect -to - cause reasoning at some point in their solution. (*Stewart, 1988*).

Another study of *Stewart, (1982)* developed a model include both procedural steps employed in a solution and the conceptual knowledge of genetics and meiosis which would allow the problem solvers to justify what they have done.

According to (Reif, 1983; Smith and Good, 1984; and Collins, 1986), described a procedure called problem redescription (which experts tend to use). In genetics, this include redescrping the problem in terms of the number of phenotypic class, the number of individuals within each class; and the distription of sexes within each class. Redescription help organize the data (in a way that facilitates the generation of hypotheses a bout inheritance patterns.

Stewart, (1988) added that there are four important learning outcomes that could result from having students solve genetics problems. They are that students will gain a better understanding of :

- 1- The conceptual structure of the discipline of genetics;
- 2- Problem-solving heuristics that are not specific to a particular discipline;
- 3- Content - specific problem - solving procedures of two types :
  - a- genetics - specific instantiations of general heuristics.
  - b- problem -solving algorithms specific to genetics; and
- 4- The nature of science as an intellectual activity.

Stewart, (1983) dealt with the representations corresponded to knowledge in the instruction recieved by the students, covering the following subgoals :

- A- Construction of a symbolic key to alleles.
- B- Determination of parental genotypes.
- C : Determination of gamete types.
- D : Determination of offspring genotypes.
- E : Determination of offspring phenotypes.

### Related Studies :

Related studies of genetics concepts and problem solving can be subdivided into four themes of concern :

(A) The first one stressed on knowledge and procedurs necessary to solve problems. Stewart (1983), reported data-gathering study that utilized 27 high school biology students. He focused on the procedural and conceptual knowledge evinced by the subjects as the each solved a monohybrid and dihybrid problem. Stewart found that three of subjects could not even begin the monohybrid problem because they could not construct aproper allelic key. Another seven subjects successfully completed the monohybrid problem, but had difficulty with the dihybrid task. Although 17 subjects produced correct solutions to both problems, Stewart warned that most were not meaningfully solving the problem because they were unable to connect meiosis to problem solutions.

Collins (1986), examined the procedural knowledge employed by geneticists in solving problems on dominance, codominance, multiple alleles, and sex linkage. Using a computer simulation, she concluded the procedural knowledge which was characteristic of expert physicists was also characteristic of expert geneticists. Both groups used data redescription at the start of problem-solving and

employed forward-working strategies, as opposed to the means-ends-analysis employed by most novices.

*Gipson; and Abraham (1985)*, identified the relationships between aspects of formal-operation thought (proportional reasoning, combinatorial reasoning; and probabilistic reasoning) as measured by three Piagetian interview tasks (the balance beam task, the electronic switch-box task, and coloured squares and diamond task) and conceptual difficulties related to problem-solving in Mendelian genetics (meiotic formation of gametes, dominance, segregation and independent assortments). By using the Punnett square model to practice problems and test of genetics problems, the results of applying 71 students revealed that; there is a relationships among Piagetian tasks and genetics problems.

(B) The second theme of related studies dealt with misconceptions of genetics concepts, (*Hackling, Treagust, 1984*), described grade 10 high school students' understanding of the mechanisms of inheritance. They identified misconceptions and missing conception after instruction. The inheritance Concepts and Propositions Interview (ICPI) instrument was designed to explore and assess student's understanding of the 18 propositions and the five concepts "inheritance, locus, meiosis, fertilization; and mitosis". Analysis of interviews from 48 students revealed several important

implication for science curriculum writers and teachers of grade 10 genetics topics.

*Cho, Kahle; and Nordland (1985)*, analysed three sources of misconceptions of genetics (concept organization, conceptual relationships, mathematical elements, and use of terms). An investigation of the three most widely used high school biology text books indicated inadequacies in all four the above areas. All of the three provided bases for misconceptions and difficulties in learning genetics by traditional sequence of topics and by the development of content materials.

(C) The third theme, dealt with the problem-solving behaviors of students like, *Tolman (1982)*, who studied the problem-solving performance of 30 high school students. The subjects were asked to solve a monohybrid problem, a codominance problem; and a sex-linked problem. Only 2% of the subjects solved the monohybrid problem, 40% the codominance problem, and 63% the sex-linked problem. A common error committed by the subjects in the monohybrid and codominance problems was that the gametes contained both genes from the pair in question.

At the post-secondary levels, *Smith and Good (1984)*, analyzed the problem-solving behaviors of 11 undergraduates and 9 graduate students and instructors who were asked to solve seven genetics

problems. The investigators discovered 32 problem solving behaviors in which novices differed from experts. Some behaviors related to problem solving in general; and other behaviors were more domain specific.

*Hackling (1986)* described a study of pedigree problem-solving involving high school students and college teachers. He found that the more successful problem - solvers used a four-stage problem-solving process (generated a hypothesis, tested the hypothesis, falsified alternative hypothesis; and evaluated the probability of each hypothesis). He found no differences in the correct answers of expert (genetics instructors) and novice (undergraduate students) subjects solving pedigree problems.

*Hackling and Lawrence (1988)*, compared the problem-solving performance of university genetics professors and genetics students and therefore fits the expert versus novice paradigm. The subjects solved three genetics pedigree problems. Data were gathered using stand think-aloud protocol procedures. The experts identified more critical cues in the pedigree which were used to generate and test hypothesis, they tested more hypotheses by assing genotype to individuals in the pedigree, and were more rigros than the novices in the falsification of alternative hypotheses. The experts varied their problem-solving strategies to suit the particular conditions of problem

involving rare or common traits. Novices did not recognize the need of such modification to their strategies.

(D) The Later theme of related studies dealt with teaching strategies used to develop problem solving skills of genetics. *Kinnear (1986)* focused on the use of computer - based problems in the study of genetics. Discriptions and comparisons of textbook, Laboratory; and computer - based problems are stated and an explanations is given of how college students (N = 68) performed in completing and understanding computer-based problem-solving tasks. Examples of problems involving dominance and linkage concepts are presented. The results revealed that computer-based problems can be encourage productive rather than reproductive thinking and thus faciliate meaningful rote Learning of genetics concepts.

*Browning and Lehman (1988)*, used a genetics problem practice program and tutor on microcomputer with (135) undergraduate education majors enrolled in an introductory biology course at Purdue University. The program presented four genetics problems, two monohybrid and two dihybrid and required the users to predict the number and type of each class of offispring. Students' responses were recorded on diskette and analyzed for evidence of misconceptions and difficulties in genetics problem-solving process. Three main areas of difficulty were identified : difficulties with computational skills,

difficulties in the determination of gametes; and inappropriate application of previous learning to new problem situations.

*Okebukola (1990)*, conducted with the ways of ensuring that students attain meaningful learning of genetics and ecology rather than learning by rote. The efficiency of the concept-mapping strategy was tried out with (138) predegree biology students. The result showed that the (63) students in the experimental group who employed the concept-mapping technique performed significantly better on the test of meaningful learning in genetics and ecology than their control group counterparts (N = 75).

*Simmons and Lunetta (1993)*, described the problem solving behaviors and genetics concepts employed by experts and novices during integration with a genetics computer simulation (CATLAB). They used clinical interviews; analysis of documents and unstructured observation for analysing data of thirteen subjects (3 experts and 10 novices). They found that successful subjects exhibited the most complex patterns of problem solving behaviors and sequences and employed principally discription problem-solving sequences. The least successful subjects exhibited more random patterns of behaviors during problem solving than did other subjects. An intermediate group of problem solvers exhibited some of the problem-solving behaviors and sequences of the successful subjects.

From the related literature and the above-mentioned related studies it could be conclude that :

(1) Some studies dealt with the importance of alternate conceptions of genetics concepts including meiosis (*Hackling & Treagust, 1984, Kinnear, (1988)*). Other studies were concerned with students' problem-solving performance (*Stewart, 1983, Smith and Good, 1984 Hackling, 1986, Kinnear, 1986,*).

(2) The major sources of misconception of problem solving genetics were, conceptual organization of genetics, conceptual knowledge, specific relationships, use of terms; and mathematical elements. (*Smith & Good, 1984 - Cho, Kahle; & Nordlond, 1985; & Finkel, 1994*).

(3) Some studies stressed the effect of conceptual structure of genetics, problem solving heuristics, content specific problem solving; and the nature of intellectual activity (*Stewart, 1983, 1988*).

(4) Some studies dealt with teaching strategies used to develop problem solving skills of genetics such as : (*Kinnear, 1986; Okebukola, 1990; and Simmons and Lunetta, 1993*).

(5) Several techniques have been used to determine a students' difficulties such as, audio-taped structured interviews, (*Stewart, 1988*) vediotaped problem-solving (*Smith and Good, 1984*); think-aloud techniques (*Stewart, 1982, Tolman, 1982; and Stewart, 1983*) and computer-simulations, (*Kinnear, 1986 , Browning and Leheman, 1988 , Okebukola, 1990 - Simomon and Luenetta 1993*).



## Method and Procedures :

### 1- Sample :

The subjects of this study are secondary school students, selected from one school of Benha Ministry of Education (N = 80), 30 females, and 50 males, who comprised third-year students enrolled in genetics unit in a context of general biology. Other subjects were biology instructors and directors who were chosen from Benha Ministry of Education (N = 20).

### 2- Instruments :

Two instruments were developed for the purposes of this study :

#### A) Questionnaire of genetics problem-solving :

After reviewing and analysing related literature, the researchers developed a questionnaire consists of 7 main parts, related to genetics problems as : monohybrid problems (symbolic and verbal), dihybrid problems (symbolic and verbal), determining the genotype of parents from phenotype of offspring, blood classes (groups) genetics, quantitative genetics, incomplete dominance; and test cross. Each one of these parts contains an example of problem and categories of behaviors, with responses. (always, sometimes, rarely).

The researchers ensured the content validity of the questionnaire and reliability coefficient of  $\alpha$ -Cronbach was 0.81, which shown to be significant at (0.01) level. (Cronbach, 1970)

Appendix (1).

### B) Genetics Problem-solving performance Test.

According to reviewing the questionnaire, two equivalent validated problem-solving test were developed with an essay question technique. Each one of them contains 7 problems as follows : 2 monohybrid, 3 dihybrid problems, 1 quantitative and 1 blood groups genetics. For each problem the students were asked to :

- 1- identify the genotype and phenotype.
- 2- identify the ratios from Punnett squares.
- 3- select all possible gamete combinations from genotype, and calculate the probability of zygote combinations.

The reliability coefficient (0.78) was estimated by correlation between the two tests. It was significant at (0.1) level Appendix (2).

### 3- Holistic strategy for genetics problem-solving.

The instructional strategy used in this study involving the following :

- a) Introducing the key concepts of genetics and its relationship by one of the researchers using instructional material and lecture discussion method. The key concepts include, meiosis and gamete formation, chromosomal separation, zygote combination, allelic pair, phenotype and genotypic ratio, monohybrid and dihybrid cross. Special emphasis was given to : the laws of dominance segregation and independent assortment.

b) Representation of procedural knowledge of genetics problem (Algorithms) which include, generated a hypothesis, tested the hypothesis, falsified alternative hypothesis; and evaluated the probability of each hypothesis. By using gene-chromosomes model and diagrams of Punnett squares to illustrate monohybrid and dihybrid cross. Though each Lesson contains :

- brief review of previous lesson.
  - brief introduction of present lesson, discussion on the topic for the lesson during this time, student, are to list all major concept words.
- c) using intensive exercises of monohybrid and dihybrid problem by using Punnett squares. (students manual, appendix (4).

**Procedures :**

The procedures of this study involved the following steps :

- a) Applying genetics problem-solving performance (form A) as a pre-test of students after they have taught genetics unit in a context of biology, year 1995.
- b) Analysing the results of the above step to diagnose the difficulties of problems faced students on this test, and the researchers choosed students they have difficulties (N 80).
- c) Teaching the students using a holistic strategy by one of the researchers.
- d) Applying the genetics problem-solving performance test (form b) after (6) weeks.
- e) Data were collected for analysis and discussion.

**Results and discussion**

(A) Concerning question (1) which states : "what problem - solving behaviors do students employ when investigating secondary school genetics problems?"

**The results showed that :**

The performance of students on (pre - test) of genetics varied from success to fail, table (1 to 7) because some of them can not justify some problems . They success in solving symbolic monohybrid, verbal monohybrid , symbolic dihybrid; and nearly to solve verbal dihybrid problems, (problems 1 to 3) and 4 respectively , but they can not solve problems 5,6,7 for determining genotype of parents from phenotype of offspring, quantitative genes, and blood groups genetics respectively.

## Symbolic monohybrid problem :

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	%	No	%	Yes	%	No	%	
Identify the gamete types of parents.	74	92.5	6	7.5	80	100	0	0	6.23*
Identify combination of gametes and determine genotype of offspring.	73	91.25	7	8.5	80	100	0	0	7.23**
Identify the phenotype of offspring.	69	86.25	11	13.75	79	98	1	1.25	9.01**
Total	73	91.25	7	8.25	80	100	0	0	7.32**

## Verbal monohybrid problem :

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	%	No	%	Yes	%	No	%	
Identify the genotype of parents by using symbols.	58	72.50	22	27.50	74	92.50	6	7.50	11.08**
Identify the gamete types of parents.	59	73.75	21	26.25	75	93.75	5	6.25	11.76**
Identify combination of gametes and determine genotype of offspring.	59	73.75	21	26.25	75	93.75	5	6.25	11.76**
Identify the phenotype of offspring.	58	72.50	22	27.50	74	92.50	6	7.50	11.08**
Total	58	72.50	22	27.50	74	92.50	6	7.50	11.08**

## Symbolic dihybrid problem :

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	%	No	%	Yes	%	No	%	
Identify the gamete types of parents.	50	62.50	30	37.0	76	95.0	4	5.0	25.25**
Draw the Punnett squares and arrange gametes.	49	61.25	31	38.75	78	97.50	2	2.50	32.11**
Identify combination of gametes and determine the genotype of offspring.	50	62.50	30	37.50	78	97.50	2	2.50	30.13**
Identify the phenotypes of offspring.	40	50.0	40	50.0	75	93.75	5	6.25	37.87**
Total	49	61.25	31	38.75	78	97.50	2	2.50	32.11**

## Verbal dihybrid problem.

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	%	No	%	Yes	%	No	%	
Identify the genotypes of parents by using symbols.	41	51.25	39	48.75	65	81.25	15	18.75	16.10**
Identify the gamete types of parents.	43	53.75	37	46.25	72	90.0	8	10.0	26.0**
Draw the Punnett square and arrange gametes.	43	53.75	37	46.25	72	90.0	8	10.0	26.0**
Identify combination of gametes and determine the genotypes of offspring.	43	53.75	37	46.25	72	90.0	8	10.0	26.0**
Identify the phenotype of offspring.	43	53.75	37	46.25	72	90.0	8	10.0	19.26**
Total	43	53.75	37	46.25	72	90.0	8	10.0	26.0**

## Determination genotype of parents from phenotype of offspring.

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	%	No	%	Yes	%	No	%	
Translate the verbal problem into symbols and determine the probable genotype of offspring.	23	28.75	57	71.25	48	60	32	40	15.83**
Identify genotype of parents due to the genotype of offspring.	23	28.75	57	71.25	48	60	32	40	15.83**
Identify the gamete types of parents.	23	28.75	57	71.25	48	60	32	40	15.83**
Draw the Punnett squares and arrange gametes.	23	28.75	57	71.25	48	60	32	40	15.83**
Identify combination of gametes and determine the genotype of offspring.	35	43.75	45	56.25	71	88.75	9	11.25	36.23**
Identify the phenotype of offspring.	33	41.25	47	58.75	57	71.25	23	28.75	14.63**
Total	23	28.75	57	71.25	48	60	32	40	15.83**

Quantitative genes.

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	No	%	No	Yes	No	%		
Identify the genotype of parents by translate verbal problem into symbols.	38	42	47.50	42	42	52.5	47.50	0.40	
Identify the gamete types of parents.	33	47	41.25	47	57	58.75	28.75	14.63**	
Use the Punnett squares and arrange gamete.	33	47	41.25	47	57	58.75	28.75	14.63**	
Identify combination of gametes and determine the genotype of offspring.	33	47	41.25	47	57	58.75	28.75	14.63**	
Identify the phenotype of offspring	33	47	41.25	47	42	52.5	47.5	2.51	
Total	38	42	47.50	42	42	52.5	47.5	0.40	

Blood groups genetics problem.

Problem categories	Pre-test				Post-test				ChiSQ
	Yes	No	%	No	Yes	No	%		
Identify the probable genotype of parents due to the phenotype.	35	45	43.75	45	71	88.75	11.25	36.23**	
Identify the gamete types of parents.	35	45	43.75	45	71	88.75	11.25	36.23**	
Identify combination of gametes and determine the genotype of offspring.	35	45	43.75	45	71	88.75	11.25	36.23**	
Identify the phenotype of offspring.	35	45	43.75	45	71	88.75	11.25	36.23**	
Total	35	45	43.75	45	71	88.75	11.25	36.23**	

This results are closely related to histograms (Fig.1 to - 7) for each problem . This means that students can not identify genotype of parents by using symbol of verbal problems of dihybrid , can not draw the Punnett squares; and can not identify phenotypes of offspring .

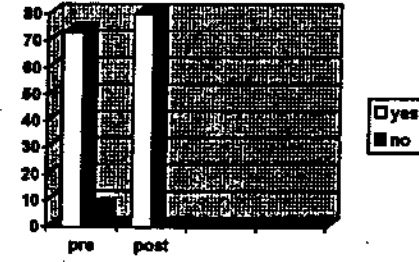


Fig. (1) : Histogram of Problem 1

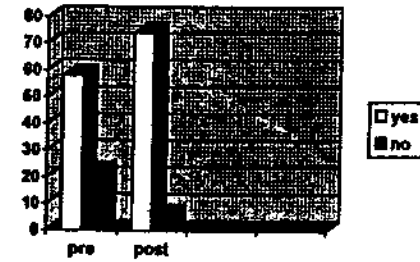
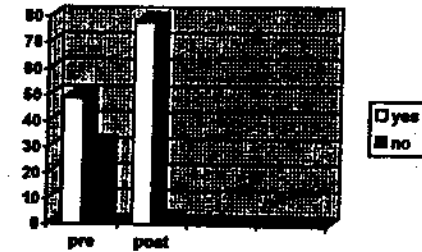


Fig. (2) : Histogram of Problem 2



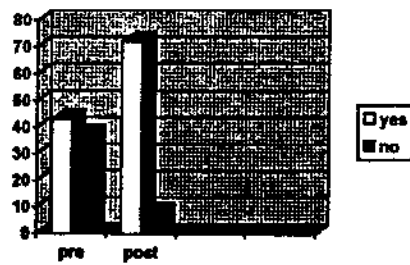


Fig. (4) : Histogram of Problem 4

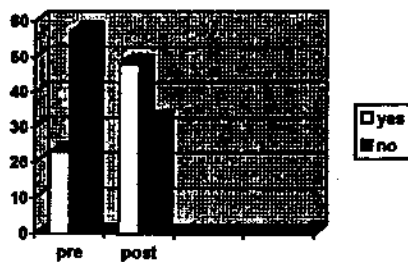


Fig. (5) : Histogram of Problem 5

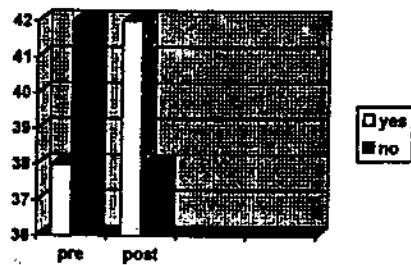
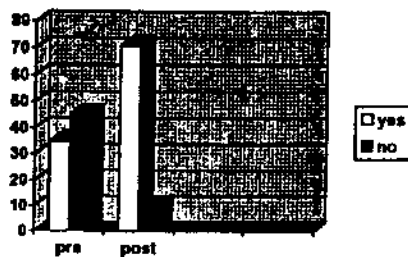


Fig. (6) : Histogram of Problem 6



These results agree with others studies as :

*Browning & Lehman, 1988* which revealed that students of high school genetics faced difficulties with computational skills, difficulties in determination of gametes and inappropriate application of previous learning to new problem situations. It also agree with *Hackling & Treagust, (1984)* mentioned that the failure of students to solve problems of genetics may be due to misunderstanding the mechanisms of inheritance of dihybrid, and relationships with other genetics concepts

Others studies like [*Walker, Hendrix & Mertens 1980 ; Gipson and Abraham, 1985; Smith and Good, 1986; Simmons and Lunnetta, 1993*] showed that these problems of genetics require formal intellectual operations and understanding of mathematics to :

- Identify ratio from the Punnett squares (requiring the use of proportional reasoning).
- Identify combination of gametes from parents genotypes (requiring use of combinatorial reasoning ; and
- Estimate gamete of offspring probabilities requiring use of probabilistic reasoning).

(B) Concerning to question (2), which states that : "what is the effect of a suggested teaching strategy for developing problem solving behaviors of genetics?"

The results showed that there are significant differences between pretest and post-test of genetics problem solving in favour of post-

test, table (1 - to - 7). This is due to the effectiveness of holistic strategy used in this study, the values of chi-sq. were significant at (0.01) and (0.05) level , of all problem categories except problem 6 Quantitative genetics .

These results were also showed by Histogram (Fig. 1 to 7).

The results on this view agree with related studies as *Okebukola (1990)* who concluded that the concept map strategy for students attain meaningful learning of genetics and ecology. He showed that there were significant differences between experimental group (N- 63) and control group (N = 75) in performed the concepts of genetics and ecology , *Simmons & Lunetta (1993)* revealed that the successful students of problem solving exhibited a good problem solving sequences due to the used teaching strategy .

This means that; the holistic strategy used in this study was efficient to mastery of knowledge base and problem solving behaviors.

Because of using procedural knowledge and conceptual organization and relationships ; diagrams of Punnett squares ; and practice examples. This help student to facilitate problem solving .

(C) Concerning to question (3) which states : "what are the distinct strategies which students use when solving genetics problems ?

By using think-aloud protocols analysis technique used in previous studies, "Stewart's model of analysis problem solving

strategies used by students ; and the questionnaire of problem solving steps and behaviors designed for this study . The Researchers analysed written papers and comments of students of the (mono hybrid problem (N = 80) after they performed the post - test .

The results was shown in table (8) .

The distinct strategies for problem solving of (monohybrid genetics . (N = 80) .

No of students	%	distinct strategy
30	37.50	Algorithmic.
11	13.75	Heuristic. a) Means-ends - analysis . b) sub. goals analysis
11	13.75	working forwards
9	11.25	working Backwards
16	20.00	planning
3	3.75	None.
80	100.00	Total

From the above results the researchers conclude that; the common strategies used by student were Algorithmic (procedural steps of problems), 37.5% of students used it, but planning strategy reached to 20% but another strategies were not distincts.

These results agree with other studies like (*Hayes, 1981; Collins, 1986 and Stewart, 1988*) they emphasizes the conceptual knowledge possessed by problem solving behavior, and they have described general proceduses (means - ends - analysis , planning working backwards. but *Finkel (1994)* concludes that, there were

three types of knowledge of genetics during model revision of problem as :

- Knowledge of genetics,
- Knowledge of the process of model revision;
- and Knowledge of students own problem solving strategy .

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