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EXPLORING THE DEVELOPMENT OF PROCEDURAL KNOWLEDGE AND RELATED COMPETENCIES THROUGH STUDY OF BIOLOGY IN MIDDLE AND HIGH SCHOOLS IN ROMANIA

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ABSTRACT. The current educational paradigm implemented worldwide is the development of competence comprising knowledge, skills, and attitudes. This research aims to investigate the acquisition of procedural knowledge and competencies targeting this type of knowledge through the study of Biology in middle and high schools in Romania. The paper first provides a brief overview of the history and existent usage of the concepts of competence and procedural knowledge. Moreover, it describes the Romanian educational system from a diachronic perspective. Following this, a careful analysis of middle and high school Biology syllabi is conducted. Particularly, development of procedural knowledge and competencies targeting procedural knowledge in these documents is examined critically. The results of this analysis indicate that, even though syllabi mention competence and procedural knowledge, they need more concrete activity guidance and assessment to train them. Finally, an online survey targeting high school ninth-graders and first-year university students is applied and analyzed. The survey assesses the implementation of instruction based on procedural knowledge. The results reveal the need for more logistics (laboratories and instruments) provision in schools and for carrying out practical activities.

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A need for reconsidering Biology syllabi, educational investment, and teacher preparation is necessary to succeed in developing procedural knowledge and competencies associated with this, through the study of Biology.

Keywords: procedural knowledge, competencies, curriculum, Biology syllabus, practical activity, competency-based education, middle school, high school.

ZUSAMMENFASSUNG. Das weltweit implemmentierte pädagogische Paradigma verfolgt die Entwicklung von Kompetenzen die das Wissen und unsere Fähigkeiten und Einstellungen umfassen. Diese Recherche hat als Ziel die Erforschung der Akquisition von prozedurales Wissen und Kompetenzen die diese Wissenart zielen, durch den Biologie-Studium in der rumänischen Mittel- und Oberstufe. Die Arbeit bietet erstens eine kürze Übersicht auf der Geschichte und schon existierende Nutzung von solche Konzepten wie Kompetenz und prozedurales Wissen. Ebenso, sie beschreibt den rumänischen Bildungssystem aus einer diachronischen Perspektive. Bildung von prozedurales Wissen und Kompetenzen die prozedurales Wissen zielen sind in diesen Urkunden insbesonders kritisch untersucht. Die Ergebnisse dieser Analyse zeigen dass, obwohl Lehrpläne solche Konzepte wie Kompetenz und prozedurales Wissen erwähnen, sie mehr konkrete Aktivitäten zur Anleitung und Bewertung brauchen. Endlich, eine Online-Umfrage die die neunte Klasse und die Studenten aus den ersten Universität-Jahr zielt wird analysiert und angewendet. Die Umfrage bewertet die Implementierung der Anweisungen die auf prozedurales Wissen basiert sind. Die Ergebnisse zeigen eine Notwendigkeit für eine größere logistiche Versorgung (Labors und Instrumente) in Schulen aber auch für die Durchführung von mehreren praktische Aktivitäten. Die Notwendigkeit einer Überdenkung der Biologie-Fachlehrpläne, einer Investition in den Bildungsystem und einer verbesserten Vorbereitung des Lehrers ist wichtig um die Entwicklung von prozedurales Wissen und Kompetenzen die prozedurales Wissen zielen durch den Studium von Biologie zu ermöglichen.

Stichwörter: prozedurales Wissen, Kompetenzen, Curriculum, Biologie-Fachlerplan, praktische Aktivität, auf kompetenz-basierte Bildung, Mittelstufe, Oberstufe.

Introduction

Competency-based education (CBE) is the latest education paradigm revolutionizing educational goals. What it entails, and what it brings in addition to the traditional ones? The term competency or competence still needs clarification regarding meaning, implementation, and assessment. Some authors consider competence as an ability that allows a person to handle a specific situation (Klieme & Leutner, 2006). Other psychological researchers (Gelman & Greeno, 1989; Greeno, Riley & Gelman, 1984; Sophian, 1997) consider that competence can be observed from three perspectives: conceptual competence, which refers to an abstract knowledge of the field; procedural competence, defined as the set of skills needed to put into practice the first type of competence and the performance one, which consists of the ability to choose the right way to solve a problem. Weinert (2001) compiled a list of elements that measure and influence a person's level of competence (a) ability, (b) knowledge, (c) understanding, (d) skill, (e) action, (f) experience, (g) motivation.

In 1996 and 1998, Cheetham and Chivers, in the context of professional skills, elaborated a holistic model that included five competencies needed by a person in the workplace. These competencies can also be transferred and analyzed through the lens of competency-based educational paradigm:

1. Cognitive competencies: include conceptual knowledge (know-that) and understanding (know-why).
2. Functional competencies: knowledge of the know-how type or skills regarding those tangible things a person must achieve in the field of work.
3. Personal competencies: of the type know how to behave.
4. Ethical competencies: possessing a value system that influences personal decisions at work.
5. Meta-competencies: the ability to react to unforeseen situations and reflect on learning.

According to the Council of the European Union recommendations, *competencies* are a set of knowledge, skills, and attitudes:

• knowledge – represents a set of factual information, concepts, ideas, and validated theories that support the understanding of a discipline or a field of knowledge;
• skills – represent the use of existing knowledge in order to achieve some results;
• attitudes – describe ways of relating to ideas, people, or situations.

Voiculescu (2011) states that competence has two interrelated internal and external factors. Internal factors consist of knowledge, skills, and attitudes. External factors comprise tasks, context, and situation (Figure 1). *Tasks* are the problems or operations a person must do to develop competencies. *Contexts* are the conditions and interactions in which an activity is carried out. *The situation* is the concrete conditions: logistics and temporospatial conditions in which a person does the task.

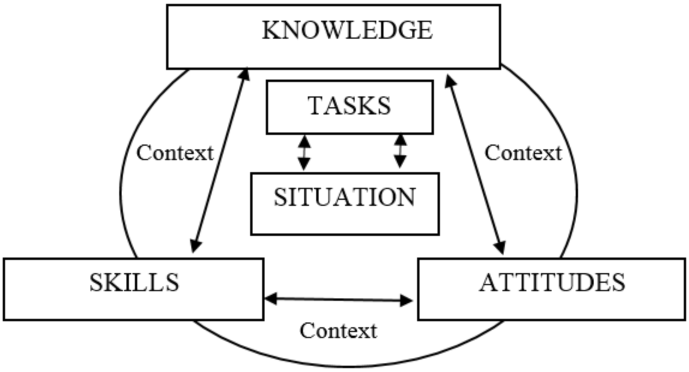

Figure 1. The integrative model of competence (Voiculescu, 2011)

According to other authors, knowledge consists of three parts: conceptual, factual, and procedural. The syllabi try to realize a concretization of the term knowledge, subsuming it under the concept of "contents", implying three distinct groups within them: factual contents, conceptual contents, and procedural contents (Mândruț et al., 2012). The French education approach offers another perspective on the type of knowledge, namely, it classifies knowledge in *savoir* (*compétences théoriques*, i.e. knowledge), *savoir-faire* (*compétences pratiques*, i.e. functional competencies) and *savoir-être* (*compétences sociales et comportementales*, i.e. behavioural competencies) (Winterton et al., 2006).

Conceptual knowledge, also referred to as declarative or propositional knowledge, is a "type of static knowledge about facts, concepts, and principles that apply within a particular domain" (De Jong & Ferguson-Hessler, 1996). It describes things, events, processes, and the relations established between them. Moreover, declarative knowledge is also called declarative memory because it refers to the information stored in the memory (Ten Berge & Van Hezewijk, 1999; Saks et al., 2021).

The main difference between conceptual and procedural knowledge is that the first involves retention and understanding of the definitions, rules, and principles in a field of study. In contrast, the second represents actions or strategies necessary to fulfill tasks or solve problems (VanScoy, 2019). The features of both types of knowledge are listed in Table 1.

In the context of the study of Biology, we will discuss competencies, specifically those targeting the development of procedural knowledge, the component "to know how to do/*savoir-faire*." This type of knowledge aims to develop to the maximum the intellectual and psychomotor capacities of students, emphasizing those of investigation and exploration of the living world. The investigation of the living world can be done through the direct exploration of nature: observation, experiment, practical work, laboratory work, and methods of indirect exploration of nature, for example, modeling. The development of scientific knowledge/investigation in didactic practice is carried out through methods that dynamize the learning process, engaging students' skills and abilities. All the practical methods: observation, experiment, practical work, and laboratory work, have an applicative character and develop students' competencies and procedural knowledge (Bîrzan, 2010).

Table 1. Features of conceptual and procedural knowledge (adapted after De Jong & Ferguson-Hessler, 1996; VanScoy, 2019)

Type of knowledge	Conceptual or declarative knowledge	Procedural knowledge
Features	• use of symbols and formulae → concepts and relations • state and explain characteristics, terminologies, properties, theories • verbalize principles, definitions → intuitive, tacit understanding • describe general structures of domains	• manipulation of rules/recipes/algebraic → meaningful action • use of isolated algorithms → action related to concept or principle • conscious choice and step by step execution • application of a procedure

Despite its acknowledged importance, CBE is a relatively new paradigm in Romania, implemented only after 1990 (Ardelean & Mândruț, 2012, p.11). Studies on the development of competencies targeting procedural knowledge and, implicitly, on the development of procedural knowledge through Biology are very scarce.

Aim and research questions

The purpose of this study is to explore the development of procedural knowledge and competencies comprising this type of knowledge through Biology. The addressed research questions are:

- *Do Biology syllabi engage students' competencies and procedural knowledge?*
- *How are competencies and procedural knowledge developed through the study of Biology?*

In order to assess this, a critical analysis of middle and high school Biology syllabi was conducted. Also, data were collected from ninth-grade high school and first-year university students regarding the learning strategies of Biology lessons and the exploitation of procedural knowledge.

A diachronic perspective of the educational system in Romania

The organization of the educational system in Romania has undergone numerous changes over time, influenced by various political ideologies. The educational trend of the last century, until 1950, was focused on didactic of content: knowledge achievement, without taking into account their processing in a critical form or the practical significance (Ardelean & Mândruț, 2012, p.11). After the middle of the 1950s, Bloom's cognitive verbs revolutionized the instructive-educational approach by introducing some elements of the psychology of learning and led to the emergence of didactics focused on achieving objectives (Bloom, 1956). Mager played a crucial role in this change, by introducing the concept of operationalization of objectives (Mager, 1984). After 1990, the educational goals reoriented towards developing competencies based on the idea that information processing leads to their development (Ardelean & Mândruț, 2012, p.11) (Figure 2).

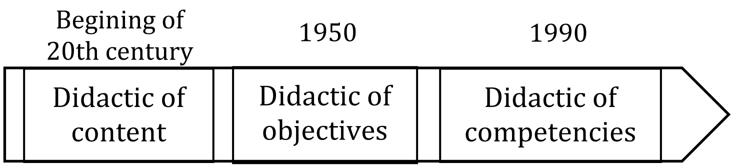

Figure 2. Timeline of the evolution of didactics in Romania

Romania's most important educational reform took place in 1994-2001, and one of its objectives was to rethink and reorganize the curriculum (Marga, 2002). In a narrow sense, the curriculum designates education content or represents the regulatory documents in which the essential data and learning experiences the school offers to the student are present: education plans and syllabi. In a broad sense, the term defines the interdependencies between educational purposes, educational content, and instructional and assessment strategies (Bocoș, 2017, p.72-73). Eliminating the excessive information from textbooks and syllabi and centering the latter on objectives, initially, and then on competencies training were and are the main outcomes of the curriculum reform (Connor, 2003).

Restructuring the curriculum is a dynamic and ongoing process by aligning it with European educational trends (Apateanu, 2009). The most current and essential aspect of the restructuring is moving toward a competency-based learning approach (Kitchen et al., 2017). The Romanian National Education Law no. 1/2011 assumed the eight key-competencies recommended by the European Commission as the objectives of the levels of compulsory and post-compulsory education: "1) communication in the mother tongue; 2) communication in foreign languages; 3) mathematical competence and basic competencies in science and technology; 4) digital competence; 5) learning to learn; 6) social and civic competencies; 7) sense of initiative and entrepreneurship; and 8) cultural awareness and expression" (OJEU, 2006).

To support teachers' adaptation to the implementation of the new curriculum focused on competencies, the Ministry of Education proposed several projects, including the "CRED: Relevant Curriculum, Open Education for all" project, financed by the European Social Fund (ESF), with a total budget of EUR 42 million (Grosseck et al., 2020). Also, since the fall of 2020, a didactic master's pilot-program started in eight large universities for the training and certification of teaching staff in the teaching-learning process focused on competence development (Ciolan et al., 2021).

However, are these programs and the others effective enough? The results obtained at PISA testing (Program for International Student Assessment) in 2018 tell not. In 2018, students from Romania achieved below-average results compared to the OECD (Organisation for Economic Co-operation and Development) rate in various areas: reading, mathematics, and science. OECD average for reading was 77%, in Romania was 59%; in mathematics, the OECD average was 77%, in Romania, 53% and in science, the OECD average was 78% and in Romania, 56% (Kitchen et al., 2017, p.47).

The current structure of the national curriculum in Romania tries to continue the idea of decentralization. The core curriculum establishes the minimum number of hours allocated to a subject. Schools can choose a part of the study subjects by choosing optional subjects through the curriculum at the school's decision (Connor, 2003). Disciplines with similar themes are organized in curricular areas (Ciolan et al., 2021). For example, biology is part of the Mathematics and Science Curricular area along with mathematics, physics, and chemistry.

In 2011, the Romanian National Education Law, Art. 23, defined the organization of the national pre-university education system in Romania for secondary education: (i) lower secondary or gymnasium education (middle school), which includes grades V – VIII, and (ii) upper secondary education which can be: - high school education: classes IX-XII/XIII, with the following profiles: theoretical, vocational and technological; and professional education with a minimum duration of three years.

Methodology

In order to investigate the development of procedural knowledge and competencies related to this knowledge, through the study of Biology, a critical analysis of Biology syllabi for middle and high school was conducted. The analysis followed the integrative and interrogative model proposed by Voiculescu (2011) and Bocoș (2017). Moreover, data related to the activities supporting the development of procedural knowledge (for example, investigations, microscopic observations, and practical activities in nature) were collected from ninth-graders high school and first-year university students through an online questionnaire (Annex 1).

Sample

The data collection was carried out through an online questionnaire, which targeted ninth-grade high school students from Cluj, Hunedoara, and Suceava counties and first-year university students from the Faculty of Biology and Geology and the Faculty of Chemistry and Chemical Engineering, Babeș-Bolyai University, Cluj-Napoca. Two target groups were chosen because the ninth-grade high school students learned from the new secondary school Biology syllabus from 2017, and those from the first year of college learned using the old Biology syllabus from 2008. In order to maintain an approximately equal proportion of respondents, the total number of participants in the first category was 129, and in the second category, 127.

Tools

The questionnaire was applied online in two copies, one intended for ninth-grade students and the other for first-year students, on the Google Form platform. Both questionnaires consisted of thirteen quantitative and qualitative questions, ensuring respondents' anonymity. There were eight multiple-choice questions and five Likert-type questions from 0 to 5. The questions varied, referring to the background of the study participants, the existence of materials for carrying out practical work (materials and laboratories), the carrying out of investigations, and practical activities in nature. Also, the questionnaire contained self-assessment questions aimed at the subjective reporting of the study participants regarding the activities that develop procedural competencies and their objective assessment through practical tests.

Study limitations

This study is an exploratory investigation of the development of procedural knowledge and competencies targeting this type of knowledge, through the study of Biology. However, there are several limitations to consider when interpreting the results and drawing conclusions. First, the study was limited to analysis only of Biology syllabi and not to other curricular materials such as textbooks or additional materials. Second, the survey targeted a limited number of students representing different backgrounds and ages. Thus, students in this sample represent a condensed number of high school ninth-grade and first-year university students. Furthermore, the lack of previous research studies on this topic made it difficult to report the results to previous discoveries made in the same field.

Results and discussions

Biology syllabi in Romanian schools

The school syllabus is the normative document from the curriculum that influences the teacher's activity in the classroom and determines the design, creation, and evaluation of didactic resources (including school textbooks) (Ardelean & Mândruț, 2012, p. 15). The Biology syllabus for middle and high school has changed throughout the curricular reform and has been oriented towards developing competencies. However, how well are they supporting developing of competencies? In what follows, a critical analysis of Biology syllabi is carried out to determine how much they sustain the development of procedural knowledge by guiding the teacher.

For whom is the middle school Biology syllabus?

The Biology syllabus aims at middle school students, grades V-VIII, between ages of eleven and fourteen. During this period, called early adolescence, young people begin to acquire abstract thinking capabilities. They can anticipate what will happen, for example, make hypotheses and operate with forms or representations (Spellings, 2005; Piaget, 1983). They also begin to realize what the consequences of their actions may be, that is, to form their identity. As Piaget believed, students' thinking can be developed in science through problem-solving questions, investigations, and practical laboratory work (Piaget, 1983).

Why or for what must follow this syllabus?

Harmonizing to the European educational trend, the Romanian Curriculum for the subject of Biology is centered on the priority development of the key-competencies: competencies in mathematics and basic competencies in sciences and technologies. Also, it indirectly values other key-competencies such as using new information and communication technologies, social and civic skills, communication in the mother tongue, and others (Biology syllabus, 2017). The old Biology syllabus for secondary education from 2008 focused on the framework and reference objectives (Ardelean & Mândruț, 2012). Later, the axis of the school program was represented by general competencies-specific competencies-content units (Bocoș, 2017, p. 119). In other words, at least theoretically, the syllabus' vision values the competence paradigm.

General competencies are educational objectives with a high degree of generality, achieved at the end of an education cycle (four years) (Șăitan et al., 2017, p. 311). The four general skills formed during secondary education are: "1. Exploring biological systems, processes, and phenomena with scientific tools and methods; 2. Adequate communication in different scientific and social contexts; 3. Solving problem situations in the living world based on logical thinking and creativity; 4. The manifestation of a healthy lifestyle in a natural environment conducive to life;" (Biology syllabus, 2017). Among these four competencies, competencies 1 and 3, through the specific competencies, aim for the acquisition and training of procedural knowledge. The specific competencies are derived from the general competencies and have a lower degree of complexity and generality. Their achievement is carried out during one school year (Șăitan et al., 2017, p. 311). The specific competencies that engage directly procedural knowledge are: 1.2. and 3.2. Specific competence 1.2. describes students' ability to conduct investigations. It is formed progressively, from the fifth to the eighth grade, its complexity changing in terms of the student's degree of autonomy. In the fifth grade, he carries out simple investigations with the help of worksheets and assisted by the teacher. In the sixth grade, he independently carries out investigations based on worksheets. In the seventh grade, he creates his own investigation sheets and performs activities according to them. Lastly, the student is expected to design the investigation activities independently in the eighth grade. Competence 3.2. describes students' ability to use algorithms in an investigation. It is also formed progressively, starting from the fifth grade, when the student uses already known algorithms; in the sixth grade, the student selects and applies specific algorithms for investigation; in the seventh grade, he designs his algorithms, until in the eighth grade, when he identifies new or alternative solutions for solving some problem-based learning tasks (Biology syllabus, 2017).

What needs to be taught?

The contents of learning represent informational means by which the achievement of competencies is pursued (Șăitan et al., 2017, p. 311). One of the outcomes of the curriculum reform was the reconceptualization of content units to develop specific competencies. However, how current and how much do the contents serve to develop the learning style specific to this age? Compared to the Biology syllabus from 2008, the discipline's internal logic principle was replaced by the integrative principle of functions and systems. How effective is this reorganization yet? From a qualitative point of view, it has the intended positive effect because students learn the notions, concepts, and relationships established between living things and the environment with more meaning and significance. However, quantitatively, the content is far too dense to support the development of specific competencies and procedural knowledge.

How will teaching and learning be achieved?

In addition to general and specific competencies, the Biology syllabus contains other components. These converge towards forming the first and guiding the teacher in the educational process. The other components are introductory notes, examples of learning activities and practical works for each class, and methodological suggestions. The relationship between general and specific competencies and the other elements of the syllabus is illustrated in Figure 3.

What is the use of these components? The introductory note outlines an overview of the syllabus. It clarifies the didactic structure addressed and summarizes a set of significant recommendations for achieving the goals of the Biology discipline (Șăitan et al., 2017, p. 311). In the introductory note, the importance of studying this subject and its contribution to shaping the profile of the secondary school graduate is argued. It also contains and presents a set of attitudes and values that the student should acquire through the study of Biology:

- curiosity and the desire to ask questions
- the spirit of observation and receptivity
- the spirit of inquiry
- critical interpretation of observed facts
- the desire to share own experiences and facilitate the learning of others
- flexibility in applying the acquired knowledge in everyday life.

The values contributing to the student's personality are: respect for scientific truth and any form of life; cooperation between people; tolerance of others' opinions; caring for one's health and the environment (Biology syllabus, 2017). How are these attitudes and values formed among students from the perspective of the program's proposed route and contents? A link between general and specific competencies, contents, and learning activities must be established, and a formative character must be implemented to develop these attitudes and values.

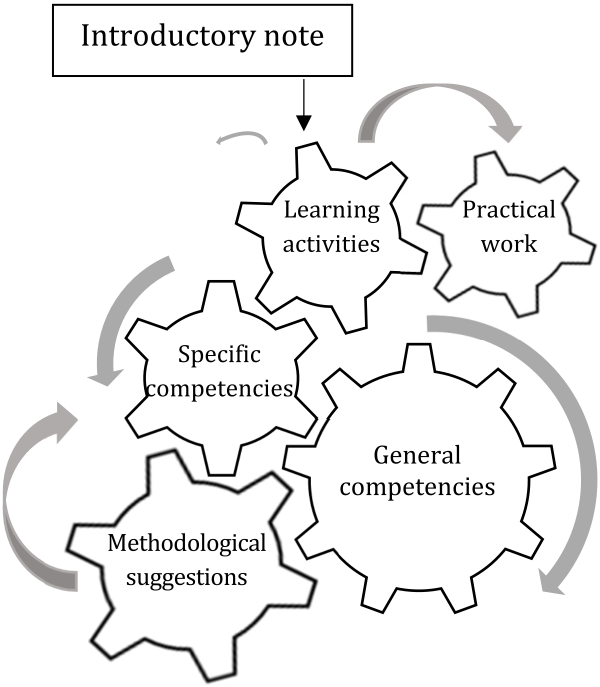

Figure 3. Relationship between components of Biology syllabus for middle school

Also, to achieve the educational goals, the teacher disposes of various examples of learning activities and practical works for each class and methodological suggestions. How useful is the information presented in these components, and how does it contribute to competency training? The careful reading of the program does not provide concrete indications of the realization of the learning activities: for example, neither material nor temporal resources. The same is noted in the case of practical works, where they are only listed without mentioning a concrete methodological suggestion for their realization.

Under what conditions (spatio-temporal and material) should and can these competencies and procedural knowledge be developed?

According to Bocoș, 2017, p.75, in the compilation of the curriculum, the time required to complete the program, the spaces and physical conditions, and the necessary material equipment must be mentioned. The Biology discipline is provided in the education framework plan having a time budget of one hour, respectively two hours (Table 2) (Șăitan et al., 2017, p. 311, Biology syllabus, 2017). Also, the syllabus mentions that teacher can allocate 75% of school time for competencies development, and the remaining 25% can be used depending on the characteristics of the students and the strategy of the school he is a part of.

Table 2. Number of hours for biology in lower secondary education (middle school)

Level	CC	**Class**			
		V	**VI**	**VII**	**VIII**
Lower secondary education (middle school)		1	2	2	1

(CC=core curriculum)

No details regarding the necessary spaces and valuable materials for the practical work are provided. The teacher must look to other resources for information to carry out a microscopic observation or an investigation. How affordable and easy to implement are they? The answers can be found in the questionnaire addressed to the ninth-grade and first-year university students discussed below.

How are outcomes (competencies) assessed?

Due to the pandemic and the need to rethink teaching-learning activities, methodological guides have recently been published to facilitate the assessment and teaching process focused on competencies. However, these materials were published late. The Biology syllabus briefly offers some evaluation methods: oral, written tests, portfolios, projects, and others, which must target specific competencies but not specifically mention how. What suggestions do the school textbooks give in this direction? The evaluation of procedural knowledge through practical tests is deficient, according to the students' answers in the questionnaire. Also, consulting the assesment questions and tasks issued for the Biology national competitions for students the ability to memorize and, very little, the ability to understand the questions or to do a practical activity are evaluated and by no means a specific competence.

High school Biology syllabi

High school Biology syllabi are the primary normative documents that guide the educational process at the upper level. These documents contain almost the same components as the middle school syllabus (Figure 3), except for examples of learning activities addressed to each specific competence. Following the same analysis algorithm proposed above, the answer to the question *to whom the syllabus is addressed* is teenagers aged between fifteen-nineteen years. Students during this period continue the process of acquisition and development of abstract thinking. They are in the formal operations stage when hypothetical-deductive reasoning develops even more (Piaget, 1983). Such reasoning presupposes the ability to advance hypotheses regarding the possibility of producing certain events and, at the same time, generate predictions regarding the evolution of those events. Structuring formal operations specific to this stage allows the student to experiment and test his ideas in the scientific sense of the word (Okun & Satisfy, 1977). These cognitive schemes can be developed through the medium of activities encouraging the formation of procedural knowledge: investigations, practical work, and microscope observations.

***Why or for what must follow this syllabus*?**

According to the curricular reform, to develop competencies. Currently, for the ninth and tenth grades, the school syllabi were issued in 2004 and have not been revised since then. There was only one revision for the eleventh and twelfth grades in 2006, and these versions are currently in use. The general competencies proposed for development are: "1. Reception of informations about the living world; 2. Exploration of biological systems; 3. Using and creating models and algorithms to demonstrate the principles of the living world; 4. Correctly oral and written communication using the terminology specific to Biology; 5. The transfer and integration of knowledge and work methods specific to Biology in new contexts". General competencies 1 and 2 (ninth grade and tenth grade) and 2 and 3 (eleventh grade and twelfth grade) aim to develop procedural knowledge through specific competencies. From the beginning, because of the separate organization of the syllabi for each grade, the discontinuity can be observed, preventing the gradual development of competencies during the four years of study. Specific competencies 1.3. from the ninth and tenth grades stimulate the acquisition of procedural knowledge through the activity of observation under a microscope (e.g., observation of microscopic biological structures and observation of organs, plants, and animals). However, they emphasize and are oriented toward the contents and not on developing applicable practical knowledge in any field.

Also, specific competencies 2.1 follow the same pattern by using investigative activities on contents such as general characters of organisms, structure, and function. Competencies 2.2. does not indicate any higher degree of acquisition from one class to another, being formulated in the same type: "2.2. Processing the results obtained from investigations and formulating conclusions".

Regarding the eleventh and twelfth grades, the specific skills 2.1. develop procedural knowledge by suggesting the use of experiment and investigation, but are also oriented towards the specific contents of these classes: "Use of experiment and investigation to highlight the structure and functions of the human body/The use of observation, experiment, and investigation to highlight the structure and functions of biological systems". The specific competence "2.2. Processing the results obtained from investigations and formulating conclusions" is mentioned only in the eleventh grade syllabus, not in the twelfth grade. Specific competencies "3.2. The development and application of algorithms for identification, investigation, experimentation, and solving problems" keeps the same form in the eleventh and twelfth grades syllabi, and are not illustrating the acquisition of superior skills when moving from one grade to another.

What needs to be taught?

The contents provide the answer to this question. Although the syllabus aims to develop general competencies through specific ones, the latter ones are not oriented towards acquiring knowledge, skills, and attitudes, which can be applied in any field and situation but are formulated with applicability only to the studied contents. For example, in the ninth grade, the specific competence that fundamentally encourages the acquisition of procedural skills: "2.1. The use of investigation to identify some general characteristics of organisms and highlight cellular components and processes," in the tenth grade is presented as: "2.1. The use of investigation to highlight the structure and functions of organisms". Therefore, the educational approach maintains the orientation towards teaching content, not competencies. Only in the eleventh and twelfth grades, after the 2006 revision, did the specific competencies begin to indicate more general applicability and a more gradual character. Competence 2.1. is formulated as "Use of experiment and investigation to highlight the structure and functions of the human body" in the eleventh grade, and in the twelfth grade: 2.1. "Using observation, experiment and investigation to highlight the structure and functions of biological systems." (Biology syllabus, 2004, 2006).

How will teaching and learning be achieved?

Regarding the contents, Marinescu, citing Ciobanu (p. 21), declares that the Biology syllabus has a systemic conception, which ensures learning about living things in relation to each other. In the ninth grade, the emphasis shifts from the systematics of living things to knowledge about the structure and physiology of the cell, to those of living things' genetics, genetic engineering, and biotechnologies. In the tenth grade, the comparative study of the functions of living things is carried out, and in the eleventh grade, the study of the human body systems continues, integrating elements of first aid and hygiene. In the twelfth grade, molecular biology and genetics of the human genome are studied in depth. The same observation is valid in the case of the syllabus for high school; from a qualitative point of view, the topics addressed are current and of interest to the young teenager. From a quantitative point of view, however, it does not encourage developing competencies. Moreover, high school syllabi need to mention that the contents should be approached from the perspective of specific competencies.

Furthermore, the lack of examples of learning activities supporting the development of specific competencies emphasizes the idea of teaching and learning content, not developing the first ones. It does not create a connection through which the transition from contents to competencies is achieved, nor their gradual formation. The only learning activity suggestion appears in the "methodological suggestions" category, where several activities are listed with a general character, almost identical in difficulty level and the only difference between these activities appears in the focus of the contents. Therefore, even here, the priority, although desired, is not the competence but the contents.

Moreover, a list of mandatory practical activities is indicated without providing indications of their achievement or the connection with a specific type of competence. The methodological suggestions include a series of didactic methods that can be integrated into the lessons but does not mention the context of their realization nor the connection with the specific competencies.

In what conditions?

Regarding the temporal conditions, at high school, the biology discipline has a budget of one hour or two hours, depending on the field and profile and specialization (Table 3); (Marinescu, 2018, School curriculum for the discipline of biology, 2004, 2006).

Table 3. Number of hours for biology in inferior secondary education

Level	Channels	Profiles	Specializations	Class							
				IX		X		XI		XII	
				CC	DC	CC	DC	CC	DC	CC	DC
Upper secondary education (high school)	Theoretical	Real	Natural Sciences	1	1	1	1	1	1	1	1
	Theoretical	Real	Mathematics-Informatics	1	1	1	1	1	-	1	-
	Theoretical	Social Sciences	All	1	-	1	-				
	Vocational	All	All	1	-	1	-	1*	1*	1*	1*
	Technological	All	All	1	-	1	-	1*	-	1*	-

(*only some specializations; CC=core curriculum; DC=differentiated curricula)

As for indication of the materials necessary for carrying out the activities in class, details also need to be provided. For example, for the realization of the practical work "plasmolysis and deplasmolysis," the teacher has the manual as the only support; the syllabus does not specify the materials needed, the organism on which the process can be observed, nor how.

How are outcomes (competencies) assessed?

All high school Biology syllabi mention that the assessment will target the formation of specific competencies and associated contents, offering as an example the following assessment items or modalities:

"- selecting the correct answer;
- the correct association between notions and statements;
- completion of sentences, drawings, schemes, and lacunae;
- recognitions of the true-false type;
- structured questions;
- problems;
- essays, structured essays;
- formulating hypotheses or conclusions related to biological processes;
- making an investigation plan;
- solving worksheets for practical applications" (Biology syllabus, 2006).

The examples provided, except for the last 3, have a predominant evaluative character oriented toward the contents and not toward the students' skills, knowledge, or attitudes. Again, the ability of memorizing is tested. Furthermore, there need to be more concrete examples of evaluation: how can a practical test be implemented? How can a teacher measure procedural knowledge?

Data analysis

In what follows next, the collected data through online questionnaire will be analyzed and discussed.

1. Intragroup comparisons

The intragroup comparisons were made taking into account the students' backgrounds. As can be seen in Figures 4 and 5, most pupils and students come from urban environments (over 60% of pupils and over 95% of students). This aspect was considered in the first five questions, which concerned school infrastructure (equipment with laboratories and laboratory instruments) due to the poorer funding of schools in rural areas compared to urban ones. Tomuletiu and Moraru (2010) confirm the poor funding of education in the rural education system through their study. Their results indicated that rural schools could have more science labs and gyms.

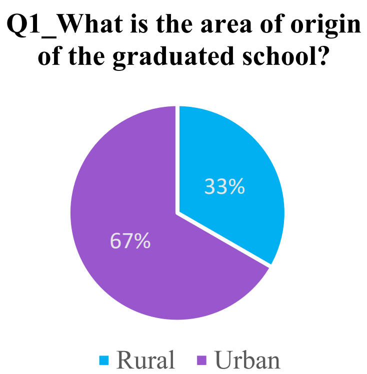

Figure 4. Graphical representation of the distribution of the responses to question no. 1 (ninth grade students)

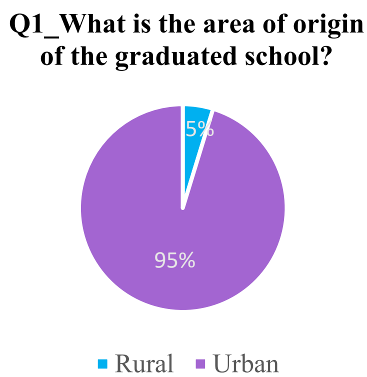

Figure 5. Graphical representation of the distribution of the responses to question no. 1 (first year students)

According to Linn and Harlow (1997), laboratories play an essential role in science teaching-learning because they facilitate students' understanding of abstract concepts using materials, stimulate the development of procedural knowledge through practical work, and contribute to students' motivation to study science. How well equipped with science laboratories are the schools in Romania? The answers to question number 2, Figures 6 and 7, regarding the existence of a laboratory in the graduate school, confirm that not so well. Moreover, the answers reinforce the idea that funding remained poorer in rural schools than in urban ones, because, more than 50% of them are not equipped with laboratories. In the case of college students, mostly from an urban area, about 80% answered that the graduate school was equipped with laboratories, and approximately 17% answered no.

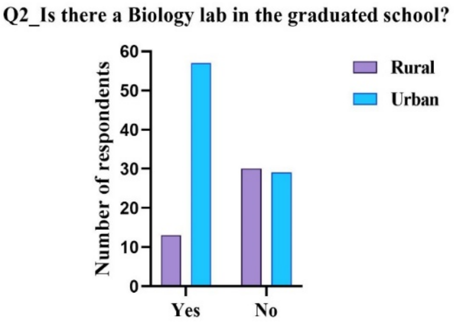

Figure 6. Graphical representation of the distribution of the responses to question no. 2 (ninth grade students)

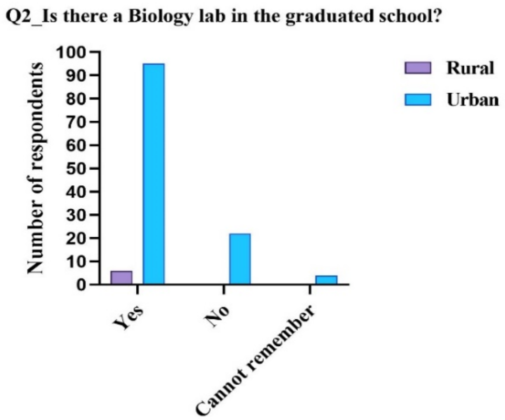

Figure 7. Graphical representation of the distribution of the responses to question no. 2 (first year students)

According to Figure 8, even though the schools were equipped with laboratories, they needed more materials and tools for carrying out practical work. More than 50% of pupils from rural areas answered that the laboratory was not provided with instruments, and only 10% answered that the laboratory had sufficient instruments. About 35% of pupils from an urban area declared that the laboratory was not adequately equipped with instruments. About 17% answered that instruments existed, however, in a low number. 40% stated that it was equipped with a sufficient number of instruments, and not even 1% of the respondents declared that the instruments were in high number.

In the case of college students, who were mostly from urban areas, more than 50% of the respondents stated that the laboratories were equipped with very few instruments. About 10% of them stated that the laboratories had no instruments, and over 30% stated that the laboratories were adequately supplemented with instruments (Figure 9).

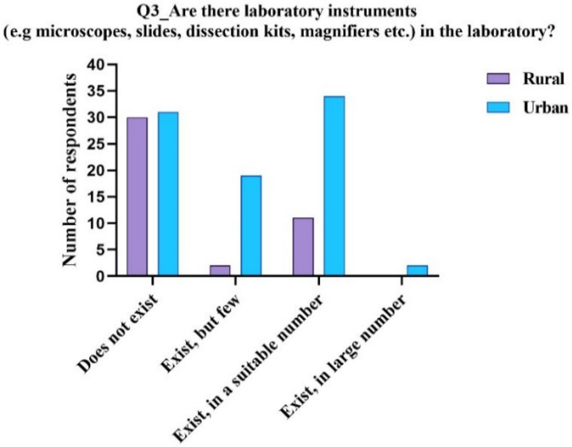

Figure 8. Graphical representation of the distribution of the responses to question no. 3 (ninth grade students)

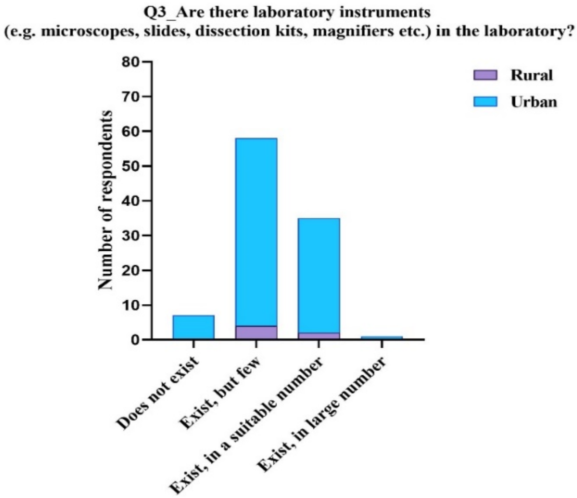

Figure 9. Graphical representation of the distribution of the responses to question no. 3 (first year students)

Students' progress rate depends on the availability of facilities that aid learning. The provisions of facilities are inadequate in schools. The defective equipment of laboratories led to the predominant non-use of the Biology laboratory, according to Figures 10 and 11, or the microscope (Figures 12, 13). The problem of equipping schools with laboratories and laboratory instruments is not new but is a recurring one, related to the government's investment in education. According to the data obtained by Eurostat, until 2019, Romania was part of the countries that allocated less than 4% of GDP to education. In 2018, 29.3 billion lei were allocated, representing 3.1% of GDP; in 2019, 38.2 billion lei (3.8% of GDP). According to the same data from Eurostat, Romania has allocated for education consistently below the average allocated in Europe.

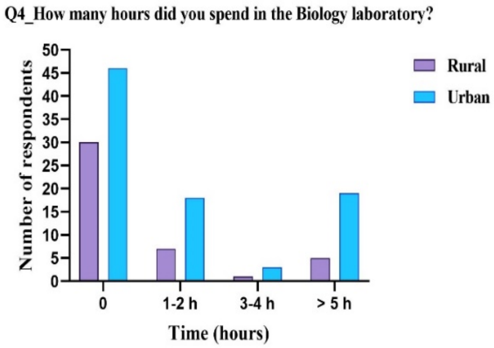

Figure 10. Graphical representation of the distribution of the responses to question no. 4 (ninth grade students)

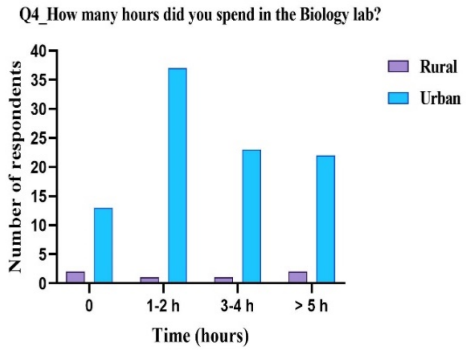

Figure 11. Graphical representation of the distribution of the responses to question no. 4 (first year students)

2. Intergroup comparisons

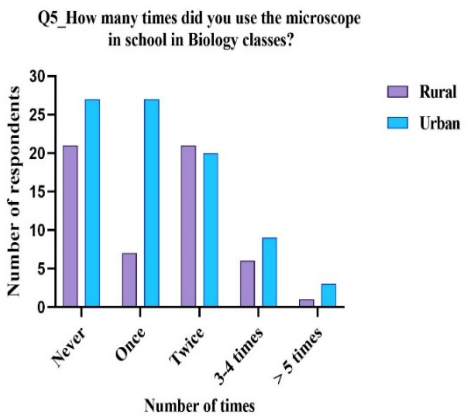

Figure 12. Graphical representation of the distribution of the responses to question no. 5 (ninth grade students)

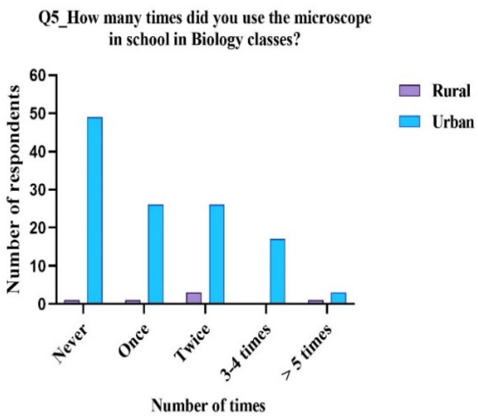

Figure 13. Graphical representation of the distribution of the responses to question no. 5 (first year students)

According to the answers to question 6, more than 50% of high school and college students stated that they did not participate in any activity in nature. About 10% and 20% carried out at least one activity in nature, 10% and 14% two activities in nature, and below 5% and 10% answered that they carried out three, four, or five activities in nature (Figure 14). Why is the number so small?

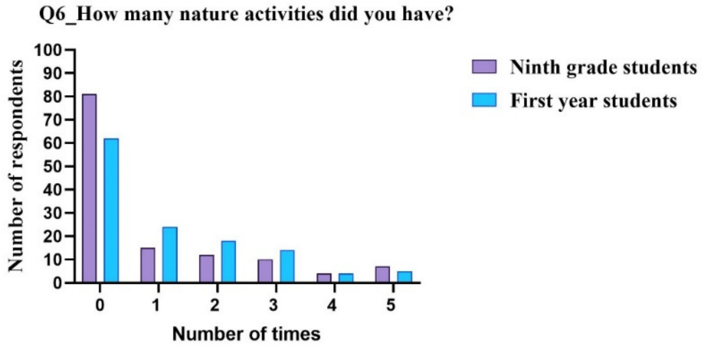

Figure 14. Graphical representation of the distribution of the responses to question no. 6

Question number 7 concerned the number of investigations/experiments carried out in school and of other activities that support the development of procedural knowledge. Approximative 33% and 40% of participants did not perform any experiment/investigation; 25% and 21% answered that they had conducted only once; 21% and 18% performed two experiments/investigations and less than 10% answered that they had conducted three, four, or more than five experiments/investigations (Figure 15).

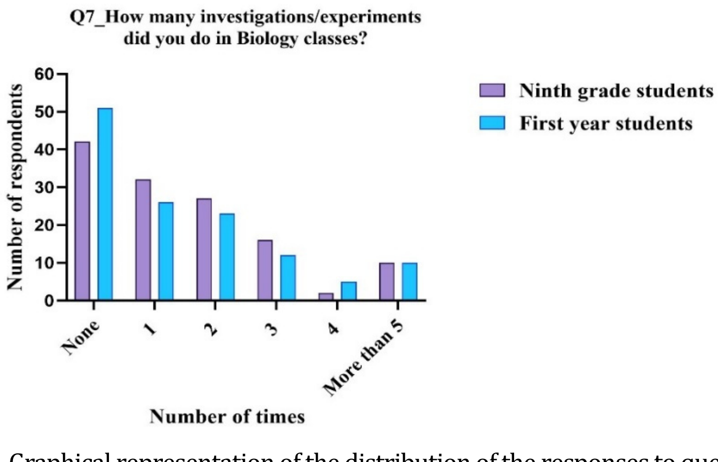

Figure 15. Graphical representation of the distribution of the responses to question no. 7

The results in questions 6 and 7 may suggest the teacher's inadequate preparation for investigative activities. In a study conducted by Rogers in 2021 related to teachers' perspectives on implementing competency-based education, 75% of the teachers declared that "I could use more professional development in learning how to implement CBE." The question that received the most substantial agreement (80%) was about needing more professional development, while the highest disagreement (41%) was that training was being provided.

Questions 8, 9, and 10 are self-assessment questions and aim at how well pupils and students can self-assess themselves in carrying out practical activities by using procedural knowledge. According to their answers, approximately 40% and 46% cannot make a microscopic preparation at the end of a learning cycle (Figure 16). Also, more than 70% stated that they could not carry out a complete investigation in the laboratory, and more than 25% could not carry out an investigation in nature (Figures 17 and 18). These results reflect the need for more implementation of practical activities in order for students to develop procedural knowledge.

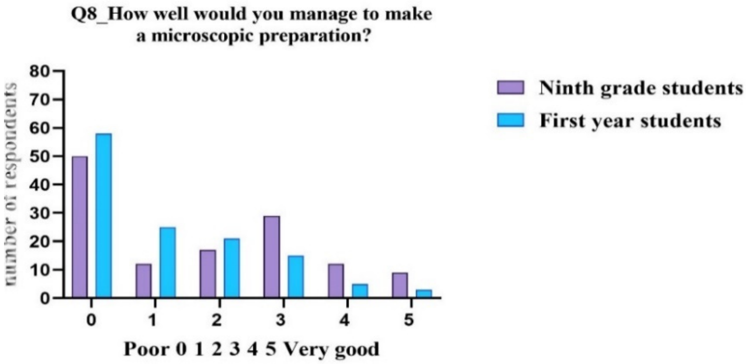

Figure 16. Graphical representation of the distribution of the responses to question no. 8

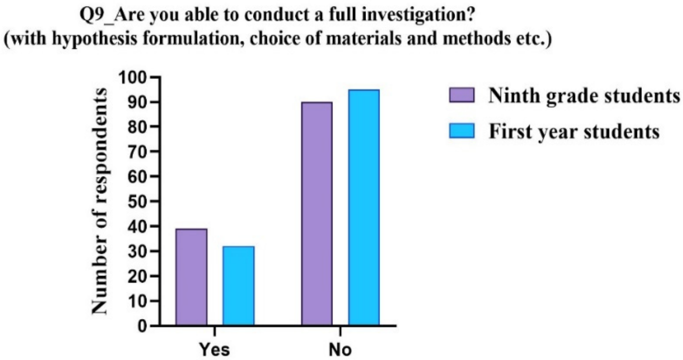

Figure 17. Graphical representation of the distribution of the responses to question no. 9

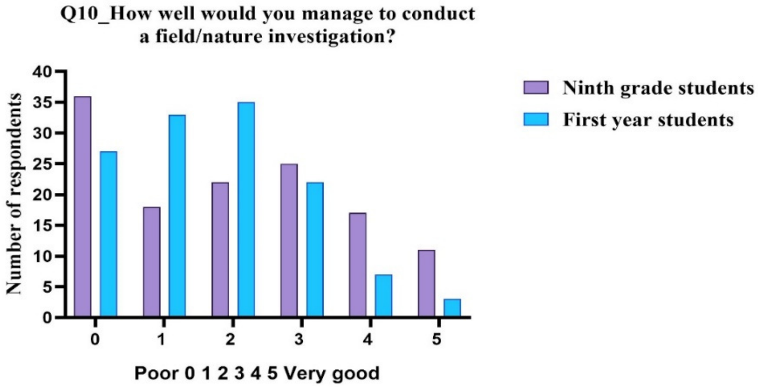

Figure 18. Graphical representation of the distribution of the responses to question no. 10

Figure 19 confirms the presumption that, although the Biology syllabus aims at developing competencies and implicitly procedural knowledge, their concrete evaluation still needs to be carried out correctly. Students are still assessed on the amount of information they retain rather than on the competencies they possess. More than 50% of pupils and more than 70% of students were never assessed by practical tests. This poor evaluation is also reflected in the subjects for the Romanian Biology National Competitions and the Biology baccalaureate exam. Moreover, in a validation phase of a test designed to measure specific competencies 1.2. and 1.3. at seventh-grade students, approximately 20 participants scored below the five mark, 28 above five but below six, and only 4 above six and 2 above the seven mark. No result was obtained above the eight mark (Table 4).

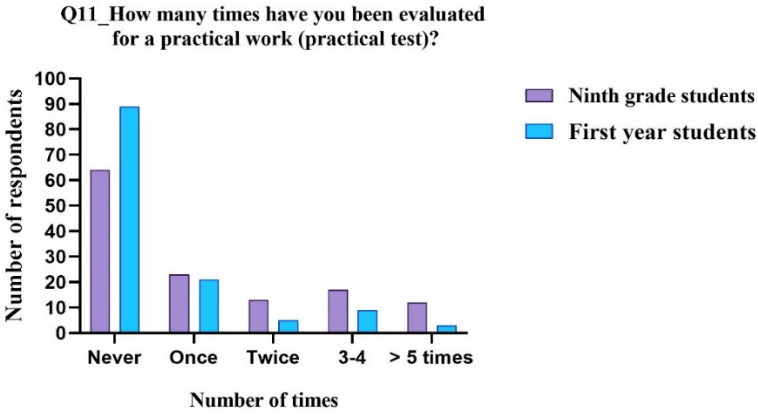

Figure 19. Graphical representation of the distribution of the responses to question no. 11

Table 4. Test validation results, unpublished

Grades	<5	<6	<7	<8	>8
Number of students	20	28	4	2	0

The last two questions concerned how pupils and students appreciate the importance of implementing practical work in Biology classes. According to the answers, more than 80% of pupils and approximately 97% of the students consider practical work in Biology classes important, giving marks of 4 and 5. When asked how often they would like to apply practical work in Biology classes, over 80% of pupils and over 96% of students would have liked to do more practical work (Figure 20 and 21).

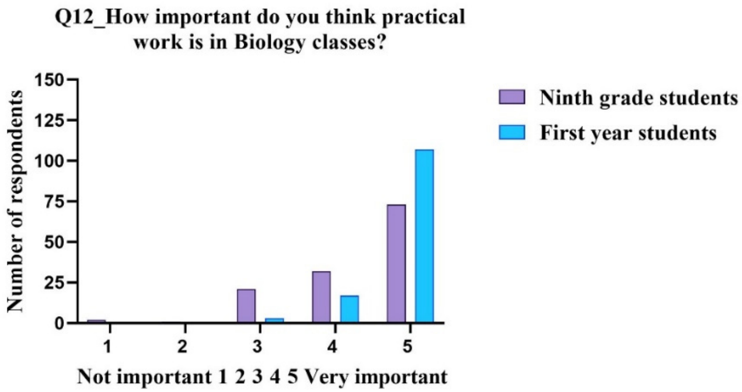

Figure 20. Graphical representation of the distribution of the responses to question no. 12

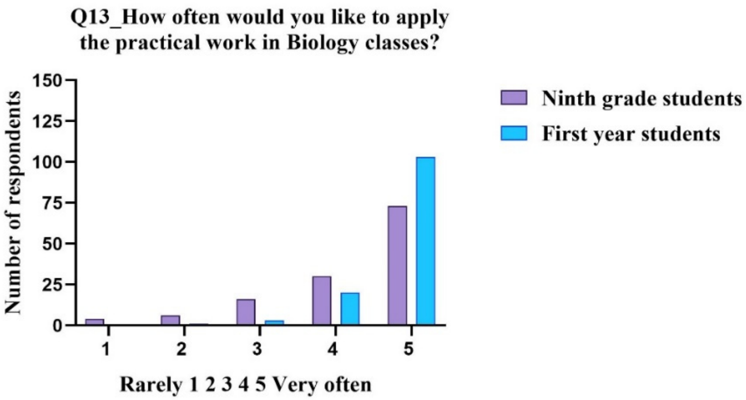

Figure 21. Graphical representation of the distribution of the responses to question no. 13

Conclusions and future directions

From the critical analysis of the Biology syllabi for middle school and high school, it can be concluded that the educational orientation towards the acquisition of competencies is attempted through the proposed learning outcomes. However, the *didactic of contents* is still predominant because of the dense subject content found in syllabi which is eventually expanded in the Biology textbooks, mostly as scientific theory. The lower Biology school syllabus is the most promising, approaching the CBE paradigm by offering concrete examples of practical activities to develop procedural knowledge and competencies. A revision of the high school syllabi is necessary. They are old and not up to date with current educational requirements. High school syllabi still retain a orientation towards content rather than acquisition of knowledge, skills, and attitudes applicable in any context. On the other hand, the syllabi need to be formulated concretely enough to guide teachers in implementing activities aimed at developing procedural knowledge and, implicitly, skills. It also does not provide any indication of their evaluation. Evaluation, in Romanian education, is still focused towards the acquisition of abstract/theoretical knowledge and not the ability to put into practice the knowledge and skills applicable in any situation.

Several aspects can be concluded from the results of the questionnaire addressed to students. First, the insufficient financing of Romanian education determines the lack of laboratories and tools for carrying out practical work. It is necessary to emphasize the need to use Biology laboratories and update their endowment with materials in all schools because they are necessary spaces for forming procedural knowledge and exploratory competence. Second, the lack of logistics necessary to carry out practical work led to the avoidance of implementing some fundamental activities to train procedural knowledge and to the poor self-evaluation of students in this direction. Failure to carry out practical activities may suggest the lack of teachers' training, as well as the lack of guidance materials in this topic.

Last, preserving a traditional, subject-conceptual content-oriented assessment still prevails in the Romanian educational system. The significant lack of practical tests, both in schools and at Biology national competitions and national exams, confirms the genuine educational purpose: acquiring conceptual knowledge and not competencies.

What can be done in the future? At a macro level, first of all, a massive reform of the syllabi is needed to reduce the amount of content and to provide concrete indications for developing competencies targeting procedural knowledge. There is also a need for prioritization and a massive financial investment in education to provide laboratories and equipment necessary for developing procedural knowledge. Moreover, the organization of conferences, workshops, and training related to CBE implementation topics should be carried out constantly. These teacher training activities should be carried out with a small number of participants to ensure their success.

At a micro level, related to teaching-learning activity, the teacher must implement the classroom activities that encourage:

• discovery through direct observation and exploration, using didactic methods such as observation, modeling, experiment, demonstration, and others;
• curiosity, starting from a question (why) and reaching a result through the question (how) and by carrying out an investigation in nature or in the laboratory;
• team collaboration to explore the living world;

As an alternative to the lack of facilities for practical activities, teachers can use virtual reality: online educational platforms such as *Labster (*https://www.labster.com/), *Phet interactive simulations* (https://phet.colorado.edu/)*, Gizmos* (https://gizmos.explorelearning.com/), and others that simulate various experiments and demonstrations.

It would also be helpful to create practical guides for teachers accessible to any teacher, which instruct practical activities. Collaboration between teachers and creating an online community where methodological suggestions can be exchanged would be another alternative to support competencies development.

Based on this research, it can be concluded that the Romanian educational system, at this stage, is not yet prepared to develop and assess procedural knowledge. However, a teacher can develop these outcomes by implementing practical activities using the laboratory, nature, and online instruments.

Acknowledgement

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Annex 1

This research aims to evaluate the existence and implementation of practical works in the Biology discipline during a school cycle (middle school or high school), activities that support the development of procedural knowledge among students.
Practical work includes macro and microscopic observations, experiments, demonstrations, nature activities data collection from the field, investigations, and others. Procedural knowledge is measured by the students' abilities to carry out the previously mentioned activities.
All information provided by completing this questionnaire will only serve the purpose of research and will be confidential.

Choose one answer:

Q1: What is the area of the graduated school?

	Rural		Urban

Q2: Is there a Biology laboratory in the graduated school?

	Yes		No

Q3: Are there laboratory instruments (e. g microscopes, slides, dissection kits, magnifiers etc.) in the laboratory?

	Does not exist
	Exist, but few
	Exist, in a suitable number
	Exist, in large number

Q4: How many hours did you spend in the Biology laboratory?

	0		1-2 h		3-4 h		> 5 h

Q5: How many times did you use the microscope in school in Biology classes?

	Never		Once		Twice		3-4 times		> 5 times

Q6: How many nature activities did you have?

	0		1		2		3		4		5

Q7: How many investigations/experiments did you do in Biology classes?

	None		1		2		3		4		More than 5

Q8: How well would you manage to make a microscopic preparation?

Poor		0		1		2		3		4		5	*Very good*

Q9: Are you able to conduct a full investigation? (with hypothesis formulation, choice of materials and methods etc.)

	Yes		No

Q10: How well would you manage to conduct a field/nature investigation?

Poor		0		1		2		3		4		5	*Very good*

Q11: How many times have you been evaluated for a practical work (practical test)?

	Never		Once		Twice		3-4 times		> 5 times

Q12: How important do you think practical work is in Biology classes?

Not important		1		2		3		4		5	*Very important*

Q13: How often would you like to apply the practical work in Biology classes?

Rarely		1		2		3		4		5	*Often*