

Building and Using Mathematical – Biological Exercises for Developing Logical Thinking Competency for High School Students in Vietnam

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Abstract Paralleling to the reform of the general education curriculum oriented to learners' competency development in Vietnam is the innovation of teaching methods. The transfer from content-based teaching to competency approach is a difficult task for high school teachers in Vietnam. The purpose of this study is to design a process for the development and use of mathematical-biological exercises in the development of logical thinking competency for high school students in Vietnam. In the article, based on the study on thinking, logical thinking, definition of logical thinking competency, we define the structure of logical thinking competency of high school students as well as build mathematical-biological exercises model and process of mathematical-biological exercises design. From there, we propose the process of using mathematical-biological exercises to develop students' logical thinking competency.

Keywords: *logical thinking, logical thinking competency, mathematical exercises, mathematical exercise model, mathematical-biological exercises*

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1. Introduction

Modern teaching not only forms and develops knowledge for students but the important thing is to develop learners' competencies. One of the competencies that every human being in society needs is the logical thinking competency. This is the competency that many countries choose as core competency to be developed for students.

However, Othman, Hussain and Nikman (2010) argued that many people fail to acknowledge logical thinking as one of the most important factors in determining the level of student in study program. Developing logical thinking competency for students is considered as an important task in teaching to help students develop problem-solving competency, self-learning competency and creativity [1].

In Vietnam, many educators interested in developing thinking competency to learners in teaching in different subjects, such as Vu Minh Tuan (2015) studied how to develop thinking competency through chemical questions and exercises [2]; Thai Thi Hong Lam, Nguyen Thi My Hang (2018), Bui Thi Huong (2013), Cao Thi Ha (2013) studied thinking competency in teaching mathematics [3,4,5].

In each subject, it can be used different methods to develop thinking. In teaching Biology, exercises,

mathematical-biological exercises can be used as competency development tool. Because, as G. Polya said, "the primary task of teaching math problem solving at high schools is *to teach students to think*." Teaching thinking means that the teacher is not only the informant but also develops student's information use competency. At the higher level, the teaching of math problem solving needs to ensure all basic aspects of thinking [6]. He emphasized: "*The math problem solving is not just about finding the answer, but covers the whole process of thinking, exploring the solution as well as explaining the cause of the problem, and finally developing the solved problem, or at least pointing out new directions on the basis of understanding where the problem arises*".

2. Content

2.1. Logical Thinking Competency

2.1.1. Thinking

According to the Encyclopedic Dictionary of Vietnam, Volume III [7]: "Thinking is the highest product of living matter organized in a special way associated with the function of the human brain", thinking positively reflects objective reality in the form of concepts, judgment,

reasoning, etc. Thinking comes in the process of social production of human being and ensures that reality is reflected indirectly, discovering rule- consistent connections of reality.

Physiology considers thinking to be an activity of the high-level nervous system in species with developed central nervous system, especially in humans; It operates on the principle of "reflecting".

Philosophy studies on thinking from the perspective of cognitive theory. Thinking is formed in the process of cognition and practical activities of human being. Thinking and practical activity are closely linked, dialectical connect to each other, which was started by Ph. Henhen: *"So far natural science as well as philosophy have completely disregarded the influence of human activities with their thinking. One of these two disciplines only know the nature, the other only knows the thought. But the fact that people change nature, not the natural world itself, as the natural world, is the most fundamental and direct basis of human thinking and human intelligence has evolved along with the way that people learn how to make nature change"* [8].

In this study, we chose the approach according to the definition in Vietnamese Dictionary by Hoang Phe (2000). *"Thinking is a high-level stage of the cognitive process that goes into the nature and discovers the regularity by forms such as symbols, concepts, theories, and reasoning"* [9], p.42].

2.1.2. Logical Thinking

According to A.V. Petrovski and L.B. Itenxon: "Thinking replacing actions with real things by manipulating concepts according to the rules of logics is called logical thinking" [10,11].

- A. Ozahech highlighted characteristics of logical thinking: Skill of pointing out consequences from axioms, Skills of dividing individual cases and merging them to be the object under consideration; Skill of asserting theories from a specific result or generalizing obtained result [12].

- The author Vu Van Vien (2006) argued that logical thinking is the cognitive stage of reason, using basic forms such as concept, judgment, reasoning and definite logical operations of the subject, to produce new knowledge with the aim of reflecting deeper and more complete on the objective reality [13].

In this study, we define logical thinking as follows: *"Logical thinking is the process of being aware of the object, identifying relevant factors for forming and connecting ideas, to find solutions and actions consistent with the context of the object which is objectively existing."*

2.1.3. Steps of Logical Thinking Process [14]

- According to psychologist K.K. Platonov, stages of the logical thinking process are expressed in the following diagram (Figure 1).

This is the logics of thinking, in some cases, the number of stages may not need to be complete, but the order of stages must comply with the Figure above. The stages of thinking only reflect the external side of thinking. In essence, each stage of the thinking process is a complex process that takes place on the basis of thinking activity to solve problems or posed tasks.

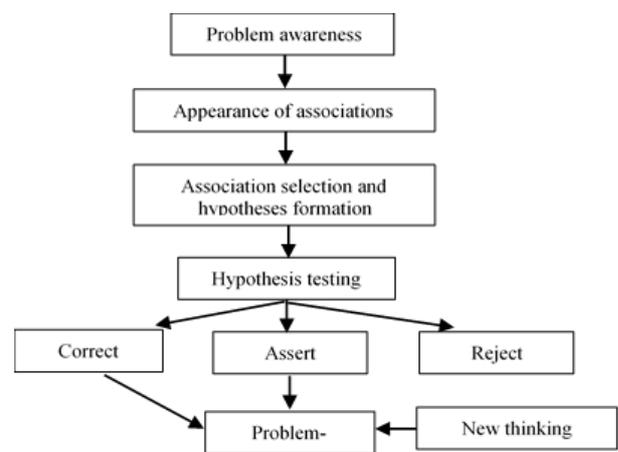


Figure 1. Stages of the logical thinking

2.1.4. Logical Thinking Competency

Hoang Thuc Lan argued that the logical thinking competency is the ability to grasp and manipulate knowledge in human life; is the ability to reflect by association, discover and process information in specific cases or situations. The logical thinking competency does not simply depend on the brain's physiological and psychological abilities but on the two areas of cognition and the application of knowledge into practice [15].

Table 1. Component skills of logical thinking competency

Component skill	Expression
Skill of identifying the object being studied/ investigated	- Preliminary aware and make preliminary judgment or valuable assumption about the object. - Logical action: Approach to the object → identify the object or name the object → define the role / task of object research.
Skill of asking questions, answers related to the object	- Ask inquiries, questions, answers related to the object - Specific logic: From name of the object and the role / task of object research → be able to ask questions about features, characteristics of the object → give the related answers and identify how to learn the object (using which documents, media, tools, measures, etc.)
Skill of forming, connecting ideas	- Search/ mobilize knowledge related to research subject and propose solutions/ object research methods. - Follow this logic: From the typical features of the object → be able to identify things related to the object being studied/ investigated → mobilize learned knowledge about the object (Have you ever had research experience on similar object? From whom and how you can learn experience on object learning?) → Imagine specific steps to learn the object → provide solutions that can be used to study/ learn the object.
Skill of finding solutions and actions	- From proposed ideas, choose one solution as the best and select appropriate methods to implement this solution effectively. - Make plan to implement the solution → implement the selected solution to determine the results.
Skill of analyzing, evaluating, and learning from experience	- Process the results obtained, be able to present relationship between results (using tables, diagrams, charts, graphs, etc); analyze the causal relationship to draw the regularity; make valuable conclusions from the results obtained; think and draw experience for yourself. - Use thinking activities to analyze the solution, consider the gained degree of the solution → think on the solution implemented and draw experience → be able to explain the results obtained and generalize the solution into process applied to similar objects.

Based on the concept of logical thinking by author Hoang Thuc Lan and analysis of logical thinking stages of K. K. Platonov, we argue that: *Logical thinking competency is the ability of the subject to identify interrelated factors to form and connect ideas, in order to find solutions and actions that are appropriate to the context in order for the subject to aware the object.*

2.1.5. Structure of Logical Thinking Competency

Based on the concept of logical thinking mentioned above, we define the structure of logical thinking competency including 5 component skills as follows: Identifying the object being studied / investigated; Asking questions, answers related to the object; Forming, connecting ideas; Finding solutions and actions; Analyzing, evaluating, and learning from experience. Because each skill reflecting a logical thinking activity creates a product of a certain degree of integrity and is organized into a logic that constitutes a logical thinking process. Therefore, it is possible to conceive each component skill as a criterion of logical thinking competency.

2.2. Mathematical-biological Exercises

2.2.1. Exercise

- Exercise is understood as a difficult problem to be solved [16]; Exercise is also a problem, the textbook question containing the conflict that needs to be addressed [17]. Or exercise is the assignment for students to apply what they have learned" [9]. It can be said that exercise is the intermediate product that helps learners perceive, complete knowledge, and apply knowledge into practice.

- It can be seen that "Exercise is a task for students to form new knowledge, consolidate, improve, and improve learned knowledge" [18].

- According to Polya, in theory, the role of the exercise manifests in the binding relationship between the datum (hypothesis) and the unknown (thing to exploit). Particularly the condition/context makes a difference between thinking-oriented exercises [19]. Thus, exercise is the best tool to train the thinking for learners.

An exercise is a set including:

+ Datums: are the information given in the exercise,

which is the basis for the learners to choose and arrange in logical order to effectively solve the requirements of the exercise.

+ Requirements: are the issues that learners must take to create the awareness product through thinking. During the implementation of the requirements of the exercise, learners are trained and developed the thinking through which they possess and improve the quality of knowledge.

2.2.2. Mathematical Exercises

An exercise built to develop formal logical thinking for students is called a mathematical exercise.

A mathematical exercise includes 2 basic sets: the known thing (data) and the thing to be found (result). According to Polya, to find an answer to a mathematical exercise is not important, and the important thing is the process of "thinking about how to solve the mathematical exercise" [20].

To solve a mathematical exercise, it is necessary to use thinking skills to analyze data and to use algorithms to change quantities and combine given data in a logical order. On such basis, a solution to the mathematical exercise is found, and students' thinking is developed.

2.2.3. Mathematical-biological Exercises

A mathematical-biological exercise is a mathematical exercise in which data are biological knowledge and events and the thing to be found is knowledge of biological concepts, processes and laws reflecting the objective reality of the biotic world.

2.2.4. Mathematical-biological Exercise Model

The mathematical-biological exercise model is a model that is built based on formal recognition logic to select, encode and combine organism components of a biological object at organism levels based on a dialectical relationship for the purpose of helping students perceive the biological object. The mathematical-biological exercise model includes objectives, contents, knowledge graph and relationships that are substantially biological. From that point, through condition change, various types of mathematical-biological exercise are created, which helps improve the quality of teaching biology.

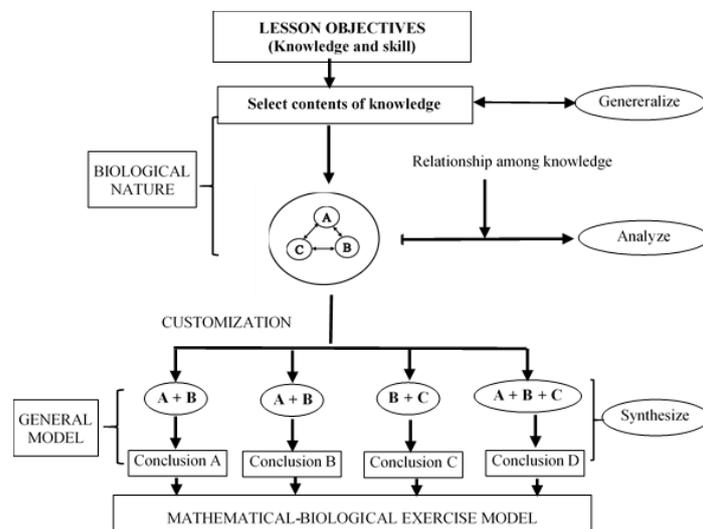


Figure 2. Mathematical-biological exercise model

The model can be generally imagined through the diagram in Figure 2. From the model, biology teachers and educators can design types of mathematical-biological exercise for different teaching purposes.

2.3. Building Mathematical-biological Exercises to Develop Logical Thinking Competency for Students

2.3.1. Requirements for Mathematical-biological Exercises

- *High generality*

The mathematical-biological exercise model is like a coordinate system, and specific mathematical exercises are witness points in such system. The larger the coordinate system is, the higher the generality and the more meaningful the teaching is.

- *When solving mathematical exercises, students can infer the greatest knowledge.*

An algorithm is the tool that is used to understand biological laws. Therefore, mathematical-biological exercises to be built must contain many substantially biological factors and relationships. This means that there must be maximum "biological competency".

- *Mathematical - biological exercises must be appropriate so that students can promote their creativity and use their thinking skills at perception levels without algorithm complexity.*

- *Flexible use*

Mathematical-biological exercises can be used in stages of the teaching process by adding or removing events to ensure proper biological competency and balance the known thing and the thing to be found.

2.3.2. Process of Building Mathematical-biological Exercises to Develop Logical Thinking Competency for Students

Based on the above-mentioned requirements to be met when building mathematical-biological exercises, we would like to propose the process of building mathematical-biological exercises to develop logical thinking competency for students, including 6 steps (Figure 3).

Explanation of the process:

Step 1: *Determine general objectives of a chapter/lesson/topic*

To build mathematical-biological exercises, teachers should study general objectives of a chapter/lesson/topic. From that point, teachers will build proper mathematical exercises and determine contents which can be encoded and designed to mathematical-biological exercises.

Step 2: *Analyze the structure of a chapter/lesson/topic and select knowledge graph for building mathematical-biological exercises*

Based on contents of a chapter/lesson/topic, teachers determine knowledge contents which can be built into mathematical-biological exercises. Notice that, with regard to such knowledge contents, how many quantities can be encoded and how much knowledge can be created, especially what types of thinking can be developed?

Step 3: *Determine relationships that can be used to design mathematical-biological exercise contents according to algorithms*

There is always a cause-and-effect relationship among biological events. To build mathematical-biological exercises which can communicate knowledge and develop logical thinking competency, teachers must determine typical *variables* (biological events and relationships) which can be easily encoded into quantities and introduced in various *contexts* (biological situations). *Variables* and *contexts* are combined to create types of mathematical-biological exercise. If the number of variables is n and the number of contexts is m , there will be $Can.C_m^n$ of mathematical-biological exercises (a and b are the number of variables and the number of contexts in the total number of n of variables and m of contexts).

Step 4: *Based on the mathematical exercise model and customization, determine a combination of mathematical exercises*

The mathematical-biological exercise model and customization are a basis for determining contents, structure and form of a mathematical-biological exercise.

- Hypotheses of mathematical-biological exercises can be direct or indirect hypotheses. In case of indirect hypotheses, intermediate transformation is required, and solvers must meet conclusion requirements.

- One or some properly selected hypotheses will be a basis for orienting how to solve mathematical-biological exercises and satisfy the established objectives concerning thinking practice and development for students.

Step 5: *Express mathematical-biological exercises according to specific context*

Here the context is understood to be the position of mathematical-biological exercises in the perception process, perception level, students' psychology and purposes of teaching mathematical-biological exercises. On such basis, it is possible to properly adjust the known thing and the thing to be found and to ensure knowledge of optimal biology.

Step 6: *Carry out a verification to adjust the mathematical exercise system according to objectives*

Based on objectives, a verification is carried out to adjust contents, easy and difficult levels, perception level, implementation time and implementation space.

Step 1	Determine general objectives of a chapter/lesson/topic
Step 2	Analyze the structure of a chapter/lesson/topic and select knowledge graph for building mathematical-biological exercises
Step 3	Determine relationships that can be used to design mathematical-biological exercise contents according to algorithms
Step 4	Based on the mathematical exercise model and customization, determine a combination of mathematical exercises
Step 5	Express mathematical-biological exercises according to specific context
Step 6	Carry out a verification to adjust the mathematical exercise system according to objectives

Figure 3. Process of building mathematical-biological exercises to develop logical thinking competency for students

2.4. Using Mathematical-biological Exercises to Develop Logical Thinking Competency for High School Students

In order to use mathematical-biological exercises to efficiently develop logical thinking competency for students, we propose the 3-stage process (Figure 4).

Analyzing the process (with examples)

Stage 1. Instruct students to use some thinking skills to solve mathematical-biological exercises

- Introduce and analyze the mathematical exercise structure to help students identify types of mathematical-biological exercises and classify these exercises.

- Instruct students to use each skill and then to solve mathematical-biological exercises.

During the process of instructing students to follow the steps, teachers ask students to pay attention to the road to knowledge creation, the method of following the steps, and means and tools.

Stage 2. Use mathematical-biological exercises to develop logical thinking competency for students

This stage aims to use mathematical-biological exercises as a tool for teaching organization, helping students acquire knowledge and develop their logical thinking competency. This stage consists of the following 5 steps (Table 2).

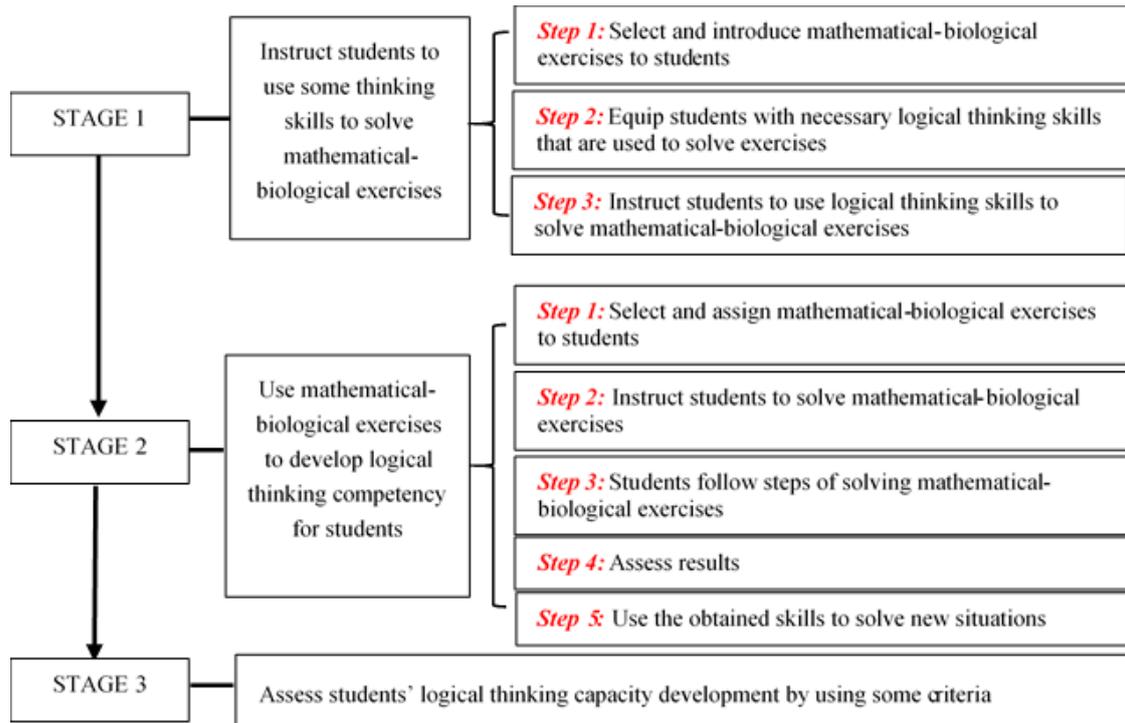


Figure 4. Stages of using mathematical-biological exercises to develop logical thinking competency for students

Table 2. Steps of using mathematical-biological exercises to develop logical thinking competency for students

Steps		Teacher's activities	Students' activities	Results to be achieved
Step	Step name			
1	Select and assign mathematical-biological exercises to students	Select and assign proper mathematical exercises to students	Receive and study topics; analyze data to understand topic information; and determine hypotheses and topic conclusion.	Students know how to determine parts of and analyze the structure of mathematical-biological exercises
2	Determine how to solve exercises	Give exercise solving suggestions to students	- Determine and underline key words - Determine relationships and contradictions among data, and between the known thing and the thing to be found. Then determine the method of solving exercises	Students determine the relationship between the thing to be found and the known thing to find a solution to exercises
3	Solve exercises and report results	Ask students to solve mathematical-biological exercises in a team or individually	Use the known related knowledge, change topic data and report results	Use the related knowledge to solve mathematical-biological exercises
4	Draw a conclusion and standardize knowledge	Synthesize students' report results and standardize results of solving mathematical-biological exercises	Make team discussion and report results of solving mathematical-biological exercises	Students report and explain the achieved results and state the method of solving mathematical-biological exercises
5	Use the obtained skills to solve new situations	Change data and create new situations	Use the obtained knowledge and thinking skills to solve similar exercises	Students know how to use thinking skills to solve similar or advanced mathematical-biological exercises

Illustrative example of the use of mathematical-biological exercises of the rule of genetic phenomenon that represents the steps of phase 2

Step 1: Select and assign mathematical-biological exercises for students

* *Purpose:* Based on the goals (knowledge, development of logical thinking skills), select appropriate mathematical-biological exercises.

* *Activities of teachers:*

- Teachers select and assign mathematical-biological exercises to students. Teachers need to determine the time of assigning mathematical-biological exercises to students in accordance with teaching goals.

Example: To teach a unit of knowledge in gene interaction rules and to develop the skills of analysis, synthesis, generalization, and reasoning, teachers may choose mathematical-biological exercises for students to do in 5 minutes as follows:

Problem: After the cross between red flowers with white flowers (P), F1 obtains 100% red flowers. Continue with hybrid between F1 red flower with yellow flowers creating F2 including 300 red flowers: 401 yellow flowers: 102 white flowers? Determine the genetic nature of the characteristic.

The purpose of using this mathematical-biological exercises is to help students identify their learning tasks, so teachers need to emphasize the requirements via questions, situations, etc, to make them ready to perform logical thinking skill in order to gain knowledge effectively.

* *Activities of students:*

After receiving mathematical-biological exercises, students begin to think: Generalize problems → Analyze information → Determine the problems

Step 2: Orient methods to the problems

* *Purpose:* To determine the method and order of steps to solve the mathematical-biological exercises

* *Activities of teachers:*

Teachers are mentors who instruct students on how to find and use relevant knowledge via questions, situations, or appropriate mathematical-biological exercises. For weak students, teachers need to give suggestions; Conversely, good students may take the initiative without the support of teachers.

With the above mathematical-biological exercise, teachers use suggestion: If F1 is gay, how will the genotype of P be? What do you say about the genotype of F1? How many gamete combinations does F2 have?

* *Activities of students:*

Based on conclusions on mathematical-biological exercises, students identify facts and relationships. Students visualize, reconstitute, select and organize relevant knowledge to orient solutions.

With the above mathematical-biological exercise, students review all knowledge of how to calculate the number of gametes of F1 when knowing the number of gamete combinations of F2; then determine the genotype of F1 and conclude on the genetic nature of the flower color characteristic.

Step 3: Solve mathematical-biological exercise

* *Purpose:* To use knowledge, algorithms and logical measures (inductive, interpreting method) to solve each problem in the mathematical-biological exercise.

* *Activities of teachers:*

Teachers still make orientation to help students make the transition to find the results of the mathematical-biological exercises. Teachers need to pay attention to the contradictions included in mathematical-biological exercises to guide students to use appropriate logical thinking skills.

* *Activities of students:*

After reviewing and selecting knowledge, based on the conclusions of the mathematical-biological exercises, students apply mathematical formulas, transformations, and transition to find results.

To make conclusion from the above exercise, students perform three specific tasks: From P → F1, F1's genotype is heterozygous; From the rate of phenotypes in F2 → comment that F2 has 8 gamete combinations, so 8 gamete combinations = 4 gametes x 2 gametes → draw conclusion: flower color characteristic is determined by 2 pairs of independently segregated genes, and the supplemental effect between two non-allele dominant alleles, yellow flowers created with two gametes, thus one pair of genes is heterozygous and one pair of genes is homozygous recessive so that F2 creates enough three phenotypes at a 3: 4:1 ratio, write the hybrid outline, based on the phenotype of F2 → make conclusion about the genotype of F1 and P.

Step 4. Make conclusion and make knowledge accurate

* *Purpose:* Teachers give answers and conclusions, help students to perceive the problem, reinforce and complete their knowledge.

* *Activities of teachers:*

Allow students to discuss and report their findings and give suggestion after using logic thinking skills in the process of solving mathematical-biological exercises.

Teachers synthesize the comments and the correct results, guide students to use logical thinking skills and to generalize gained knowledge.

With the above mathematical-biological exercise, The teachers ask students to re-analyze the characteristics of the mathematical-biological exercises, then generalize it into more general knowledge that with the complementary interaction of two non-allele dominant alleles in 9: 6: 1, which means that in the appearance of two non-allele dominant alleles, the plant's phenotype is red flowers while with only one dominant alleles, the plant's phenotype is yellow, and for the lack of both dominant alleles, the plant's phenotype is white flowers. Therefore, when F has 8 gamete combinations, the phenotypic segregation ratio is 3: 4: 1.

* *Activities of students:*

Students argue, make hybrid outlines and discuss in groups, make self-assessments and assessments. To make this step work, students are required to be proficient in comparing the results with the requirements of the mathematical-biological exercises and with the theory of types of genetic interactions that makes the learned theory clear.

Step 5. Apply knowledge and solve new situation.

* *Purpose:* Assist students in reinforcing their acquired knowledge and flexibly using knowledge to solve similar or new and strange mathematical-biological exercises.

* *Activities of teachers:*

Teachers can change an element in the exercise, or keep the original situation, or change the situation ... or create

further new situations, then ask students to solve new problems in mathematical-biological exercises, and find the corresponding conclusions

** Activities of students:*

Use logical thinking skills to analyze, identify new situations, apply knowledge and algorithms to solve, find results.

Stage 3. *Assess the ability to acquire knowledge and the level of development of logical thinking competency in students*

This phase is intended to help teachers evaluate each student's ability and also help students evaluate themselves or evaluate each other's learning processes, understand the meaning of each skill; Teachers receive feedback information to control the teaching process.

Example: F1 maize pollinates, the F2 phenotype was decomposed at the rate of 9 long pollen plants, red seeds, 4 short pollen plants, white seeds, 3 short pollen plants, red seeds. Knowing that seed color is determined by a pair of genes.

1. The question assessing the levels of development of students' logical thinking competency:

- a. What type of mathematics is this exercise? Have you ever met that type or its similar type?
- b. From the given data, suggest the conclusions for the mathematical exercise?
- c. Recommend some methods to solve that mathematical exercises.
- d. Evaluate the solution you have chosen
- e. Generalize a solution to that kind of mathematical exercise.

2. The question assessing students' ability to acquire knowledge:

- a. Which part of knowledge do you use to solve this mathematical exercise?
- b. How many genetic rules that governing the two above characteristics?
- c. Please argue for P's genotype and make hybrid outline for verification.
- d. The knowledge and skills learned by solving this mathematical exercise?

3. Conclusion

Teaching in accordance with the new curriculum is the goal of reform in the current high schools in Vietnam. Our research mentions the development and use of mathematical exercises as a tool for developing students' logical thinking competency in teaching new knowledge, completing, consolidating, improving knowledge and

skills. This study can be considered as a reference to help high school teachers meet the new curriculum.

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