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**Developing critical thinking in biology and health education teaching – 7th grade “Type of molluscs”**

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**Abstract:** *In recent years, research related to critical thinking has increased significantly. The new educational paradigm emphasizes the development of 21st-century skills, one of which is critical thinking, declaring it a fundamental skill for learning in the 21st century. Critical thinking is a set of skills that need to be integrated into all disciplines so that students can become aware of their own thought processes, make informed decisions about their future development, and take responsibility for the consequences of their actions. The biology curriculum provides students with this opportunity by placing them in situations where they have to solve biological, environmental, and health problems, propose solutions, analyze, and become aware of their actions. The article presents the application of a three-stage model "I know – I want to know – I learned for the development of critical thinking in the study of the topic "Type of Molluscs" in Biology and Health Education in 7th grade.*

**Keywords:** critical thinking, biological education, students, educational technologies, teaching strategies

**Introduction**

The globalization of modern society, digitization and digitalization, and the advent of artificial intelligence have led to the need for urgent changes in the educational process. The new educational paradigm needs to adapt the learning process to the conditions and needs of the future information generation. The set of skills needed for life in the 21st century is constantly expanding and changing dynamically. These skills are related to our thinking. They represent a set of personality traits, behaviors, and attitudes that allow individuals to communicate effectively, collaborate with others, navigate difficult situations, and direct their efforts toward achieving goals, self-assessment, and self-actualization. These competencies are related to the development of new, "analytical"

thinking that is not guided by certain boundaries, flexibility and adaptability, problem solving, and proposing workable solutions. To all these competencies we can also add critical thinking as a component skill, "which, however, is not always consistently and systematically present in the curriculum." [1].

Critical thinking is one of the most important skills that students will increasingly need. This means not just reproducing information, but the ability to understand, analyze, and draw conclusions from it [2].

The development of critical thinking is enshrined in various regulatory documents. The Strategic Framework for the Development of Education, Training, and Learning in the Republic of Bulgaria emphasizes the development of transferable skills, one of which is critical thinking [3]. Critical thinking is also part of the 21st-century skills listed in the Partnership for 21st Century Skills (P21) Framework, known as the 21st Century Learning Framework [4]. It identifies four areas of critical thinking skills: 1) effective interactions; 2) use of thinking models; 3) making choices and decisions; 4) problem solving [1].

But what do the facts show? PISA results show that more than half of Bulgarian students lack the skills for critical and analytical thinking, making logical connections, reading with understanding, interpreting events, arguing, and solving everyday problems. The PISA 2022 results are among the lowest ever observed in all three subjects: an initial increase in 2006 – 20.3%, in 2012 – 16.6%, leading to the 2022 performance, which is close to the 2006 values. The difference between the average results from 2012 and 2022 in all subjects is greater than the expected achievements of 15-year-old students over a whole year. In the most recent period (2018 to 2022), the difference between the highest-performing students (10%) and the lowest-performing students (10%) has not changed significantly [5]. The lack of basic skills and the low proportion of top-performing students are an obstacle to the development of skills, competitiveness, and innovation. In the 2022 edition of the OECD's Programme for International Student Assessment (PISA), 48% of Bulgarian students performed poorly in science [6].

The development of critical thinking skills is also present in the 7th grade biology and health education curriculum, which focuses on developing skills for critically evaluating information, understanding and analyzing the connections between different arguments; problem solving and decision making; evaluating ideas, arguments, and assumptions [7]. These skills are developed through the use of logical operations – definition, classification, and proof – and are represented by the corresponding verbs – define, classify, interpret, analyze, evaluate, etc. As expected, outcomes of the development of critical thinking in biology and health education, students should [7, 8]:

- *Reason effectively* – use different types of reasoning (inductive, deductive, etc.) depending on the situation;

- *Use systematic thinking* – analyze how parts of a whole interact with each other to achieve common results in complex systems, e.g. describe the structural and functional basis of organs and organ systems in basic vertebrate taxa;
- *Make judgments and decisions* – Justify the need for prevention of diseases caused by invertebrates and injuries caused by biogenic poisons;
- *Discuss, analyze, and evaluate* evidence, arguments, claims, and beliefs, e.g. Discuss issues and apply rules related to the protection of personal and public health, biodiversity, and the natural environment;
- *Analyze and evaluate key alternative* points of view. Evaluate and support activities aimed at protecting biodiversity, the natural environment, and personal and public health;
- *Synthesize and make connections* between information and arguments, e.g. Predict the results of human impact on nature;
- *Interpret information and draw conclusions* based on the best analysis, e.g. Comment on options for individual contributions and lifestyles for nature conservation;
- *Think critically* about learning experiences and processes, e.g. test hypotheses and argue possible solutions and justifications for positions on balanced and nature-friendly consumption of energy resources;
- *Solve unfamiliar problems* in both conventional and innovative ways;
- *Identify and ask meaningful* questions that clarify different points of view and lead to better decisions – comment on the role of national and supranational protected areas in preserving biodiversity.

#### *The essence of critical thinking - key elements and characteristics of critical thinking*

Critical thinking has been the subject of much debate and reflection since the time of early Greek philosophers such as Plato and Socrates, who said that the ability to think critically involves rigorously questioning ideas and assumptions rather than accepting them as "given". In pedagogy and psychology, critical thinking is considered a higher-level form of thinking. Critical thinking means the ability of students to think clearly and rationally, to formulate basic ideas accurately, and to discover the logical connection between them.

The idea of developing critical thinking was systematized and defended by the American philosopher John Dewey, who believed that "successful learning requires not only the simple transfer of knowledge from teacher to student, but also the creation of critical thinking skills" [9]. This thinking arises only when learners are not placed in a situation where they have to reproduce a specific solution, but are encouraged to seek one in relation to a given problem. According to Dewey, "The basic question that can be asked in teaching about a situation or phenomenon is what kind of problem causes this phenomenon?" [9]. Dewey believes that encouraging the development of

critical thinking is a fundamental goal of the teacher, who motivates students to identify the problem, orient themselves towards this new way of exploring ideas, and succeed in formulating their own problems.

When analyzing the concept, it is often equated with the concepts of "analytical thinking", "logical thinking", and "creative thinking". Regardless of the interpretation, the main components included in the structure of the concept of "critical thinking" are [10]:

- Thinking related to logical thought patterns;
- The information necessary to expand knowledge, which in turn allows for the performance and deepening of more complex thought operations;
- Asking questions and solving problems – the question "sets in motion" cognitive activity aimed at solving certain problems and clarifying specific uncertainties. The question also helps to identify and formulate a given problem. Therefore, "those who know how to think know how to ask questions";
- Searching for convincing arguments – problems usually take the form of questions. Once the problem is identified, a thesis emerges, which is a thought expressing an attitude toward the problem, supported by various arguments, i.e., if the problem appears in the form of a question, the thesis must be a reasoned answer to that question;
- Understanding – the need for understanding leads to knowledge. Psychologists define understanding as a process in which the superficial structure becomes deep and internal.

The development of critical thinking is a cognitive process that is an integral part of the educational structure. In this sense, P. Petrov and M. Atanasova share that "critical thinking is not taught separately from the general context of education" [11]. It is a purposeful, planned, and precisely timed process through which active and interactive teaching and learning techniques are applied, providing lasting and accessible knowledge. Critical thinking is a new, sophisticated type of thinking that can and must be developed. It is focused on solving problems that require special skills: the ability to analyze, make decisions, interpret, form conclusions, evaluate, etc. [12].

Steel et al. define critical thinking as a complex, active, and interactive cognitive process of "creatively combining ideas and resources, applying new concepts, and restructuring concepts and facts". Or, in other words, "critical thinking is a complex thought process that begins with information and ends with decision-making" [13]. The process of teaching biology and health education is based on connecting students' new knowledge with familiar or previously acquired knowledge and their awareness of it. In this way, the students understand the information they have become aware of by building on their knowledge. In order to gain a full, lasting, and critical understanding of biological knowledge, students must be engaged and motivated by providing them with a positive environment for active participation in the educational process. In this way, individual cognitive knowledge is

formed at the "level of awareness, by building a pre-established framework for thinking about a given topic, case, or problem" [13]. In the context of this definition, the main role of critical thinking is expressed in the accurate definition and understanding of the meaning of specific ideas, a skeptical attitude towards them, an in-depth systematic analysis of conflicting points of view, and the construction of complex systems of reasoned opinions supporting a particular position based on these systems. By understanding the problems that are raised for consideration in the learning process and anticipating the path to their solution, the student arrives at a correctly formulated solution [14].

According to Cluster, "only by acquiring critical thinking skills can learners find the direct link between learning as a process and their own activities and interests" [15]. The author points out 5 main characteristics of critical thinking:

- It is independent – we must be able to form our own opinion based on knowledge we have already acquired;
- Information is the starting point (not the end point) of critical thinking;
- It begins with asking a question and is oriented toward problem solving;
- It seeks convincing arguments, as there may be more than one solution, and it must be proven why the preferred statement is logical and practical;
- It is necessary to discuss and challenge ideas in order to improve one's own position [15].

The development of critical thinking skills, as part of the expected outcomes, is included in the Biology and Health Education curriculum for 7th grade. This is achieved through the basic forms of thinking: concept, judgment, and inference through the application of analysis, synthesis, comparison, abstraction, generalization, and classification.

The analysis of the literature allows us to summarize the following: Critical thinking is the ability to understand information and reflect on it, to ask questions, to propose solutions to solve problem situations. Therefore, it is necessary to update students' 'old' knowledge, on the basis of which they are involved in a systematic process leading to the discovery, restructuring and understanding of new knowledge. It is important for students to understand what they know, what they do not know and what they want to learn. Consideration and critical analysis are related to in-depth discussion of how new knowledge can be applied to old knowledge and how old knowledge can be changed to assimilate and make sense of new information. The author believes that this three-stage model is one way to develop critical thinking because it focuses on the acceptance and appreciation of differences, on the one hand, and on the creation and maintenance of interest, on the other. Critical thinking requires inspiring the independent thinking of each student, rather than memorizing and reproducing ready-made

information. Biology content in 7th grade includes information that is often difficult for students to understand. At some point, it is necessary to create an atmosphere that changes the motivation for learning.

The model for developing critical thinking is partially identical to the classical lesson structure, where the components of updating basic knowledge, motivating learning activities, and understanding the learning material are elements of the overall organization and implementation of the learning process. To this end, without claiming to be exhaustive, I believe that this model for developing critical thinking, which includes reading, analyzing information, and writing, is an alternative for improving the structure of the lesson. By reading and analyzing new information, students become aware of the available knowledge reserves and apply them in the thinking process. Writing represents the active participation of students in the concrete activity where their knowledge becomes visible. This is precisely what independent, critical thinking is, which includes presenting arguments, searching for connections between information and arguments, presenting solutions, and drawing conclusions.

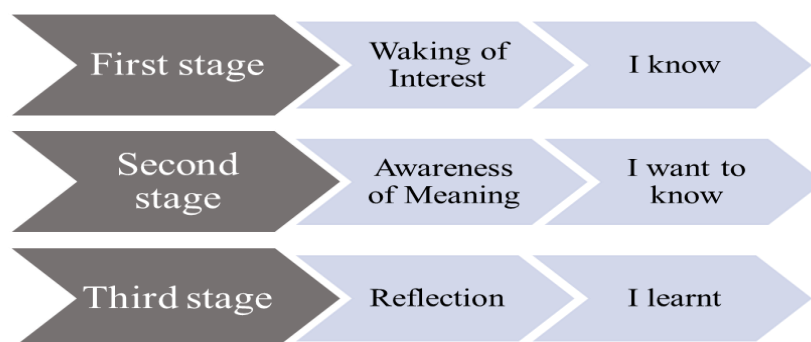
## Materials and Methods

The purpose of this article is to share the application of a three-step model I know – I want to know – I learned (ZIN) when studying the topic "Mollusks," which is part of the biology and health education curriculum in 7th grade, to develop students' critical thinking skills – problem solving and finding solutions to different situations, distinguishing between facts and concepts.

The main methods used in the study are theoretical analysis, observation, INSERT strategy, and discussion. The presented model has been tested with 20 7th grade students studying at the Kliment Ohridski Primary School in Pleven during the 2021/2022 school year.

The applied three-stage model I Know – I Want to Know – I Learned includes the following stages: Awakening interest – Realizing meaning – Reflection. (Evocation-Realization-Reflection; ERR") (Figure 1). This technology was proposed by American educators J. Stil, C. Temple, and K. Meredith and is known as the technology for developing critical thinking (TCDT) [13].

- *The first stage (awakening interest)* aims to provoke the reproduction of old information and awaken interest in examining a new problem (mobilizing old knowledge). This component is essential because all lasting knowledge is perceived in the context of what is already known and understood. The functions of this stage are: motivational - stimulating interest in the new concept, encouraging work with new information; informational - using existing knowledge that students have on the topic; communicative - all students are given the opportunity to offer their views on the topic [16];



**Figure 1.** Three-stage teaching model [13]

- *Second stage (realizing the meaning)* - students become familiar with the new information while maintaining active engagement on their own. The main goal of this stage is to monitor the process of students' assimilation of new material. The main thing is to maintain the interest generated during the first stage and to support the students' efforts to control their understanding, to connect the new with the familiar, i.e. "build bridges between old and new knowledge" [13]. The main functions at this stage are: informational – obtaining new information on the topic; organizational – classifying knowledge by degree; motivational – maintaining interest in the topic [16];

- *The third stage is called reflection.* Krasteva defines reflection as a research process that involves analysis of one's own actions and internal psychological states [14]. The third stage is crucial for the development of critical thinking in students, as its main tasks are not only to summarise and systematise the material studied, but also to reflect on the process and results of the educational activity of both oneself and other students. During reflection, an opportunity is created for the exchange of ideas between students. This leads to the expansion of their communication skills, as well as the presentation of different schemes that they consider while creating their own. This entire process takes the form of a discussion. The main functions at this stage are: informational - acquiring new knowledge; communicative - summarizing new knowledge; motivational - encouraging the expansion of knowledge on the topic studied; evaluative - comparing acquired and existing knowledge on the topic [16].

## Results and Discussion

**I. Awakening interest.** The main goal is to arouse curiosity and activate knowledge related to the topic of the lesson, to provoke students to come out of a state of apathy, boredom, and fatigue. We start with a "warm-up strategy" where students are asked to write a short text, with each sentence beginning with the words

"fortunately" or "unfortunately." Here is an example from the students' texts: *"Fortunately, I woke up on time this morning. Unfortunately, I realized that I had to give a presentation today, but I had forgotten to prepare it. Fortunately, I found out that the teacher would be absent. Unfortunately, I found out that someone else would be substituting for him."*

*"Fortunately, I found out that we were going on a field trip today. Unfortunately, it started raining, but fortunately, that didn't change my mood."*

*"Unfortunately, we have a biology test today. Fortunately, I am prepared. Unfortunately, the test was very difficult. Fortunately, I did well."*

Next, apply the "brainstorming" method. The word MOLLUSKS is written on the board, and students are given time (2-3 minutes) to write down everything they know or think they know about them. Questions are asked to guide the students: What do you associate with the concept of mollusks? Have you encountered mollusks in your daily life? Why do you think they are called mollusks? Which do you think are more dangerous—octopuses or snails? Why? What would you like to learn about these creatures? This is followed by an interactive provocation called "Knowledge vs. Reality." Students watch videos showing the movement of an octopus, the use of ink in the mating ritual of cuttlefish, and the cooking of mussels and snails – [https://youtu.be/APdRR2bL\\_Z0](https://youtu.be/APdRR2bL_Z0)- movement of an octopus, <https://youtu.be/7ka7kR31aQI> - use of ink in the mating ritual of cuttlefish. This is followed by a short discussion on the following questions:

1. Were you surprised by any of the facts presented in the videos? What surprised you?
2. Can mollusks be intelligent? Justify your answer.

After completing the activities in the first stage, students write their answers in the first and second columns of the table: I KNOW – I WANT TO KNOW – I LEARNED (Table 1).

**Table 1.** Presentation of some of the students' answers

| I KNOW                                                                                                                                                        | I WANT TO KNOW                                                                                                                                                         | I LEARNT                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mussels, snails, octopus have a soft body;<br>They can crawl – the snail, or swim – octopuses. Mussels attach to rocks; they inhabit saltwater or freshwater; | How the shell is formed in snails and mussels?<br>Why cuttlefish and octopuses do not have a shell?<br>Where are the eyes in mussels?<br>Where is the head in mussels? | Mollusks are three-layered animals. They have soft body, where their name comes from, a head, a body and a foot. They have a mantle that surrounds the body, a shell that is formed from the mantle. For the first time in |

|                                                         |  |                                                               |
|---------------------------------------------------------|--|---------------------------------------------------------------|
| Octopus has tentacles, snails and mussels have a shell. |  | mollusks, salivary glands form, and a heart and liver appear. |
|---------------------------------------------------------|--|---------------------------------------------------------------|

**II. Awareness of meaning.** The main goal is to acquire new knowledge through discovery, comparison, and analysis.

At this stage, INSERT is applied - a strategy for effective reading and thinking through marking, which is a means of controlling comprehension [17]. Students are given a time limit (15-20 minutes) within which they are tasked with reading the educational content presented in the topic "Mollusks" on pages 91-92 of the textbook. After reading, each student fills in a table of symbols, following the requirements for classifying information. The symbols reflect the attitude towards the information as a whole (Table 2):

„√“ – This sign means that what you are reading is known to you or you think you know;

„+“ – This sign means that some of the information is new to you;

„–“ – This sign means that some of the information you are reading is different from what you knew or thought you knew;

„?“ – This sign means that there is information that bothers you or you want to learn something new about the subject.

**Table 2.** Presentation of some of the students' answers

| <b>Characteristics and basic processes of vital functions</b> | <b>„√“<br/>I know</b>                  | <b>„+“<br/>New information</b>      | <b>„–“<br/>Different than what I know</b>  | <b>„?“<br/>Something new on the topic</b>                       |
|---------------------------------------------------------------|----------------------------------------|-------------------------------------|--------------------------------------------|-----------------------------------------------------------------|
| Body plan                                                     | Shell, head, body, foot                |                                     | Mantle                                     | How the shell is formed?                                        |
| Movement                                                      | Through muscle foot                    |                                     | The muscle foot is modified into tentacles | Where the muscle foot is in mussels and cuttlefish?             |
| Digestive tract                                               | Mouth-esophagus-stomach-intestine-anus | Snails have chitinous teeth         | They have foregut, midgut and hindgut      | What does the feeding process in mussels and octopuses involve? |
| Respiratory system                                            | Gills and lungs                        | Gills are modified part of the skin |                                            |                                                                 |

|                     |                                                    |                                                        |                                   |                                                                            |
|---------------------|----------------------------------------------------|--------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------|
| Urinary tract       | Undigested material is eliminated through the anus | Through kidneys                                        | Kidneys are large, metanephridium |                                                                            |
| Vascular system     | They have heart and blood vessels                  | Mollusks reproductive system has a different structure |                                   | Why is blood colorless? What is the role of the three hearts in octopuses? |
| Reproductive system | Hermaphrodites                                     |                                                        |                                   |                                                                            |
| Nervous system      | They have statocysts                               | A brain is formed                                      |                                   | Why are octopus brains amazing? How many brains do the mollusks have?      |

After time for work expires, a discussion on the topic follows, during which students gain a clear understanding of the mollusks' characteristics that distinguish them from other invertebrates. The emphasis is on the peculiarities of their internal structure, the first appearance of a liver, salivary glands, and heart.

**III. Reflection** - the main goal is for students to answer: What did I learn? How can I use it? by filling in the third column of Table 1, after which personal-reflective questions are discussed in a subsequent discussion, and the overall course of the lesson is evaluated.

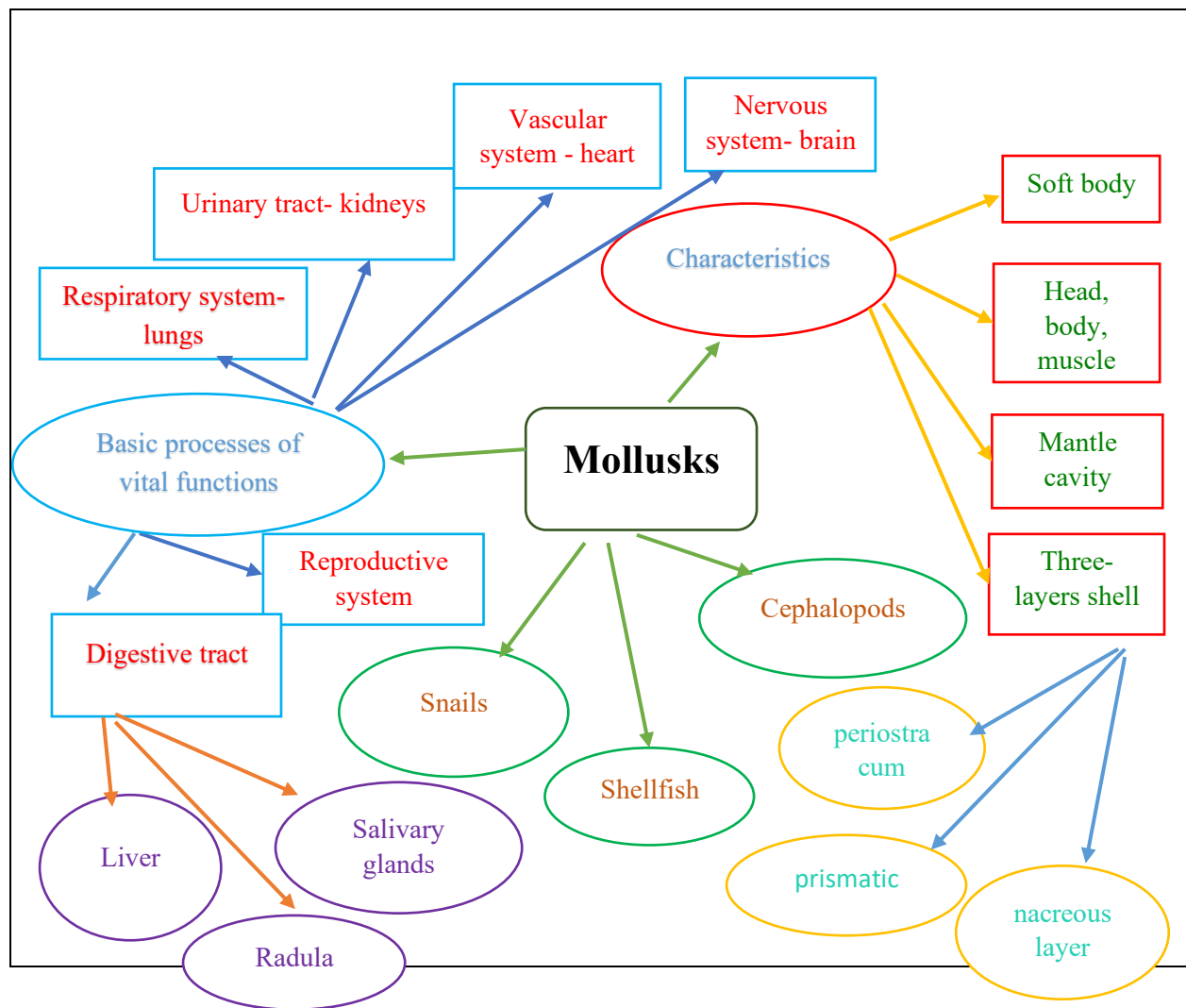
1. The most interesting thing I learned today is.....
2. One of the things I didn't understand today is....., or I want to learn more about .....
3. Has your perception of your own capabilities changed?
4. How can I check if information I found on the Internet about mollusks is reliable?
5. Do you feel satisfied with your work during the class?
6. Do you think that applying this model helps you understand the learning content?

Some of the answers students wrote down include: *I didn't know that octopuses have three hearts; I learnt that mussels don't actually have a head or a radula. I learnt that all octopuses are actually poisonous, because we use them for food. I learnt that the main reason for the short lifespan of octopuses is their reproduction. I didn't know that snails have a goiter and a tongue with teeth. I didn't know that snail blood is blue.*

During the discussion, students shared they understood the essentials of the lesson, they feel satisfied, they prefer this way for biology classes to proceed because the application of this strategy is aimed at their ability to

think while reading the learning content - they make connections with the knowledge they have regarding the topic. They feel part of the lesson; the perceptions of their own capabilities change. As a final assessment, they share they feel satisfied with the lesson.

To summarize and organize the foreground, students build an intellectual map in which they present new concepts related to the topic of the lesson (Figure 2).



**Figure 2.** Intellectual map centered on the concept "Molluscs"

## Conclusion

Without claiming to be exhaustive, I believe that the application of the three-stage model showed an opportunity to build a deeper understanding, independent thinking and active participation of students when studying "Mollusks". This method changes the attitude of students from the traditional reproduction of information to critical thinking. This encourages students to ask questions, make connections between their own knowledge and the analyzed information, and evaluate and interpret different points of view. Students demonstrated the ability to think effectively, analyze information and solve complex problems, make assumptions, analyze their own and others' actions, make good decisions, and develop social skills. The clear structure of the three stages allows learners to activate their prior knowledge and form a cognitive attitude - What do I know? In the work process, they are given the opportunity to explore, draw conclusions, ask critical questions - What do I want to know? Finally, they reflect on what they have learnt and apply the knowledge in new situations - What have I learnt and how can I apply it?

The model for developing critical thinking through reading and writing changes the motivation, inspires each student's active thinking, depending on the individual opportunities for using the knowledge they have.

This way, Biology classes not only improve the general psychological climate, but also increase the effectiveness of learning, making it deeper, more conscious and socially significant.

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