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AREAS OF DIFFICULTY IN SCHOOL CHEMISTRY CURRICULUM – BULGARIAN STUDENTS' AND TEACHERS' VIEW. STUDENTS' DIFFICULTIES IN LEARNING ORGANIC CHEMISTRY AT THE BASIC LEVEL

Abstract on the dissertation submitted for acquiring the Doctorate degree (PhD) in professional field 1.3 Pedagogy of teaching … (Methodology of teaching Chemistry), Sofia University "St. Kliment Ohridski"

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The dissertation contains a total of 174 pages and consists of six chapters, including introduction and conclusion, 60 tables, 15 figures, a bibliography (a total of 400 sources, of which 16 in Cyrillic and 384 in Latin), a glossary of terms and 6 appendices.

The dissertation has been discussed and directed for defense by the Departmental Council of the Department of Physical Chemistry (Research Laboratory on Chemical Education and History and Philosophy of Chemistry) of the Faculty of Chemistry and Pharmacy at Sofia University “St. Kliment Ohridski”, held on 30.01.2023, Protocol No. 1B/30.01.2023.

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The materials for the defense are available to those interested in office № 107 of the Faculty of Chemistry and Pharmacy at the Sofia University “St. Kliment Ohridski”, 1 James Boucher Blvd.

CHAPTER 1. INTRODUCTION

Chemistry is one of the most important branches of science – it enables students to gain a scientific understanding of the world around them and make informed decisions as individuals and citizens of modern society. The study of chemistry is fundamental to those pursuing career in science.

At the same time, a tendency of declining interest towards chemical education is observed worldwide (Toshev, 2012; Potvin & Hasni, 2014). Fewer and fewer students are choosing to study natural sciences, and chemistry, in particular at Sofia University (Zamfirov, 2013). Fewer and fewer scholars choose to study advanced chemistry at the secondary level of school education. A study of students' attitudes towards natural sciences reveals chemistry is the second least liked school subject, following mathematics (Gendjova, 2017).

The decline of interest towards the subject is partly due to the difficulties encountered in the learning process. According to a number of studies in the scientific literature, Chemistry remains an abstract, complex and incomprehensible subject for the majority of students worldwide (Bradley & Brand, 1985; Gabel, 1999; Mortimer & Scott, 2000; Taber, 2001; 2002; 2009; 2013; Sirhan, 2007; Snow, 2010; Dumon & Mzoughi-Khadhraoui, 2014; Quílez, 2019).

Such a problem is observed in Bulgaria as well. The points Bulgarian students score on the international study PISA place the country among the ones with alarmingly low results (OECD, 2019; Tafrova-Grigorova, 2013). Results from research conducted by academic members of the Faculty of Chemistry and Pharmacy at Sofia University "St. Kliment Ohridski" indicate that students face difficulties in learning Chemistry, despite the fact subject content for compulsory education has been reduced (Tafrova-Grigorova et al., 2009, Kirova et al., 2010).

In order to overcome or reduce the difficulties students face, we first have to establish the areas of content difficulty in the Chemistry curriculum and afterwards "diagnose" particular difficulties. This has led us to focus our attention on identifying the difficulties students encounter while studying the subject "Chemistry and environmental protection", part of compulsory education in Bulgarian second-dary schools.

In recent decades, there's a trend towards conducting research in Chemistry education for identifying student difficulties and misconceptions, and their sources (Taylor & Coll, 1997; Taber, 2002; Ravialo, 2001; Taber & Coll, 2003; Özmen & Ayas, 2003; Pınarbaş, & Canpolat, 2003; O'Dwyer & Childs, 2011, 2017; Atanassov & Gendjova, 2019).

Teachers' knowledge of students' difficulties and their sources is an important element of Pedagogical Content Knowledge, abbrev. PCK, (Kind, 2009; Fernandez, 2014) and a critical factor for ensuring quality instruction and learning process (Coe et al., 2014). Research on teachers' PCK for student difficulties in chemistry is relatively scarce (Pfundt, H. & Duit, R., 1998, as cited in Treagust, Nieswandt & Duit, 2000).

The issue of identifying areas of content difficulty, both from teachers' and students' point of view, is particularly important for ensuring quality instruction and a successful educational reform in the Bulgarian educational system. Teachers, textbook authors, programs for teacher training and the teaching practice as a whole would all benefit from addressing it, which in turn determined the aim of the present study, namely:

To identify the areas of content difficulty in the Chemistry curriculum according to secondary school students and teachers and the specific difficulties in learning Organic chemistry at the basic level, compulsory education.

The following ***research questions*** were raised to guide the study:

1. Which topics from the Chemistry curriculum students perceive as difficult/interesting? Do students' and teachers' opinions differ? What are the causes for the perceived difficulties and the important skills needed to be successful in chemistry class according to students and teachers?

2. What are the actual difficulties students face when learning Organic chemistry at the basic level?

3. What are students' perceptions of difficulty and self-efficacy in Organic chemistry at the basic level?

4. What do teachers know about the difficulties in teaching and learning Organic chemistry at the basic level, the causes of these difficulties and which teaching methods/approaches they consider effective?

The following ***methods*** are employed in the current study:

1. Analysis of the scientific literature and documentary analysis on the topic of dissertation;
2. Questionnaire survey among students and teachers;
3. Semi-structured interviews with prominent Chemistry teachers;
4. Diagnostic testing of students;
5. Statistical methods for data processing and analysis.

Chronological framework and time-line of the study

The overall research was conducted within several periods:

Theoretical-conceptual period – observing pedagogical practice; literature review on the problem to determine the main research parameters; development of a research idea and a conceptual model for the study and corresponding methodology.

Empirical period – specifying research design and conducting experimental-diagnostic activity for identifying learning difficulties. The empirical period is carried out in two cycles as follows:

- *First cycle* – identifying areas of content difficulty (difficult topics in the Chemistry curriculum). A survey was conducted among students (April 2018 - March 2019) and Chemistry teachers (April 2018 - March 2019);
- *Second cycle* – identifying actual difficulties in learning and teaching Organic chemistry at the basic level. This cycle includes: preliminary diagnostic testing – June 2020; interviews with prominent chemistry teachers – October 2020; teacher survey – September - October 2020; primary diagnostic testing – May - June 2021; student survey – May - June 2021.

Resultative period – summarizing collected empirical material and interpreting obtained research results (July 2021 - December 2022).

Research sample groups

A total of 778 Bulgarian students and 76 Chemistry teachers participate in both cycles of research.

321 Bulgarian students aged 16-17 years, attending in-person classes, from five secondary schools in Sofia and 20 teachers from different types of secondary schools in Sofia take part in the first cycle. The research sample in the second stage consists of 457 Bulgarian students aged 15-16 years, studying in different types of secondary schools, located in different settlements in Bulgaria. The students were taking online classes due to the COVID pandemic. A total of 56 Chemistry teachers participated in the second cycle. Most of them work in different types of secondary schools from several different areas in Bulgaria, have high qualification and significant teaching experience.

Structure and main content of the dissertation

The dissertation consists of six chapters, including an introduction and conclusion, bibliography and appendices.

Chapter One – Introduction – briefly discusses: significance and relevance of the topic; objectives of the study and research questions guiding it; chronological periods and sample groups as well as employed research methods along with glossary of terms and concepts.

The main content is structured in three thematically separate chapters as follows:

Chapter two reviews the literature on the difficulties in teaching and learning Chemistry in secondary schools, including contributing factors of different nature and origin. The position of organic chemistry (at the basic level) among other topics from the 9^{th} grade Chemistry syllabus is discussed. Some characteristics of Organic chemistry, posing learning difficulties are also highlighted. Previous scientific research on the topic of dissertation is analyzed.

Chapter three outlines the adopted research approach for each of the two cycles in terms of: research design, sample, employed methods and instruments, data collection and analysis.

Chapter four presents, discusses and summarizes the obtained research results for: difficult and interesting topics in the Chemistry curriculum; reasons for student difficulty and important skills needed for success, both from teachers' and students' point of view.

Chapter five of the dissertation reviews, discusses and summarizes: students' perception of difficulty and self-efficacy in organic chemistry at the basic level; identified students' actual learning difficulties as well as teachers' knowledge of the obstacles in teaching and learning organic chemistry.

In the *Sixth Chapter* – the conclusion – conclusions and summaries are drawn upon the analyzed results. The current research's contributions and limitations are explicitly stated. Possible applications of current findings are outlined along with prospects for further research.

CHAPTER 2. DIFFICULTIES IN TEACHING AND LEARNING CHEMISTRY

2.1. Sources of difficulty in teaching and learning chemistry

Millar (1991) argues that science's reputation as a "hard" subject can be attributed to external (not within the student's control) and internal factors (within the student's control). In this work, we will refer to them as external and internal sources of difficulties in teaching and learning chemistry.

The nature of chemistry implies certain difficulties in its study as a subject. In terms of the scope of its subject, chemistry stands midway between physics and biology (Reinhardt, 2001). Chemistry is similar to these branches of science in that it is an experimental science (Tsaparlis, 2001). The chemistry curriculum usually incorporates many abstract concepts, understanding of which is crucial for further learning, but they are not easy to grasp (Taber, 2002; Taber, 2013). An interaction between empirical experience and theory is characteristic to chemistry. In order to provide explanations for properties of substances and chemical phenomena observed at the macro level, we need to conceptualize them at the submicroscopic level and then use theoretical models (Taber, 2013; Dumon & Mzoughi-Khadhraoui, 2014; Justi & Gilbert, 2002). Misunderstanding theoretical models – their nature, role in learning, scope and limitations – is one of the causes of students' difficulties at the submicro level. Teachers themselves unintentionally may also contribute to the problem (Gilbert, 1998; Justi & Gilbert, 2002; Harrison & Treagust, 2002; Talanquer, 2007; De Jong et al., 2013; De Jong & Taber, 2014). An essential characteristic of chemistry is the constant interplay between macroscopic, submicroscopic and symbolic levels of thinking and representation (chemistry triplet), which is a serious challenge for learners (Johnstone, 1982; Johnstone, 2000). Studies reveal students face difficulties both at each level (Gilbert, 1998; Justi & Gilbert, 2002; Harrison & Treagust, 2002; Talanquer, 2007; De Jong et al., 2013; De Jong & Taber, 2014), as well as establishing a link between them (Gabel, 1998, 1999; Onwu & Randall, 2006; Sirhan, 2007; Taber 2013). Devetak et al. (2004) justifies the complexity in teaching and learning chemistry with the relationship between levels of the chemistry triplet and students' difficulty to transfer knowledge from one level to another. According to Gabel (1999), the primary barrier to understanding chemistry is not the existence of the three levels of representing matter, but that instruction occurs predominantly on the most abstract one – the symbolic level. Additionally, the use of chemical language increases cognitive demand on learners and leads to cognitive overload (Dumon & Mzoughi-Khadhraoui, 2014; Markic & Childs, 2016, Snow, 2010; Quílez, 2019). The frequent use of mathematical symbols, formulas and equations to represent relationships between the macro- and submicro- levels further elevates the levels of cognitive demand placed on students and promotes difficulties (Gabel, 1999; Orton & Roper, 2000; Davison, Miller & Metheny, 1995). Laboratory activities are problematic if conceived only as appendages to theory classes (Mbajiorgu & Reid, 2006). According to Tsaparlis (2009), concrete experiences may be a prerequisite for a conceptual understanding of chemistry, but this understanding is eventually provided through the submicroscopic and symbolic levels and the connection of the macro level with the other two levels is an integral but difficult task. The chemistry curriculum is also a factor that can hinder learning if it: simultaneously incorporates all three levels of the chemistry triplet (Sirhan, 2007); emphasizes learning rules and algorithms (Tsaparlis, 1997); is not structured in a way allowing students to easily follow logical links between particular concepts (Vos van Berkel & Verdonk (1994); is burdened with lots of concepts and facts and context is lacking (Gendjova, 2012); follows scientific logic without taking into account psychological characteristics, needs and interests of students (Reid, 1999, 2000; Johnstone 2000).

Students' difficulties are also influenced by knowledge and learning related internal factors, for example cognitive abilities such as perception, formal reasoning, memory, information processing speed (Robinson, 2012). Chemistry instruction demands a considerable amount of formal reasoning. Studies indicate that many high school and college chemistry students are not operating as formal thinkers (Crippen & Brooks, 2009). According to Ausubel (1968), the most important single factor influencing learning is what the learner already knows. A large number of studies on the role of prior knowledge found that it is the most significant and important factor in determining students' future performance even when considering other factors (Seery, 2009). Ausubel (1968) emphasized the difference between rote learning and meaningful learning. Understanding chemistry necessitates that students make sense of a number of interrelated concepts and ideas, i.e. develop knowledge structures organized around key concepts or ideas, that in turn guide their thinking (Bransford, Brown & Cocking, 2000; Burrows & Mooring, 2015; Galloway, Leung & Flynn, 2018; 2019). Students' difficulties may also result from limited working memory capacity (Kirschner et al., 2006; Sirhan, 2007; Reid 2008, 2014). When working memory is overloaded, there is no "space" left for processing, that is, to think and comprehend (Johnstone 1997; Baddeley, 1999; Reid 2008; Kirschner et al., 2006). Alternative conceptions play a bigger role in learning Chemistry than simply producing inadequate explanations to questions (Mulford & Robinson, 2002). New information could contradict the student's current understanding so accepting that information can be difficult as it seems wrong to him (Nakleh, 1992; Mulford & Robinson, 2002; Taber, 2002, 2009; De Jong & Taber, 2014). Students' attitudes toward science correlate positively and moderately with their performance (Mao et al., 2021). Difficulties can also arise due to lack of motivation for learning the subject (Pintrich & Schunk, 2002; Sirhan, 2007). The lack of interest in topics, and schooling in general, results in boredom, apathy, and disruptive behavior or, particularly in science, in dropout from advanced science classes (Nieswandt, 2007; Pintrich & Schunk, 2002). A study conducted among Bulgarian students outlines polar attitudes and low levels of interest in science subjects (Gendjova, 2017). There's a moderate direct correlation between self-efficacy beliefs and chemistry performance (Honicke & Broadbent, 2016; Zusho et al., 2003; Tenaw, 2013; Villafañe et al., 2016; Ferrell et al, 2016; Ramnarain & Ramaila, 2018). However, no amount of self-efficacy will produce a competent performance when students lack the needed skills to succeed (Schunk, 2012, cited in Schunk & DiBenedetto, 2016). Behavior is also influenced by students' values (perceptions of importance and utility of learning) and outcome expectations (Schunk & DiBenedetto, 2016).

Considering the learner as an active participant in the learning process and the concept of meaningful learning, along with the adopted model for information processing (taking into account students' alternative conceptions, cognitive and non-cognitive characteristics) makes it possible to identify difficulties in chemistry education, to identify some of the causes and outline guidelines for overcoming them.

2.2. Previous research on areas of perceived difficulty in school chemistry from teachers' and students' viewpoint

The areas (topics) from school chemistry curriculum perceived as difficult both by students and teachers have been subject to study by a number of researchers. Questionnaire surveys are employed most often as instruments for data collection. The following areas (topics) have been identified as difficult in previous studies: *Chemical symbols, formulae and equations* (Childs & Sheehan, 2009; Uzezi et al., 2017; Penn & Umesh, 2020); *Atomic structure and particulate nature of matter* (Jimoh, 2005; de Quadros et al., 2011; Childs & Sheehan, 2009); *Chemical bonding* (Childs & Sheehan, 2009; Gafoor & Shilna, 2013); *States of matter* (Achor & Agbidye, 2014; Jimoh, 2005; Uchegbu et al., 2016); *Elements and compounds* (Gongden et al., 2011 ; Gafoor & Shilna, 2013; Uzezi et al., 2017); *Periodic table of elements and periodic trends* (Gafoor & Shilna, 2013); *Reaction energetics* (Jimoh, 2005; Broman et al., 2011; Akani, 2017); *Reaction kinetics* (Jimoh, 2005; Akani, 2017; Uzezi et al.,2017); *Chemical equilibrium* (Gongden et al., 2011; Thomas & Schwenz, 1998; Bergquist & Heikkinen, 1990; Van Driel et al., 1998; Özmen, 2008); *Redox reactions and Electrochemistry* (Childs & Sheehan, 2009; Gongden et al., 2011); *Classification of chemical reactions* (Jimoh, 2005; Gongden et al., 2011); *Chemical analysis* (Childs & Sheehan, 2009; Broman et al., 2011; Akani , 2017); *Organic chemistry* (Jimoh, 2005; de Quadros et al., 2011; Gongden et al., 2011; Uchegbu et al., 2016; Childs & Sheehan, 2009; Broman et al., 2011); *Chemical calculations* (de Quadros et al., 2011; Uchegbu et al., 2016; Childs & Sheehan, 2009). The abstract nature of topics, the necessity of prior knowledge in mathematics and insufficient practical activities (labs) are the most frequently cited reasons for students' difficulties. There are no records of similar studies conducted in Bulgaria.

2.3 Difficulties in learning organic chemistry

Organic chemistry at the basic level in 9th grade

Students ought to acquire basic knowledge and skills in organic chemistry during compulsory education in the 9th grade, part of the first high school stage of secondary education. The study of organic compounds takes place in a relatively short period of time – within 30-35 instructional hours. The content is grouped into three chapters in accordance with the syllabus, namely: *Hydrocarbons*, *Hydrocarbon derivatives* and *Organic compounds in nature and in practice*.

Organic chemistry even at the basic level bears the characteristics of the subject area and poses a real challenge for the learner. A statement one can make after taking into consideration the importance and position of organic chemistry in the chemistry curriculum, its logical structure, basic and subsidiary concepts, as well as the three levels of representing chemical knowledge (according to Johnson, 1999). Analysis of course content in terms of cognitive learning levels and categories of knowledge (according to Anderson et al, 2001) further supports the above statement.

To highlight some of the characteristics of organic chemistry (at the basic level) that could pose a difficulty we could point out the following: many facts to remember; use of specific vocabulary, different from that of inorganic chemistry; abundance of symbolic representations, incl. three-dimensional models; necessity to develop specific procedural knowledge, logic and conceptual understanding of the structure-properties relationship and stepwise progression of organic chemistry in and of itself (by ideas of Gendjova, 2022; Sendur, 2020). The chapters on *Hydrocarbons* and *Hydrocarbon derivatives* in our case are representative of organic chemistry and serve as content basis for conducting empirical research.

Previous research on difficulties in learning organic chemistry

According to previous research findings, almost all main topics from an introductory organic chemistry course are difficult: *representation of organic compounds* (Kozma & Russell, 1997; Bodner & Domin, 2000; Johnstone, 2006; Anderson & Bodner, 2008; Graulich, 2015; O'Dwyer & Childs, 2017); *stereochemistry* (Keig, & Rubba, 1993; Bhattacharyya, 2004; Kozma, 2003; Wu & Shah, 2004; Anderson & Bodner, 2008; Harle & Towns, 2011; Stull et al., 2012; Padalkar & Hegarty, 2013; Eticha & Ochonogor, 2015; Graulich, 2015); *nomenclature of organic compounds* (Gongden et al., 2011); and *isomerism* (Schmidt, 1992; Taagepera & Noori, 2000; O'Dwyer & Childs, 2017). Learners also face difficulties with: classification (Hassan, Hill & Reid, 2004; Gongden et al., 2011; Uchegbu et al., 2016; O'Dwyer & Childs , 2017) and properties (Taber, 2002; Bryan, 2007; Ferguson & Bodner, 2008; Anderson & Bodner, 2008; O'Dwyer & Childs , 2017) of organic compounds; types of organic reactions (Childs & Sheehan 2009; Ferguson & Bodner, 2008; O'Dwyer & Childs, 2017); reaction mechanisms (Bhattacharyya & Bodner, 2005; Ferguson & Bodner, 2008; Kraft et al.,2010; Graulich, 2015; Galloway, et al., 2017; Crandell et al., 2018; Bodé & Flynn, 2019; Petterson et al., 2020; Watts et al., 2020) and practical work (Johnstone & Letton, 1991; Schroeder & Greenbowe, 2008; O'Dwyer & Childs, 2011). Diagnostic studies on difficulties in organic chemistry have been conducted primarily among university chemistry students with the use of diagnostic tests, surveys or by analyzing exam papers. During our review of the literature on the actual and perceived learning difficulties in organic chemistry we did not find such or similar studies carried out in Bulgaria.

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Research design

This study adopts a mixed method design (Creswell, 2003), combining qualitative and quantitative research methods of gathering and evaluating data, in order to gain a better understanding of the research problems.

Semi-structured interviews were used as qualitative methods, while quantitative methods included diagnostic tests, questionnaires and statistical analysis of obtained data. The integration of quantitative and quantitative data provides a clearer view on difficulties and perspectives in learning chemistry, and organic chemistry in particular, which, in turn, would allow us to give useful recommendations and suggestions for improving the learning process.

The present study is carried out in two cycles. The first cycle aims to identify the difficult topics in the chemistry curriculum and outline subject difficulties in general – from students' and teachers' point of view. The second cycle focuses on a particular topic identified as difficult – organic chemistry (at the basic level) in our case.

3.2 Methodology of cycle one

The purpose of this research cycle is to investigate how both students and teachers perceive the difficulty of individual topics from the school chemistry cirriculum, compulsory education. The following research questions were posed: Which topics from the Chemistry curriculum students perceive as difficult/interesting? Do students' and teachers' opinions differ? What are the causes of students' difficulties and the important skills, needed to be successful in chemistry class according to students and teachers?

Description of the sample groups

321 students aged 16-17 years participate in this cycle of research. Of these 53% are girls and 47 – boys. Participants are in 10th or 11th grade and attend in-person classes with a different profile in 5 secondary schools of different type: secondary schools without profiled training in the subject (105 SU "At. Dalchev", 134 SU "D. Debelyanov", Sofia); secondary schools with profiled training in chemistry (119 SU "Acad. M. Arnaudov", Sofia) and Natural sciences/Mathematics high schools with profiled training in chemistry and with a different profile (Sofia High School of Mathematics "P. Hilendarski", National High School of Mathematics and Natural Sciences "Acad. L. Chakalov").

The teacher group consists of a total of 20 teachers, 85% of which are female and 15% – males. More than half of the respondents (55%) have more than 20 years of teaching practice, whereas those with experience between 11 and 20 years are a quarter (25%), and young teachers with up to 3 years of experience constitute one fifth (20%) of the sample. Half of the teachers (50%) work in secondary schools, 25% in Natural sciences/Mathematics high schools and 10% in bilingual and vocational high schools. Most of them (60%) teach only chemistry while the rest have double majors (Chemistry and Physics or Chemistry and Biology).

Research tools

A questionnaire survey was employed in this cycle of research.

Table 3.6. Distribution of survey questions in students' questionnaire according to their focus

Focus	Sub focus
Personal information	Grade, school, sex
Student characteristics	Interest in chemistry, study habits, self-efficacy
Evaluation of skills for success	Level of importance of the skills needed to succeed
Areas of perceived difficulty	Level of perceived difficulty for curriculum topics
Areas of perceived interest	Level of interest in curriculum topics
Elaboration on perceived difficulty	Possible causes of difficulties
Overcoming subject difficulties	Ways to make instruction more successful and attractive

The survey questionnaire is used in two versions – one for students and one for teachers. Both versions contain a total of 6 questions formulated in a personal form for the purpose of obtaining direct information. Questions are adapted from the literature (Fui & Lian 2011; Glynn et al, 2011; Johnstone & Mahmoud, 1980; Broman et al., 2011). The distribution of questions in the student questionnaire, according to their goals, is given in Table. 3.6.

The questions in the teachers' questionnaire are similar to those found in the student version. In response to an additional question, teachers had to pick the obstacles they encounter in their teaching practice.

Implementing the first cycle of research and collecting data

The student questionnaire was administered on paper in April of the 2017/2018 school year and in March of the 2018/2019 school year, during in-person classes. Participants had about 30 minutes to complete the questionnaire.

The teacher survey was conducted in the period April 2018 - March 2019. The questionnaire was administered to teachers on paper in April of the 2017/2018 school year and in March of the 2018/2019 school year.

Data analysis

Descriptive statistics is applied to process and analyze students' results. The percentage of those who answered 4 and 5 on the Likert scale is taken as percentage of agreement with the statements regarding student interest, study habits and self-efficacy. An index of relative difficulty (IRD), resp. relative interest index (IRI), is computed for each topic (Johnstone & Mahmoud, 1980). Topics with an average difficulty value above 3.33 are said to be difficult. Topics with an average value of interest above 3.33 are considered interesting.

A five-point Likert scale from ***1*** = *Strongly disagree* to ***5*** = *Strongly agree* is used to measure teachers' agreement with the statements from the first question in the questionnaire. The percentage of responses with ***4*** and ***5*** is considered as percentage of agreement. The importance of the skills listed in the second question is expressed using a scale from ***1*** = *Not important* to ***5*** = *Very important*. The percentage for every skill is computed based on the number of responses with ***4*** and ***5*** on the scale. Teachers' responses to questions number three and four are collected and arranged in frequency distribution tables. An index of difficulty (IRD) and an index of interest (IRI) is calculated for each topic. Relative frequency is used in analyzing responses to questions number five and six.

3.3 Methodology of cycle two

This cycle of research is aimed at diagnosing students' difficulties in learning organic chemistry (at the basic level). The following research questions were posed: What are students' actual difficulties and subjective perceptions of difficulty and self-efficacy in learning organic chemistry at the basic level? What do teachers know about the difficulties in teaching and learning Organic chemistry at the basic level, the causes of difficulty and which teaching methods/approaches they consider as effective?

Description of the sample groups

379 students aged 15-16-years, studying the *subject Chemistry and environmental protection* in the 9th grade, participate in the second cycle of study. Of these 211 are girls and 168 are boys. The students were selected in a random manner from schools located in different residential areas in Bulgaria. The schools differ in type: 7 secondary schools (73. SU "Vl. Gramatik", Sofia; SU “E. Stanev”, V. Tarnovo; SU “N. Bonchev”, Panagyurishte; SU “H. Botev”, Tutrakan; SU “H. Smirnenski”, Kochan village; SU “St. St. Cyril and Methodius”, Satovcha village); 4 bilingual high schools (157 High school with Foreign languages “S. Vayeho”, 91 German Language School “Prof. K. Gylybov”, Sofia; First Language School, Varna); 1 high school with a mathematical profile (Math High School “Acad. Kiril Popov”, Plovdiv); 1 secondary school with a natural sciences profile (119. SU “Acad. M. Arnaudov”); one professional (National High School in Finance and Business, Sofia) and one specialized school (National School of Dance art, Sofia).

A total of 56 teachers participate in this cycle of research. The sample of surveyed teachers consists of 43 females and 10 males. They all teach Chemistry, some of them also teach Biology, Physics or Science. Respondents are from different residential areas in Bulgaria: capital (27.8%), major and minor regions (42,6%) and municipalities (16,7%), including villages (3,7%); and are working in different types of Bulgarian secondary schools: secondary schools (37%), bilingual (20,4%), vocational and natural-mathematical schools (11,1%) and other types (13%). Most teachers (48.1%) have more than 20 years of teaching practice, 18.5% – from 11 to 20 years, and the rest, equally distributed (16.7%), 4-10 years and 1-3 years, respectively. Most teachers (72%) have acquired an additional professional qualification degree. Three prominent chemistry teachers (1 male and 2 females) from the National High School of Mathematics and Natural Sciences – Sofia participate on a voluntary basis in a semi-structured interview. They have different teaching experience (26, 19 and 3 years, respectively) in both compulsory and profiled chemistry classes.

Research tools

A diagnostic test for students, a questionnaire surveys for students and teachers and interviews with prominent teachers are used to gather information.

The diagnostic test was developed following the methodology described by Treagust (1988) and Tafrova-Grigorova (2007). The pilot version of the test consists of 19 test items and was tested with 78 students. Test items with inappropriate difficulty and discriminating power were dropped from final version of the test after item analysis. The final test consists of 29 validated test items, 21 of which are multiple-selection matrix questions and 8 – single-select questions. A concise version of the test specification is presented in Table 3.12.

Table 3.12. Test specification (concise version)

Areas of competence and instructional objectives **Students will be able to:**	**Tasks**	
	Count	**Knowledge level**
Classification and nomenclature of compounds		
Recognize structures of organic compounds	3	U
Represent organic compounds using structural formulas	2	Ap
Name organic compounds	3	Ap
Structure and properties of compounds		
Distinguish isomers	1	U
Deduce properties of organic compounds from their structure	4	U
Chemical processes		
Represent chemical properties of organic compounds using equations/schemes. Describe chemical properties of organic compounds	4	Ap

Recognize chemical equations of organic reactions of practical interest	3	U
Application and biological role of organic compounds, impact on the environment		
Evaluate Application and biological role of organic compounds, impact on the environment	2	R
Experiment and research		
Planning experiments to identify organic compounds	2	A
Presenting experimental results and drawing conclusions	2	A
Retrieving and evaluating chemical information from diagrammatic and graphic presentation of data	3	A

Legend: R – remembering; U – understanding; Ap – application; A – analysis or higher.

The diagnostic test was provided to university professors working in the field for expert review and to experienced chemistry teachers for evaluation of content validity. Test questions were reformulated in accordance with received feedback and recommendations. Content validation through expert judgement was carried out with the contribution of 10 experts (chemistry teachers). The experts confirmed that the test items cover the educational content subject to verification, which in turn is an indicator of its content validity (according to Tafrova-Grigorova, 2007). Therefore, the test is suitable for students studying organic chemistry at the basic level. Test reliability is assessed using the valid results of 100 students based on 29 test items. The reliability of the test (Cronbach‘s alpha) is $\alpha = 0{,}89$, therefore the test is reliable. The calculated overall difficulty is 49.1%, which indicates the test is moderately difficult.

The student questionnaire aims to collect information about certain student characteristics (study habits, interest in the subject) as well as perceptions of difficulty and self-efficacy in learning organic chemistry. The questionnaire consists of a total of 24 questions adapted from literature sources (Fui & Lian 2011; Glynn et all, 2011; Lee & Tajino, 2008; Adesoji et al. 2017, Aydın & Uzuntiryaki, 2009; Uzuntiryaki & Aydın, 2009). Students express their level of agreement with the statements using a five-point Likert scale. The distribution of questions, according to their objectives is shown in Table. 3.13.

Table 3.13. Distribution of survey questions in students’ questionnaire according to their focus

Focus	Examples of statements/questions
Student characteristics level of agreement for interest in chemistry and study habits	Learning chemistry is interesting I’m interested in chemistry even out of school I study my Chemistry lessons consistently I do the practice problems at the end of each lesson
Perceptions of difficulty in learning organic chemistry	To what extent it is difficult for you to recognize structures of hydrocarbons and their derivatives?
Perceptions of self-efficacy in learning organic chemistry	How confident are you in explaining chemical properties of organic compounds using their structure?

A semi-structured interview with selected prominent teachers is conducted for the purpose of the study. It is a type of mixed interview, with a predetermined set of questions, which are open-ended, giving the interviewee more opportunities to fully express himself (Turner, 2010). In developing the interview questions, focus was put on teachers’ practical experience and knowledge about teaching and learning organic chemistry. The distribution of questions by areas and sub-areas is shown in Table. 3.14.

Table 3.14. Distribution of questions from the teachers' interview according to their focus

Focus	Sub focus	Questions
Knowledge for learning organic chemistry	Students' interest in organic chemistry	Do your students find organic chemistry interesting? What do you think is most interesting for them and what – least?
	Students' learning difficulties in organic chemistry	Is organic chemistry easy for students to learn? What is most difficult for them?
	Causes of learning difficulties	What do you think are the causes for students' difficulties?
Knowledge for instructional strategies and difficulties in teaching	Teaching difficulties	Is organic chemistry easy to teach? What difficulties do you encounter most often?
	Effective methods/approaches to teaching	What methods/approaches do you think are most effective for teaching organic chemistry at the basic level?
	Ways to overcome teaching difficulties	What are your recommendations and suggestions for overcoming the difficulties you face in teaching organic chemistry?

The teacher survey is carried out through a four-section questionnaire. The first section collects participants' demographics, the second – information on whether organic chemistry is interesting/easy for students, based on a five-point Likert scale rating. The third section asks teachers to assess students' degree of difficulty in achieving the most important curriculum learning objectives, using a five-point scale. In the last section, teachers are prompted to provide a free response to questions regarding the causes of difficulties in learning organic chemistry and effective methods for addressing them. The distribution of questions by objectives is presented in Table. 3.15.

Table 3.15. Distribution of survey questions in teachers' questionnaire according to their focus

Focus	Sub focus	Statements/Questions (example)
Knowledge for learning organic chemistry	Students' interest in organic chemistry	Organic chemistry is interesting for my students
	Students' learning difficulties in organic chemistry	Organic chemistry is easy for my students to learn
	Degree of specific difficulty in organic chemistry (at the basic level)	Representing chemical properties of organic compounds using equations/schemes
	Causes of learning difficulties	What do you think are the causes for students' difficulties?
Knowledge for instructional strategies and difficulties in teaching	Teaching difficulties	Is organic chemistry easy to teach? What difficulties do you encounter most often?
	Effective methods/approaches to teaching	What methods/approaches do you think are most effective for teaching organic chemistry at the basic level?
	Ways to overcome teaching difficulties	What are your recommendations and suggestions for overcoming the difficulties you face in teaching organic chemistry?

Implementing the second cycle of research and collecting data

Final diagnostic testing and questionnaire survey of 15-16-year-old students, as well as interview and survey among chemistry teachers, were conducted in the Second cycle of the current study.

The diagnostic test is administered to students at the end of the second term of the 2020/2021 school year, in electronic form using Google forms. At that point all the organic chemistry course content has been covered and chemistry instruction has taken place entirely online. They had 40 min. to complete the test.

The student survey was carried out simultaneously in electronic form using Google forms. Participants were given the opportunity to fill in the survey at a time of their convenience. The survey had to be filled out prior to solving the diagnostic test.

The semi-structured interviews with teachers were conducted in October, 2020. The duration of interviews varies between 12 and 22 minutes. Each interview was audio recorded and transcribed.

The teacher survey was administered in October-November 2020 using an online questionnaire in Google Forms. Teachers were provided a link and they participated voluntarily.

Data analysis

When analyzing students' test scores, it was accepted that for an item to be classified as showing widespread difficulty for students, it ought to be experienced by at least 50% of the students (Adesoji, 2017). Descriptive statistics is applied for data analysis.

Students' agreement with the statements from the questionnaire is measured using a five-point Likert scale from ***1*** = *Strongly disagree* to ***5*** = *Strongly agree*. The percentage of responses with ***4*** and ***5*** is considered as percentage of agreement, whereas percentage of responses with ***1*** and ***2*** – as percentage of disagreement. The mean values of some responses are used for better description of the sample group and to provide answers to research questions. To determine perceived difficulty, students' responses are divided into three categories: easy (***1*** = *very easy*; ***2*** = *easy*), neutral (***3*** = *neither easy nor difficult*), difficult (***4*** = difficult; ***5*** = very difficult) and relative frequency and mean is calculated for each. For perception of self-efficacy, students' responses were divided into three categories: not confident (***1*** = *not confident at all*; ***2*** = *somewhat confident*), neutral (***3*** = *somewhat confident*), confident (***4*** = *I am relatively confident*; ***5*** = *I am completely confident*), relative frequency is calculated for each.

Analysis of teachers' data began with the transcribed interviews. The interviews were cross-analyzed to search for similarities and differences among teachers' opinion and the results were summarized. A five-point Likert scale starting from ***1*** = *Strongly disagree* to ***5*** = *Strongly agree* is used to measure teachers' agreement with the statements from the survey. The percentage of responses with ***4*** and ***5*** is considered as percentage of agreement, whereas percentage of responses with ***1*** and ***2*** – as percentage of disagreement. The scale used to measure teachers' agreement on statements for levels of difficulty ranges from ***1*** = *Very easy* to ***5*** = *Very difficult*. The percentage of teachers who answered that a given objective is difficult is the percentage of responses with ***4*** and ***5*** on the scale, as for easy – the percentage of responses with ***1*** and ***2*** on the scale.

CHAPTER 4. FIRST CYCLE RESULTS AND DISCUSSION

4.1 Results from the student survey

4.1.1. Student characteristics

Responces to the first question in the questionnaire allow us to gain a general perspective of the study sample. It has been established that it is diverse – consists of students differing in learning abilities, levels of interest towards the subject and study habits.

4.1.2. Difficult topics from the chemistry curriculum according to students

The topics are sorted in descending order of their index of relative difficulty (IRD, %) in order to identify the most difficult ones (Fig. 4.1).

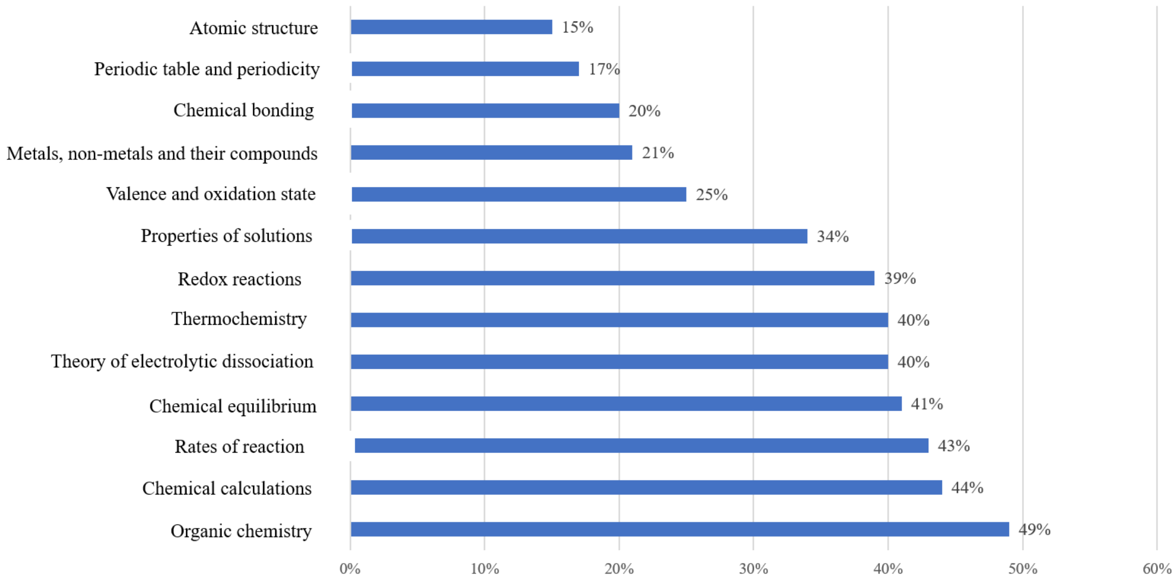

Fig. 4.1 Comparison of topics by index of difficulty according to student responses (n = 321)

In accordance with the computed index of relative difficulty, the topics perceived by students as most difficult are: *Organic Chemistry* (IRD = 49%); *Chemical calculations* (IRD = 44%); *Rates of reaction*. *Catalysis* (IRD = 43%) and *Chemical Equilibrium* (IRD = 41%). The topics: *Theory of electrolytic dissociation. Acids and bases* (IRD = 40%), *Thermochemistry* (IRD = 39%) and *Redox reactions* (IRD = 39%) are perceived as being less difficult. The six that remain can be considered neither difficult nor easy.

4.1.3. Interesting topics from the chemistry curriculum according to students

Topics were ranked in accordance with their calculated index of relative interest (IRI, %) in order to identify the interesting ones (Fig 4.2).

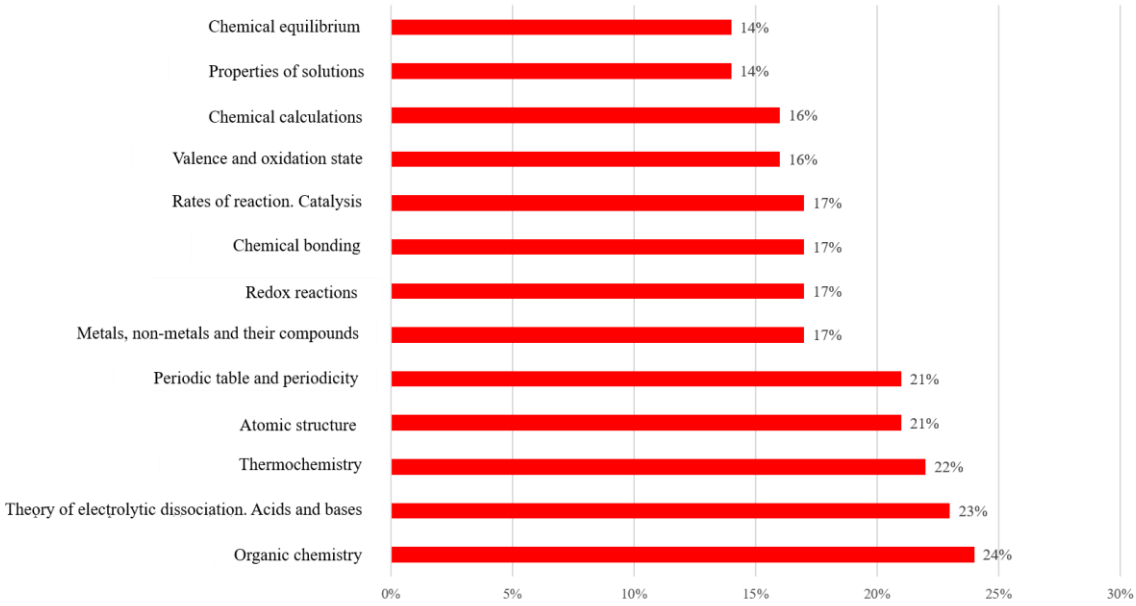

Fig. 4.2 Comparison of topics by index of relative interest according to student responses (n = 321)

The topics most often indicated as interesting are: *Organic Chemistry* (IRI = 24%), *Theory of electrolytic Dissociation. Acids and Bases* (IRI = 23%), *Thermochemistry* (IRI = 22%), *Atomic Structure* (IRI = 21%) and *Periodic table and periodicity* (IRI = 21%).

4.1.4. Comparison of student views on difficult and interesting topics

Fig. 4.3 presents a graphical comparison of student views on difficult and interesting topics in the chemistry curriculum.

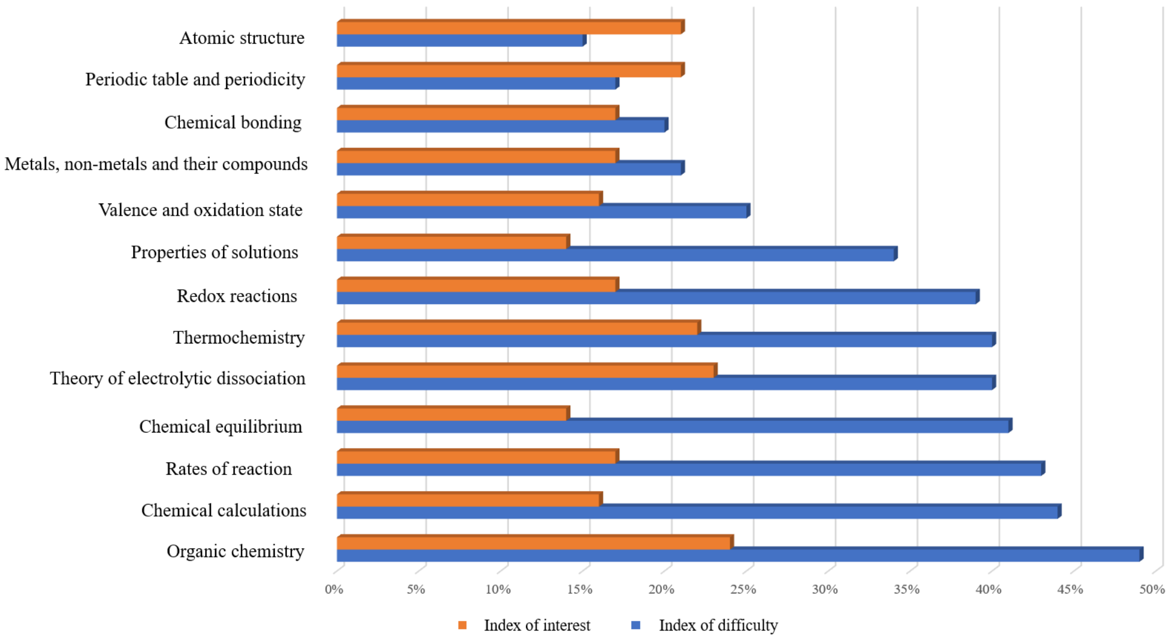

Fig. 4.3 Comparison of student views on difficult and interesting topics in the chemistry curriculum.

Our initial expectations that difficult topics are not interesting were not confirmed. Some of the topics are difficult and yet uninteresting, for example *Chemical Calculations*. Others, like *Organic Chemistry*.

are indicated by students as being most difficult (IRD = 49%) and, at the same time, most interesting (IRI = 24%). *Atomic structure* and *Periodic table and periodicity* (IRD = 15%) are perceived as interesting and easy simultaneously. It is worth noting there is no topic with a particularly high index of relative interest.

4.2 Results from the teacher survey

4.2.1. Difficult topics from the chemistry curriculum according to teachers

The topics which teachers consider as being difficult for their students are ranked by index of relative difficulty (IRD, %) and shown in Table. 4.3.

Table 4.3 Topics ranked by index of relative difficulty according to teacher responses

Rank	Topics	IRD, %
1.	Chemical equilibrium	70
2.	Chemical calculations	65
3.	Organic chemistry	60
4.	Redox reactions	55
4.	Thermochemistry	55
6.	Rates of reaction. Catalysis	35
7.	Valence and oxidation state	25
8.	Theory of electrolytic dissociation. Acids and bases	15
8.	Properties of solutions	15
8.	Chemical bonding	15
8.	Periodic table and periodicity	15
12.	Atomic structure	10
13.	Metals, non-metals and their compounds	5

According to Table 4.3, the topics teachers most often indicate as being difficult for their students are: *Chemical equilibrium* (IRD = 70%), *Chemical calculations* (IRD = 65%) and *Organic Chemistry* (IRD = 60%). Conversely, the topics *Metals, non-metals and their compounds* (IRD = 5%) and Atomic structure (IRD = 10%) are the easiest.

4.2.2 Interesting topics from the chemistry curriculum according to teachers

The topics in the chemistry curriculum that teachers consider as interesting for their students are ranked by index of relative interest (IRI, %) and shown in Table. 4.4.

Table 4.4 Topics ranked by index of relative interest according to teacher responses

Rank	Topics	IRI, %
1.	Metals, non-metals and their compounds	60
2.	Redox reactions	55
3.	Atomic structure	50
4.	Theory of electrolytic dissociation. Acids and bases	45
5.	Periodic table and periodicity	40
6.	Chemical bonding	25
6.	Valence and oxidation state	25
8.	Organic chemistry	15
9.	Properties of solutions	10
10.	Rates of reaction. Catalysis	0
10.	Chemical calculations	0
10.	Thermochemistry	0
10.	Chemical equilibrium	0

According to surveyed teachers, the topics *Metals, non-metals and their compounds* (IRI = 60%), *Redox reactions* (IRI = 55%) and *Atomic structure* (IRI = 50%) are the most interesting for their students. The most uninteresting are: *Chemical equilibrium* (IRI = 0%); *Thermochemistry* (IRI = 0*%); Rates of reaction. Catalysis* (IRI = 0%) and *Chemical Calculations* (IRI = 0%). *Properties of solutions* (IRI = 10%) and *Organic Chemistry* (IRI = 15%) are among the relatively uninteresting topics. It is noteworthy that for teachers, topic difficulty is associated with lack of interest, and conversely – easy-to-learn topics are interesting for students.

4.3. Comparison of teacher and student results

4.3.1 Comparing the difficult topics according to teachers and students

Comparing data from Tables 4.1 and 4.3 shows there's a good match in both groups' perceptions regarding the difficult topics in the chemistry curriculum, probably due to the teachers' teaching experience. The topics (Table 4.5), most often indicated as difficult by the students, are also most often pointed out by teachers, namely: *Organic chemistry*, *Chemical calculations*, *Chemical equilibrium*, *Rates of reaction*. *Catalysis*. These topics contain abstract concepts, employ specific chemical logic and terminology, and require mathematical skills.

Table 4.5 The most difficult topics in the chemistry curriculum according to teachers and students

Topics	Students		Teachers	
	IRD, %	Rank	IRD, %	Rank
Organic chemistry	49	1.	60	3.
Chemical calculations	44	2.	65	2.
Reaction rates. Catalysis	43	3.	35	6.
Chemical equilibrium	41	4.	70	1.
Theory of electrolytic dissociation. Acids and bases	40	5.	15	8.
Thermochemistry	39	6.	55	4.
Redox reactions	39	6.	55	4.

4.3.2. Comparing the interesting topics according to students and teachers

A significant discrepancy in teachers' and students' perceptions regarding interesting topics in the chemistry course becomes notable when comparing data from Tables 4.2 and 4.4. The relatively most interesting topics are shown in Table 4.6.

Table 4.6 The relatively most interesting topics according to teachers and students

Topics	Students		Teachers	
	IRI, %	Rank	IRI, %	Rank
Organic chemistry	24	1	15	8
Theory of electrolytic dissociation. Acids and bases	23	2	45	4
Thermochemistry	22	3	0	10
Atomic structure	21	4	50	3
Periodic table and periodicity	21	4	40	5
Metals, non-metals and their compounds	17	6	60	1
Redox reactions	17	6	55	2

The topics indicated by the teachers as being interesting for their students – *Metals, non-metals and their compounds* and *Redox reactions* – are not among the most preferred by the students themselves.

At the same time, the relatively most interesting topic for students – *Organic Chemistry* is indicated as such by a very few teachers. This goes to shows that teachers are not sufficiently aware of their students' self-interest motives.

4.3.3. Comparing the important skills needed to be successful in chemistry class according to teachers and students

It should be noted (Table 4.7) that understanding scientific concepts, principles and laws is an important skill according to both sample groups. But while most students consider it very important to be able to memorize chemical formulas and facts, only a minority of teachers shares this view. At the same time, for almost half of the teachers, the skills to gather and compare information from different sources and share it with others is important, they are not indicated as such by any student.

Table 4.7 Important skills needed to be successful in chemistry class according to teachers and students

Student skills for success	Students		Teachers	
	%	Rank	%	Rank
Self-training	100	1	90	2
Understanding scientific concepts, principles and laws	90	2	95	1
Memorizing chemical formulas and information	60	3	35	6
Making reasoned inferences and logical conclusions	40	4	85	3
Working together in groups	10	5	45	4
Solving problems creatively, including practical ones	10	5	40	5
Gathering and comparing information from different sources	0	6	45	4
Sharing and presenting ideas to others	0	6	40	5

4.3.4. Comparing the causes of learning difficulties in chemistry according to teachers and students

Table 4.8 summarizes the causes for learning difficulties in chemistry from a different perspective.

As causes for student difficulties, teachers most often point out: insufficient number of instructional hours; no effort from students and lack of mathematical knowledge and consistency in their preparation; low levels of study habits and interest toward the discipline among students. Teachers indicate problems related to the school environment as well. According to students, their difficulties in learning chemistry are mainly due to the large amount of information and the need to memorize it, the lack of apparent connection between theory and practice, as well as the need for systematic preparation. Both groups believe that the most important skills need to be successful in the subject are: self-training; understanding scientific concepts principles and laws and making reasonable inferences and logical conclusions.

4.5. Summary and discussion of the results obtained in the first cycle of research

Results obtained from the student survey show the topics *Organic chemistry* and *Chemical calculations* to be perceived as being most difficult. Broman et al. (2011) report similar findings. Topics identified as difficult indicate where teachers should focus their efforts in the classroom. *Organic chemistry*, *Theory of electrolytic dissociation* and *Atomic structure* are among the most interesting topics, consistent with the results obtained by Broman et al. (2011). The majority of students perceive *Organic chemistry* as being both difficult and interesting at the same time. Students' interest in the topic could be explained with the role and importance of organic compounds for living organisms and the processes taking place within them, as well as their wide industrial and everyday use.

Chemical calculations stood out as the area cited by most students as difficult and uninteresting. This may be due to insufficient mathematical skills on their part, inappropriate pedagogical approaches employed by teachers in problem solving, formally assigned tasks, and others reasons.

There appears to be no correlation between topic interest and perceived topic difficulty. Perhaps, for students who have an interest in chemistry, difficulty is not an obstacle, but rather a challenge, while for others it leads to waning interest.

Bulgarian students' recommendations for a conducive learning environment coincide with the ones given by the students in the study of Broman et al. (2011). Clarifying the causes of students' difficulties and their recommendations will allow for making improvements in the learning process, both in terms of content and procedural activities.

The results obtained from the teacher survey provide insight into the pedagogical knowledge of Bulgarian teachers for the difficulties their students encounter in studying certain topics in the chemistry curriculum. The topics indicated as particularly difficult (*Chemical equilibrium*, *Chemical calculations* and *Organic chemistry*) are also reported in other studies (Broman et al., 2011; de Quadros et al., 2011; Alake Monica, 2013; Bilek et al, 2019). For the most part, these topics contain abstract concepts, specific chemical logic and terminology, and require mathematical skills. The good match in teachers' and students' perceptions is probably due to teachers' teaching experience. Broman et al. (2011), however, found a discrepancy in the viewpoints of teachers and students on this matter.

The topics identified by the Bulgarian teachers as being interesting for students (*Metals, non-metals and their compounds*, Redox reactions and *Atomic structure*) only partially coincide with the results obtained by Broman et al. (2011). It is worth noting that Bulgarian teachers believe that topic difficulty leads to a lack of interest, and vice versa – easy-to-study topics are interesting for students. According to their students this is not the case.

Additionally, the topics pointed out by the teachers as being interesting are not among the most frequently indicated as such by the students themselves. This goes to show that teachers are not sufficiently aware of their students' self-interest motives.

According to surveyed teachers, the most important skills needed to be successful in chemistry class are: understanding scientific concepts, principles and laws; self-training and logical thinking. Their students consider memorizing facts and concepts as most important, followed by self-training and understanding scientific concepts, principles and laws. The "cramming study strategy" adopted by students is clearly ignored or implicitly encouraged by teachers.

As most important reasons for their difficulties, students indicate: the amount of material they have to learn; the need for it to be memorized and lack of connections to everyday life. A large part of them realize that their difficulties are due to the fact that learning chemistry requires effort and systematic preparation.

According to pupils, their difficulties in the subject can be reduced mainly by more practical activities, better written textbooks and ancillary resources, more group work and use of technology in class.

As reasons for student difficulties, teachers most often point to the insufficient number of instructional hours, the abstract concepts, the fact that learning chemistry requires effort and systematic preparation, and the use of mathematics. As other obstacles in their work, teachers consider the lack of interest and study habits among students, as well as problems with discipline and the absence of well-equipped chemistry labs in school. Teachers' responses are in good agreement with previous research results obtained by Alake Monica (2013) and Uchegbu et al. (2015).

CHAPTER 5. SECOND CYCLE RESULTS AND DISCUSSION

5.1 Student diagnostic test results

Students' test scores are presented both as a raw score for each problem and a total raw score for the entire test, as well as in grades.

5.1.1 Frequency distribution of students' test scores

The computed frequency distribution of students' test scores is shown in Fig. 5.1.

The raw scores are distributed in 3-point increments. The number of individuals with a score that falls within a given interval gives the absolute frequency *f*. The frequency divided by the total number of participants in the study gives the relative frequency f_r. Relative frequency is expressed as percentage. We can single out four peaks in the distribution: at scores 9-11 (14%), 6-8 (13%), 12-14 (13%) and at 24-26 (12%) points. The number of students with a test score in the range of 9-11 points is the largest. A total of 49.6% of the students have a score below 50% of the maximum, i.e., half of the students have learning difficulties in chemistry. The least are the students with a score in the interval 0-2 points – 2%. The number of students with test scores in the intervals of 6-8 and 12-14 points is approximately equal. A total of 11% of those tested fall into the 27-30 points range.

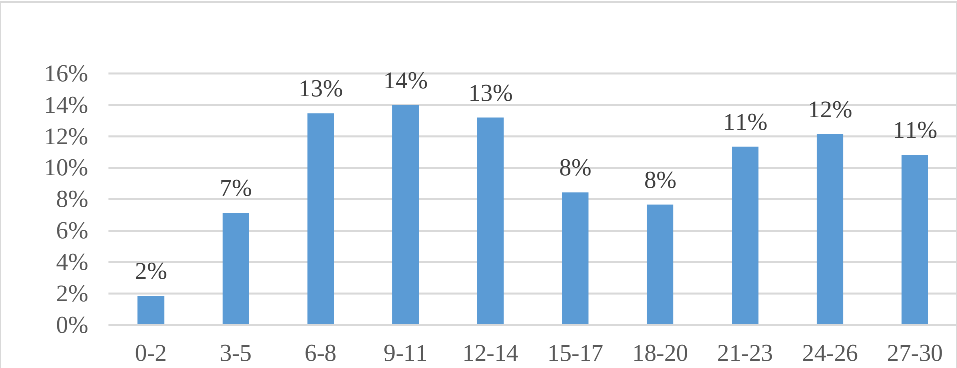

Figure 5.1 A histogram of students' test scores frequency distribution (n = 379)

Table 5.1 shows the values of some basic statistical variables that characterize the frequency distribution. The mean serves as a measure of central tendency, and the standard deviation is a measure of dispersion around that value.

Table 5.1 Values of some statistical variables, characterizing the obtained test results

Variable	Value
Mean test score $\bar{X}$	14
Standard deviation σ	8
Median	13
Mode	8

The average test score is less than half of the maximum score on the test, indicating the test was difficult for the students. The large value of the standard deviation (27% of the maximum number of points) indicates the studied sample group consists of students with different levels of knowledge and skills, i.e. it includes both high-achieving and low-achieving students. The mean and median are close – a sign of normal distribution. The mode shows the density of the test score distribution. It takes the numerical value of the test score that appears most often in the distribution. In this case, its value is 8 (9-11) meaning distribution is unimodal and the mode is in the interval 9-11 points. We can also say that most students from the entire sample scored between 6 and 14 points.

5.1.2 Frequency distribution of students' test grades

Each student's test score was converted into a grade on the six-point grading system in Bulgaria (Bizkov, 1996). A distribution of students by test grades is presented in figure 5.2.

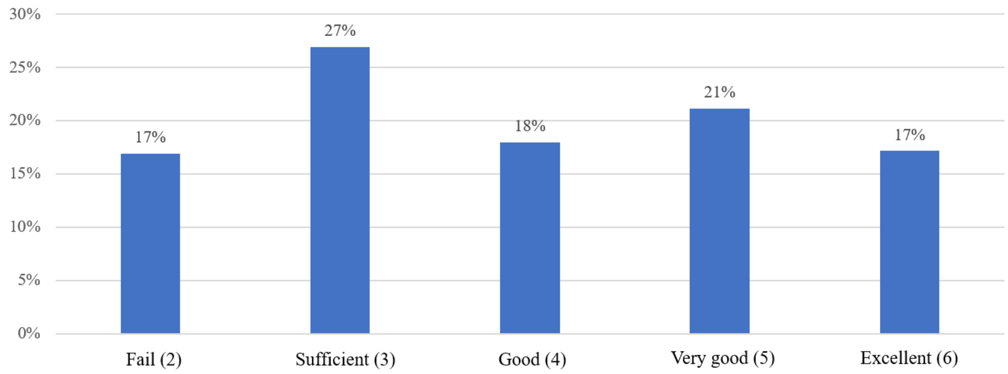

Fig 5.2 A histogram of students' test grades frequency distribution (n = 379)

The largest number of students got an "Sufficient (3)" grade (102), and the smallest – those graded with "Fail (2)" (64). The number of students with grades "Fail (2)" and "Excellent (6)" is approximately equal (64, respectively 65). Sixty-five of the students tested got an "Excellent (6)" grade.

5.1.3 Distribution of students' actual learning difficulties by content areas in organic chemistry at the basic level

For the purposes of the current study, it was important to identify students' difficulties in each content area in organic chemistry at the basic level in 9th grade. The obtained results are presented in the table. 5.2, which distributes students' difficulties by content areas (as accepted in research literature), provides a description of the respective difficulty and indicates its frequency of occurrence.

Table 5.2 Distribution of students' actual learning difficulties by content areas in organic chemistry at the basic level and their frequency of occurrence (n = 379)

Prob. №	Content area	Nature of difficulty	Frequency of occurrence	
			n	RF
1.1	*Classification of OC*	Does not classify hydrocarbons as alkanes, alkenes, alkynes by structure	122	32%
2.1.		Does not recognize structures of hydrocarbon derivatives	146	38%
2.2			139	37%
1.2.	*Nomenclature of OC*	Does not name structures of hydrocarbons according to IUPAC rules	95	25%
2.3		Does not name structures of hydrocarbon derivatives according to IUPAC rules	140	37%
2.4			130	34%
3.1	*Representation of OC*	Does not represent certain hydrocarbon derivatives using chemical formulas	177	47%
3.2			305	66%

Prob. №	Content area	Nature of difficulty	Frequency of occurrence	
			n	RF
1.3	*Isomerism*	Does not distinguish chain isomers of alkanes by structure	109	29%
1.4	*Structure and properties*	Does not associate properties of organic compounds (hydrocarbons, alcohols, aldehydes, ketones and monocarboxylic acids) with the type of chemical bonds and functional group, present in their molecules	211	56%
1.5			242	64%
2.5			214	56%
2.6			207	55%
4.1.1	*Chemical processes*	Does not represent characteristic chemical properties of studied organic compounds using chemical equations or reaction schemes	235	62%
4.1.2			224	59%
4.1.3			220	58%
4.2			219	55%
5.1		Does not recognize types of organic reactions presented with chemical equations or reaction schemes: combustion, addition, polymerization and esterification	216	57%
5.2			208	55%
5.3			212	56%
2.7	*Role, application and impact of OC*	Does not describe practical application of organic compounds	143	37%
2.8			136	36%
6.1	*Experiment and research*	Does not plan chemical experiments to test for the presence of certain organic compounds	195	51%
6.2			170	45%
6.3.		Does not present results from chemical experiments; does not make inferences and conclusions	214	56%
6.4			207	55%
7.1		Does not retrieve and analyze chemical information from graphic presentation of data	222	59%
7.2			201	53%
7.3			234	62%

Legend: OC – organic compounds; RF – relative frequency

Problem 1.1 requires students to classify the hydrocarbon represented with a structural formula as alkene or alkyne depending on the test variant. The majority of ninth-graders coped with the task – 68%. The relative frequency of those who faced difficulties is relatively low – 32%.

Problem 1.2 asks students to match the given hydrocarbon name with the corresponding structure which clearly is not problematic for them – 75% of the answers provided are correct. Only 25% of students encountered difficulties.

A similar situation is observed with problem 1.3, which tests students' ability to distinguish chain isomers of alkanes. A total of 71% participants indicated the correct answer, while 29% of them seem to struggle with naming organic compounds.

Problem 1.4 tests if students understand the composition-structure-properties relationship and in particular, whether they are able to associate chemical properties of hydrocarbons with the type of chemical bonds in their molecules.

Successful solving of problem 1.5, requires students to pick the structure of the hydrocarbon obtained when H_2 is added to an alkene or alkyne, depending on test variant. A large part of the students (64%) found it difficult to associate the type of multiple bond in molecules of alkenes and alkynes with the characteristic for them reactions of addition. This shows students lack conceptual understanding for the reactions alkenes and alkynes typically undergo.

In problems 2.1 and 2.2 students are presented with structures of several organic compounds (alcohols, carbonyl compounds and carboxylic acids) and asked to classify them by functional group.

The share of those who were able to do so is 62%, respectively 63% (depending on test variant) while 38%, resp. 37% faced difficulties in solving the problem.

Naming structures of hydrocarbons derivatives in solving problems 2.3 and 2.4 is difficult for more than nearly 1/3 of the ninth-graders (37%, 34% respectively) tested. Answers provided show they don't know the names of the hydrocarbons with the corresponding number of carbon atoms in their molecules, that determine the name's stem, don't know the appropriate suffix to the name or fail to recognize the corresponding functional group.

Problems 2.5 and 2.6 check whether students are able to associate particular chemical properties of organic compounds (hydrocarbons, alcohols, aldehydes, ketones and monocarboxylic acids) with the types of chemical bonds and functional group present in their molecules. The majority of ninth-graders failed to answer correctly – 56% and 55%, respectively, which means achieving this particular learning objective poses a difficulty for them.

Problems 2.7 and 2.8 are concerned with the practical application of important organic compounds. Most of the students were able to provide correct answers, but more than 1/3 of them (37% and 36%) were not, which indicates gaps in knowledge regarding practical application of studied organic compounds.

Problems 3.1 and 3.2 test students' ability to represent organic compounds (hydrocarbons and their derivatives) with chemical formulas. Students are asked to write the condensed formula of one hydrocarbon and one derivative. Given the test is taken in electronic form (online), an example formula is provided to illustrate an answer entered correctly and its interpretation. It is noteworthy that more ninth-graders had difficulty (66%) writing the formula of the hydrocarbon, while 47% – that of the hydrocarbon derivative. This observation could be explained if we take into account that the derivatives whose formulas were required contain only one carbon atom in their structure (methanol, resp. methanal), opposed to the hydrocarbons which have more than one carbon atom (butane, resp. pentane), hence the higher chance of making a mistake when writing/providing the formula. Although the sample formula implicitly gives away which chemical formulas are condensed formulas, it is striking that quite often the target compounds were represented using molecular formulas instead.

Problems 4.1.1, 4.1.2 and 4.1.3 and 4.2. assess students' ability to represent chemical properties of studied organic compounds with chemical equations or to complete reaction schemes. Results indicate that more than half of the tested ninth-graders (62%, 59%, 58% and 55%) either do not know the chemical properties of the compounds, involved in the reaction scheme shown, or experience difficulty when chemical properties are presented with reaction schemes. In solving problem 4.2, for example, methanol is most often chosen instead of acetaldehyde (second option), which is probably due to the fact its chemical formula resembles that of acetaldehyde (methyl group present in both structures).

Problems 5.1, 5.2 and 5.3 check whether students are able to determine the type of each organic reaction (combustion, addition, substitution, esterification, polymerization) in a reaction scheme. More than half of students tested failed to provide correct answers for all reactions (57%, 55%, 56%). Therefore, recognizing types of organic reactions proves to be difficult for most ninth-graders.

Problems 6.1, 6.2 and 6.3 bring to students' attention a mental experiment for distinguishing organic compounds using tests for functional groups. Test variant I requires distinguishing propanone from propanal, whereas test variant II – ethanal from ethanol.

Solving problem 6.1 asks students to pick the appropriate reagent to carry out the functional group test. Such a reagent is indicated by almost half (49%) of the students. For both test variants, this is most often silver(I) oxide, and depending on the student's level of preparation, is named either as Tollens' reagent or as ammonia solution of Ag_2O. Felling's solution is a popular choice among those solving the second test variant. Although the Iodoform test is not studied in compulsory chemistry classes, Iodoform (triiodomethane) can be spotted among the answers provided. Most students (51%) failed in choosing the right reagent. A large share of them either entered random characters/letters in the answer box to carry on filling the diagnostic test (the question was set as mandatory) or wrote “I don’t know”.

The reaction conditions for the particular test must be provided in solving problem 6.2. Most students (55%) correctly point out heating the reaction mixture. A variety in the wording of the answer is also observed: heating, high temperature, temperature, even the Bulgarian slang "heat". Some have extended their answers by adding high pressure and a catalyst. The problem proved to be difficult for 45% of the students which did not provide an answer.

In solving problems 6.3 and 6.4 students have to answer what changes would be observed, if any, after the addition of the suggested reagent to each of the compounds. In other words, students are asked to predict the outcome of the mental experiment. 56% respectively 55% of the tested ninth-graders did not give a correct answer. Regarding the propanone/propanal pair some students state that upon addition of the reagent: “other hydrocarbons would be produced”; combustion would be observed or a change in color, “would be converted to acetone” or even … “silver/silver mirror is deposited”. Among the wrong answers for the ethanal/ethanol pair are: “separation”, “the alcohol would burn”, “silver mirror”, “the solution turns ink blue” and even “the composition changes”. Answers clearly indicate students struggle with planning a functional group test, predicting its outcome and drawing conclusions. It is evident there’s confusion and mix up of different functional groups tests.

Problems 7.1, 7.2 and 7.3 aim to test students’ ability to retrieve information for organic compounds from a graph. These are free response questions. A chart of boiling points plotted against the number of carbon atoms in straight chain organic compounds is brough to the students’ attention. The boiling points of the first members of the homologous series of alkanes and alcohols are compared in test variant I whilst in test variant II – those of alcohols and carboxylic acids.

Providing an answer to 7.1 requires ninth-graders to determine, using the graph, which homologous alkane, resp. alcohol, has a lower boiling point and afterwards to enter its name in the box. Most students (59%) gave wrong answers. At the same time, some didn’t even note boiling points of which homologous series are being compared and/or failed to read the graph. We even found " It's not written anywhere" among the answers.

Problem 7.2 requests that students, using the graph, write the name of the alcohol, resp. carboxylic acid that boils at the given temperature. Here, 53% of them gave wrong answers. Some of the wrong answers given to test variant I are: “rakia[1]”, “alcohol with a high concentration”, “I have no idea, vodka”, even “ethylene glycol or 1,2-ethanediol”.

To solve problem 7.3, the students, using the graph, must determine, which homologous member with three carbon atoms in the molecule has a lower boiling point and then write its name. This is the problem that the most students have failed to solve – 62%. The obvious lack of understanding and powerlessness leads to paradoxical answers such as "rakia but weaker".

In general, problems 7.1, 7.2 and 7.3, are the ones posing the greatest challenge for students. Here we read “I don’t know” or see random characters/letters in the answer box most frequently. We could argue that the learning process places more emphasis on acquisition of information rather than on extracting and interpreting it from models, tables, graphs and diagrams, for example.

Students' difficulties are also viewed in terms of cognitive levels: remembering, understanding, applying and other higher levels (in our case, analyzing and evaluating). The results obtained are summarized in Table. 5.3.

According to the data, as the cognitive level increases in direction from memorization to application, the number of students with difficulties increases as well. Indeed, solving the problems corresponding to higher cognitive skills such as understanding, applying, analyzing and evaluating proves difficult for a greater number of students.

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[1] Rakia is the collective term for fruit spirits (or fruit brandy) popular in the Balkans.

Table 5.3 Distribution of students according to difficulty in reaching the corresponding cognitive level

Cognitive level	**Students who have not reached the appropriate cognitive level**	
	n	**%**
Remembering	140	37%
Understanding	184	48%
Applying	194	49%
Other (higher)	206	54%

5.1.4 A summary on the areas of difficulty in learning organic chemistry at the basic level

Table 5.4 distributes our research results by areas of competence (in accordance with the chemistry syllabus) and content areas (indicated in the scientific literature) and therefore summarizes the areas of student difficulty in organic chemistry at the basic level. No data is shown for difficulties in the content area "Impact of OC" since it was dropped from the final version of the diagnostic test.

Table 5.4 Distribution of student difficulties by content areas and competence areas and frequency of their occurrence (n = 379)

Areas of competence	**Content areas**	**Occurrence of difficulty by:**			
		content area		**competence area**	
		n	**RF**	**n**	**RF**
Classification and nomenclature of organic compounds	Classification of OC	135	36%	152	40%
	Representation of OC	197	52%		
	Nomenclature of OC	118	31%		
Structure and properties of organic compounds	Isomers of OC	109	29%	167	44%
	Properties of OC	219	58%		
Chemical processes	Representing chemical reactions using equations	223	59%	220	58%
	Types of reactions	216	56%		
Application and biological role of organic compounds, their impact on the environment	Application of OC	140	37%	140	37%
	Impact of OC	N/A	N/A		
Experiment and research	Analysis of OC	198	52%	212	56%
	Information analysis	227	60%		

Legend: OC – organic compounds; RF – relative frequency

The content areas that stand out as being most difficult are *Information Analysis*, *Representing chemical reactions using equations*, *Properties of organic compounds*, *Types of organic reactions* and *Analysis of organic compounds*. Problems testing skills from these content areas proved to be difficult for more than 50% of the tested ninth-graders.

When comparing test results by areas of competence in the chemistry syllabus, it is evident that the most difficult ones are *Chemical processes* (58%,) and *Experiment and research* (56%). *Structure and properties of organic compounds* (44%) and *Classification of organic compounds and nomenclature* (40%) turn out to be less difficult. The competence area A*pplication, biological role of organic compounds and impact on the environment* is relatively easier – 37%.

5.2 Student survey results

5.2.1 Distribution of students according to their characteristics

According to the literature review some student characteristics, such as study habits and interest in the subject, could be related to the perceived difficulty of chemistry. Therefore, we wanted to evaluate the levels of these characteristics for the students participating in the current study.

Obtained data indicates that the student sample consists of different types of students, i.e., it is heterogeneous in nature. It is interesting that 51% of the surveyed ninth-graders consistently study their chemistry lessons, but only 15% of them indicate they do the practice problems following each lesson, which is a serious obstacle for learning the subject. Although 40% of students point out that chemistry is relatively interesting, only 16% of them are interested in chemistry even out of school.

5.2.2 Perceived difficulties in learning organic chemistry at the basic level

The learning outcomes for organic chemistry at the basic level, set by the syllabus, are sorted by mean value and relative frequency of perceived difficulty in Table 5.5.

Table 5.5 Ranking of learning outcomes in decreasing order of perceived difficulty

Rank	Learning objectives/Outcomes	Mean Difficulty	% Difficult	% Neutral	% Easy
1	Explain the structure-properties relationship	3,19	37	39	24
2	Represent chemical properties using equations/schemes	3,14	34	41	25
3	Plan and conduct experiments	3,14	34	41	25
4	Recognize types of organic reactions	3,03	31	38	31
5	Represent organic compounds using structural formulas	3,00	31	39	30
6	Distinguish isomers	2,98	28	41	31
7	Classify organic compounds	2,84	22	42	36
8	Name organic compounds	2,83	27	34	39
9	Describe application of organic compounds	2,76	21	39	40
10	Retrieve and evaluate chemical information	2,74	22	35	43

Assessment of the relative difficulty of each learning outcome shows they can be sorted in three groups as follows: relatively easy (retrieving and evaluating information, describing application of organic compounds); neither easy nor difficult (classifying organic compounds, naming organic compounds); difficult (explaining the structure-properties relationship, representing chemical properties using chemical equations/reaction schemes, planning and conducting chemical experiments, recognizing types of organic reactions, representing organic compounds using structural formulas, distinguishing isomers).

Students most often indicate it is difficult for them to: explain the chemical properties of organic compounds with their structure (37%, Mean = 3.19); represent organic reactions using chemical equations or reaction schemes (34%, Mean = 3.14); plan and conduct chemical experiments (34%, Mean = 3.14); recognize the types of organic reactions (31%, Mean = 3.03) and use structural formulas to represent organic compounds (31%, Mean = 3,00). For most of them, classifying organic compounds (42%, Mean = 2.84) is neither easy nor difficult, whereas naming them (39%, Mean = 2.83), describing their application (40%, Mean = 2,76) and evaluating chemical information (43%, Mean= 2.74) is relatively easy. Overall, the level of perceived difficulty ranges from 2.74 to 3.19. This means that organic chemistry instruction needs to be improved in order to help students achieve most of the learning outcomes set by the syllabus.

Table 5.6 Distribution of perceived difficulties in organic chemistry at the basic level by areas of competence and content areas

<table>
<tr><th rowspan="2">Areas of competence</th><th rowspan="2">Content areas</th><th colspan="2">Average perceived difficulty by:</th></tr>
<tr><th>content area</th><th>area of competence</th></tr>
<tr><td rowspan="3">Classification and nomenclature of organic compounds</td><td>Classification of OC</td><td>2,84</td><td rowspan="3">2,89</td></tr>
<tr><td>Representation of OC</td><td>3,00</td></tr>
<tr><td>Nomenclature of OC</td><td>2,83</td></tr>
<tr><td rowspan="2">Structure and properties of organic compounds</td><td>Isomers of OC</td><td>2,98</td><td rowspan="2">3,09</td></tr>
<tr><td>Properties of OC</td><td>3,19</td></tr>
<tr><td rowspan="2">Chemical processes</td><td>Representing chemical reactions using equations</td><td>3,14</td><td rowspan="2">3,09</td></tr>
<tr><td>Types of reactions</td><td>3,03</td></tr>
<tr><td rowspan="2">Application and biological role of organic compounds, their impact on the environment</td><td>Application of OC</td><td>2,76</td><td rowspan="2">2,76</td></tr>
<tr><td>Impact of OC</td><td>N/A</td></tr>
<tr><td rowspan="2">Experiment and research</td><td>Analysis of OC</td><td>3,14</td><td rowspan="2">2,94</td></tr>
<tr><td>Information analysis</td><td>2,74</td></tr>
</table>

Legend: OC – organic compounds

According to students' responses, the most difficult areas of competence are *Chemical processes* (Mean = 3.09) and *Structure and properties of organic compounds* (Mean = 3.09). Following in descending order of difficulty are *Experiment and research* (Mean = 2.94), *Classification and nomenclature of organic compounds* (Mean = 2.89) and *Application, biological role of organic compounds and impact on the environment* (Mean = 2.76).

It is noteworthy pointing that students perceive the competence area Chemical processes as the most difficult and indeed the majority of problems they solved incorrectly are from that particular area of competence.

The high levels of perceived difficulty for representing properties of organic compounds using chemical equations or reaction schemes, as well as representing them with structural formulas, could be explained if we consider how organic compounds differ from inorganic ones and the fact that students are studying organic chemistry for the first time. The peculiarities of organic compounds necessitate their representation in a different manner from that already familiar to students – namely by using structural formulas. Here, the time allocated for exercise, both when studying at home and in class, is of great importance.

For students to classify organic reactions by type they have to be able identify compounds by functional group and poses knowledge for the type of reactions characteristic to them. We could attribute the high levels of perceived difficulty to the required ability to "read" the chemical structure as well as good theoretical background. The course content is logically organized according to functional groups instead of mechanisms and reaction types, which is now considered as more efficient for studying organic reactions since it promotes their conceptual understanding.

It can be seen that the area of competence *Structure and properties of organic compounds* is equally difficult for students as the one discussed earlier, and in particular – explaining chemical properties of organic compounds using their structure. Here, in compulsory chemistry classes, by "structure" we mean types of chemical bonds (single and multiple) between atoms and the functional groups present in the molecules. According to the syllabus, students must "explain characteristic properties of saturated, unsaturated and aromatic hydrocarbons using the type of chemical bonds in their molecules" and "associate the chemical properties typical for hydrocarbon derivatives with their functional group". Therefore, the following reason can be pointed out: students are not familiar with the term “structure” due to significant gaps in their knowledge, including such on chemical bonding and the concept of functional groups. It is no coincidence that the concept of functional group is essential to the study of organic chemistry and that scientific literature so heavily emphasizes the importance of understanding molecular structure (Graulich, 2015).

The *Experiment and Research* area of competence is rated as difficult by a significant share of students and test results indicate it is indeed difficult. The ability to plan experiments for distinguishing organic compounds and draw conclusions upon them requires higher thinking skills. The high levels of perceived difficulty may be due to insufficient emphasis placed on research by the chemistry curricula, which in turn determines the teaching approaches applied by teachers in class. The insufficient number of practical activities, students’ characteristics and equipment of the school labs are other, also important factors to consider. However, it should be kept in mind that the ninth-graders tested studied organic chemistry online and did not observe or perform any in-person chemistry experiments, involving organic compounds, which inevitably affects their comprehension.

5.2.3 Student self-efficacy in organic chemistry at the basic level

Distributing students’ answers according to their levels of perceived self-efficacy in organic chemistry makes it visible that for some learning outcomes three groups of almost equal number of students are observed. This pattern of distribution can be explained with the previously noted fact that the study sample consists of students having different characteristics (study habits and interest in the subject).

Students’ responses for self-efficacy in organic chemistry at the basic level are sorted in descending order of their mean values and relative frequency in Table 5.7.

Table 5.5 Ranking of learning outcomes in decreasing order of students’ self-efficacy

Rank	Learning objectives/Outcomes	Mean Confidence	% Confident	% Neutral	% Not confident
1	Name organic compounds	3,01	36	32	32
2	Retrieve and evaluate chemical information	2,95	32	33	36
3	Describe application of organic compounds	2,94	30	35	35
4	Represent organic compounds using structural formulas	2,88	29	34	37
5	Recognize types of organic reactions	2,84	27	35	38
6	Classify organic compounds	2,82	27	33	39
7	Distinguish isomers	2,78	27	33	40
8	Represent chemical properties using equations/schemes	2,73	22	38	40
9	Plan and conduct experiments	2,69	21	36	43
10	Explain the structure-properties relationship	2,61	21	32	48

We can say that, in general, ninth-graders do not feel particularly confident in organic chemistry (range of mean values 2.61 - 3.01), which goes to show there’s room for improvements in chemistry instruction. Students feel least confident they are able to: explain chemical properties of organic compounds using their structure (48%; Mean = 2.61); plan and conduct chemical experiments and draw conclusions from them (43%; Mean = 2.69); represent chemical reactions with equations/reaction schemes (40%; Mean = 2.73).

Ninth-graders are most confident in their abilities to name organic compounds (32%; Mean = 3.01), retrieve and evaluate chemical information (32%; Mean = 2.95) and describe application of organic compounds (30%; Mean = 2.94). There is a significant discrepancy between students' perceptions of self-efficacy and actual performance when it comes to retrieving and analyzing information. A likely reason for this is the perception that processing provided information is easier compared to solving problems that require certain knowledge.

5.2.4 Characteristics of students with significant actual difficulties

In order to check if there's a relationship between some student characteristics (interest, habits, perceived difficulty and self-efficacy) and the level of actual difficulties, only students with significant actual difficulties (above 40%) were selected and then divided into three groups. Students with very high levels of actual difficulties are considered to be those having 80-100% wrong answers on the diagnostic test and poor grades. Students with high levels of actual difficulties are considered to be those having 60-79% wrong answers on the test and grades "Sufficient". Students with 40-59% wrong answers on the test have moderate levels of actual difficulties and good grades. Fig. 5.3 shows the mean values of student characteristics (study habits, interest, perceived difficulty, abbrev. PD, and self-efficacy, abbrev. SE) for each of the groups.

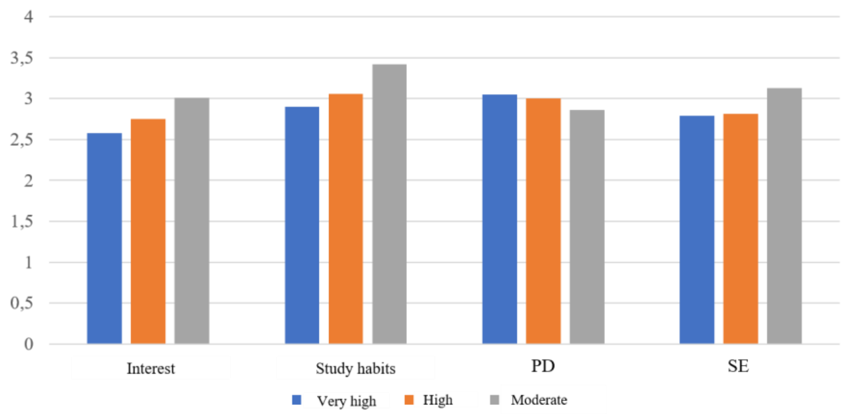

Fig. 5.3 Characteristics of three groups of students, with different levels of actual difficulties in basic organic chemistry: very high, high and moderate

5.3 Results from teachers' semi-structured interviews

In order to establish teachers' knowledge for the difficulties in organic chemistry, we conducted semi-structured interviews with three prominent chemistry instructors. Their answers are summarized below.

Q: *Do your students find organic chemistry interesting?*

Teachers believe that some students find organic chemistry more interesting than others.

Q: *What do you think is most interesting for them and what – least?*

According to interviewees "topics on physiological action, practical application of organic compounds and their impact on the environment are most interesting for students". What seems to be interesting is "the logic in studying the different classes of organic compounds: homologous series, nomenclature, isomerism, etc. applied in considering a particular compound representative of a given class", "The ability to predict the properties of an organic compound only by considering the homologous series it belongs to also awakens students' interest".

Q: *Is organic chemistry easy for students to learn?*

Teachers: "With each passing school year, organic chemistry becomes more and more difficult for high school students"; "Students are frightened at first until they realize organic chemistry is a lot more logical".

Q: *What is most difficult for them?*

Molecular structure and properties of organic compounds along with interconversions between are most difficult. Types of organic reactions are also difficult to grasp. Writing reactions and representing the spatial arrangement of atoms in organic compounds challenge the majority of ninth-graders.

Q: *What do you think are the causes for students' difficulties?*

Certain aspects characteristic to the study of organic chemistry are among the causes of difficulty such as molecular structure, for example. Most students fail to make sense of it all for establishing logical connections. Today's scholars are overwhelmed with information, but are unable to analyze it. Today's generation lacks study habits, is not used to analyzing information, hence the logic of organic chemistry eludes them. Many of the students also find it difficult to make sense of information when reading. Lack of motivation is a big problem for today's students, and, according to a teacher, it manifests itself not only in chemistry classes, but also in others. Students have not reached the appropriate age to understand organic chemistry according to one of the interviewees. He thinks it's a bit early to be studying this branch of chemistry in ninth grade. Another interviewee reasons that students have yet to develop their formal thing skills. The reduction of instructional hours for studying organic chemistry is also an important cause for students' difficulty teachers point out. All agreed that in order to cope with the challenges of organic chemistry, students need to practice more.

Q: *Is organic chemistry easy to teach?*

Teachers report that they find organic chemistry enjoyable and easy to teach. All of them agree this is due to its logical nature.

Q: *What difficulties do you encounter most often when teaching organic chemistry?*

In teachers' opinion instruction is hampered by the absence of important compounds from the syllabus, ammonia for example, prerequisite for the study of amines. They encounter difficulties in teaching chemical properties, structure of organic compounds, the relationship structure - chemical properties, as well as completing reaction schemes. The difficulties become even greater when you have to build up on previous knowledge, and students lack such knowledge – then working becomes extremely difficult". A third teacher adds: "Not only students face difficulties in profiled chemistry classes covering advanced organic chemistry (reaction mechanisms. stereoisomerism, etc.), but teachers too." The more abstract concepts such as hybridization, spatial relations, etc., which are object of study in profiled chemistry classes, are deemed as difficult to explain.

Q: *What methods/approaches do you think are most effective for teaching organic chemistry at the basic level?*

Teachers are unanimous that visual methods are first on the list. Chemical experiments are also of great importance, but "unfortunately, not all chemical reactions can be demonstrated in class". Interdiscipli-nary approaches involving mathematics, art, technology are also considered important. The traditional lecture method is also noted as effective. All teachers agree problem solving is of great importance.

Q: *What are your recommendations and suggestions for overcoming the difficulties you face in teaching organic chemistry?*

Two of the interviewees recommend an increase of instructional hours for the current amount of subject content being covered. The third one recommends an alternative approach – reducing subject content for students to learn better.

The teacher interviews served as basis for developing the teacher questionnaire and conducting a survey with more participants.

5.4 Teacher survey results

5.4.1 Teachers' pedagogical knowledge of students' difficulties in learning organic chemistry at the basic level

Nearly half of the teachers (45%) consider Organic chemistry to be interesting for students, but most (58%) are convinced it is difficult for them to learn it.

Table 5.6 presents the learning objectives from the chemistry syllabus, sorted in descending order of their average difficulty and proportion (%) of teachers identifying them as difficult.

Table 5.6 Teachers' pedagogical knowledge of students' difficulties in achieving the learning outcomes for organic chemistry at the basic level, sorted by rank.

Rank	Learning objectives/Outcomes	Mean Difficulty	% Difficult	% Neutral	% Easy
1	Retrieve and evaluate chemical information	3.87	62	26	11
2	Represent chemical properties using equations/schemes	3.66	62	19	19
3	Write lab reports	3.63	60	28	11
4	Recognize types of organic reactions	3.40	45	30	25
5	Describe properties of organic compounds	3.36	51	19	30
6	Classify organic compounds	3.17	40	28	32
7	Distinguish isomers	3.10	45	19	36
8	Represent organic compounds using structural formulas	3.09	40	29	31
9	Explain the structure-properties relationship	3.03	34	28	38
10	Naming organic compounds	2.85	34	21	25
11	Plan and conduct experiments	2.75	26	29	55
12	Evaluate biological role of organic compounds and their impact on the environment	2.62	19	25	57
13	Describe application of organic compounds	2.53	25	30	45

Teachers rate the difficulty of basic organic chemistry much higher than students do.

They point out the following learning objectives as most difficult to achieve: retrieving and evaluating chemical information (Mean = 3.87; 62%); representing chemical properties organic compounds using equations/schemes (Mean = 3.66; 62%); presenting results from chemical experiments (Mean = 3.63; 60%); recognizing types of organic reactions (Mean = 3.40; 45%). The objectives considered less difficult are: describing physical and chemical properties of organic compounds (Mean = 3.36; 51%); distinguishing isomers (Mean = 3.10; 45%) and representing organic compounds using structural formulas, based on chemical nomenclature (Mean = 3.09; 40%). The rest are perceived as neither difficult nor easy.

Table 5.7 summarizes students' difficulties in learning the basics of Organic chemistry by content area and area of competence in accordance with the syllabus.

According to teachers, the most difficult areas of competence are *Chemical processes* and *Experiment and research*. Less difficult are *Structure and properties of organic compounds* and *Classification of organic compounds*. The competence area *Application and biological role of organic compounds, their impact on the environment* is neither difficult nor easy. Similar results were obtained from the interviews.

Table 5.7 Teachers' pedagogical knowledge of students' difficulties in learning organic chemistry at the basic level, sorted by content areas and areas of competence

Areas of competence	Content areas	Average difficulty by:	
		content area	area of competence
Classification and nomenclature of organic compounds	Classification of OC	3,17	3,07
	Representation of OC	3,09	
	Nomenclature of OC	2,85	
Structure and properties of organic compounds	Isomers of OC	3,10	3,15
	Properties of OC	3,20	
Chemical processes	Representing chemical reactions using equations	3,66	3,53
	Types of reactions	3,40	
Application and biological role of organic compounds, their impact on the environment	Application of OC	2,53	2,57
	Impact of OC	2,62	
Experiment and research	Analysis of OC	3,21	3,49
	Information analysis	3,87	

5.4.2 Teachers' pedagogical knowledge of sources of difficulty when teaching organic chemistry at the basic level

Here both the survey and interview findings have been combined due to their similarity. Topic specifics, subject's curriculum and syllabus, as well as school environment and student characteristics are all sources of difficulty when studying the basics of Organic chemistry in 9th grade.

Specifics of Organic chemistry

A large part of the teachers believe that students' difficulties are related to the specifics of organic chemistry – the chemical structure and interconversions of organic compounds with different functional groups. That major difference between inorganic and organic chemistry makes the transition hard for students. Teachers note there's an abundance of information in the organic chemistry course: specific terminology, bulky chemical formulas, complex names and chemical equations. The different levels of representation (macro-, submicro- and symbolic) are also problematic. The cross-curricular connections of organic chemistry with physics, biology and mathematics further complicates the work of both students and teachers.

Curricula and syllabi

Teachers believe the main reason for students' difficulties is the discrepancy between the reduced instructional hours set by the new syllabus and the amount of content to be taught. Students are overwhelmed with a lot of information within a short period of time. Other sources of difficulties are: gaps in the syllabus – missing important topics (e.g. amines, essential for studying amino acids); and content organization – the logic between individual lessons and topics is often lost and there are not enough connections to students' everyday life experience. A particular problem occurs in 9th grade of the bilingual schools, where students go through the chemistry topics for both 8th and 9th grades within 90 instructional hours, which teachers cite as very wasteful.

School environment – school facilities, learning organization, teachers

Educators share there are only few schools in Bulgaria having a well-equipped chemistry lab: reagents, glassware or other important laboratory equipment is missing. This obstacle in turn hinders normal chemistry instruction. Some teachers point out the high price of chemistry textbooks as another issue – some students don't have a textbook. But only few teachers consider their teaching skills a possible reason for students' difficulties. Some instructors fail to engage students' attention or have difficulties themselves understanding the educational content.

Student characteristics – cognitive, motivational-affective and metacognitive components

Students' cognitive and affective characteristics are often cited by participants as reasons for learning difficulties: lack of interest and motivation to learn, low level of self-training, lack of previous knowledge, lack of good upbringing, lack of vision for one's life and goals, etc. Pupils manage regurgitating information, but struggle when it has to be understood or analyzed. A common practice among students is rote learning. Most of them have not developed study habits. The majority of students don't bother reading their lessons home and rely on the memorized from class and this does not yield good results. Negative attitude towards chemistry combined with lack of previous knowledge is a problem that hinders learning. The undeveloped logical thinking and spatial visualization skills of most students is also a serious obstacle.

5.4.3 Teachers' pedagogic knowledge of effective methods and approaches for teaching organic chemistry at the basic level

Teachers' responses regarding which methods, approaches and/or strategies are most effective for studying the basics of organic chemistry are summarized and ranked in Table 3.

Table 5.8 Teachers' pedagogical knowledge for the most effective methods and approaches for studying organic chemistry at the basic level

Rank	Instructional approaches, methods and strategies	No. resp.
1.	Didactic questioning, lecture, explanation, giving examples and analogies	53
2.	Demonstrations, observation of video and animations, simulations	50
3.	Problem solving, modeling, hand-on learning, laboratory work	49
4.	Problem-based learning	23
5.	Interactive methods - discussion, group work and collaborative learning	21
6.	ICT-assisted learning, project-based learning	18
7.	Context-based learning	17
8.	Inquiry learning, historical, logical approach	15

It turns out that teachers mainly use direct methods (lectures, explanations, questioning and visualization related ones) and to a lesser extent indirect methods (problem solving, modeling), interactive methods (discussion, group work) or experience related methods (laboratory work) as well as students' independent learning (project-based learning and ICT-assisted learning).

Determining the most effective methods meets a different response from teachers: for most of them, these are practical methods – problems solving, hands-on activities, laboratory work, while for others – visual and interactive methods. The teachers interviewed share that today's generation is a technology generation, and education should be interactive using ICT. Instructors reason that "for students' motivation to increase, they need to realize the real-world application of the material covered". Therefore, emphasis needs to be on "the practical use of organic compounds and experiments at home in order to increase students' interest in the subject".

Teachers also give recommendations related to changes in educational policy, curricula and syllabi, providing a suitable learning environment, and conducting teacher training courses on a regular basis, for further improving education quality.

5.5 Summary and discussion of results

5.5.1 Summary and discussion of students' results

Students' results on the diagnostic test indicate they encounter real difficulties in the content areas: *Representation of organic compounds*; *Properties of organic compounds*; *Writing chemical reactions*; *Types of organic reactions*; *Analysis of organic compounds* and *Information analysis*. Most student difficulties lie in the areas of competence *Chemical reactions* and *Experiment and research*.

The identified difficulties are probably due to missing basic knowledge and skills from the general chemistry course (representing compounds with formulas and writing reactions, gaps on chemical bonding). Another possible reason is that new material has not been learned or practiced enough, which hinders the understanding of basic concepts such as functional group as well as the establishment of causal relationships (structure → reactivity → properties). Retrieving and evaluating chemical information from data presented graphically and planning a chemical experiment are skills, the formation of which largely depends on the learning environment and instruction (availability of chemistry lab in school and supplementing materials and equipment for conducting experiments and enough time allocated by the teacher to practice interpreting graphs).

A similarity between our results and those obtained by O'Dwyer & Childs (2011) is observed in terms of perceived difficulty in the content areas *Nomenclature of Organic Compounds*, *Representation of Organic Compounds*, *Reactions of organic compounds* and *Analysis of Organic Compounds*. Despite the difference in the curricula and the studied content, we also found a discrepancy between actual performance and perceived difficulty.

Students who have low interest in the subject, low levels of study habits, and self-efficacy are those who face the most difficulties in organic chemistry.

5.5.2 Summary and discussion of teachers' results

The results obtained from the teachers' survey clearly show that, according to them, the competence areas *Chemical Processes* and *Experiment and Research* are most difficult for students. These are indeed the ones that proved to be most problematic for students. Such a concurrence of results is not random, but rather a consequence of teachers' high levels of subject pedagogical knowledge and professionalism. Obtained results are in agreement with those from previous studies (Ferguson & Bodner, 2008, O'Dwyer & Childs, 2011).

The difficulties encountered according to some educators are due to the nature of chemical knowledge and the way it is presented, the complex scientific language and the organization of learning content, as established by other researchers as well (Johnstone, 1991; Childs, 2006; Sirhan, 2007; O'Dwyer & Childs, 2017). Most teachers believe that the obstacles to learning are: students' level of cognitive development; the way they perceive the subject content and process information; their attitudes and approaches to learning, findings again in line with previous research (Taber, 2002; Sirhan, 2007; Reid, 2008; De Jong & Taber, 2014; O'Dwyer & Childs, 2017). As in the study by Woldeamanuel et al. (2014), a number of teachers share difficulties related to providing an appropriate learning environment, which shows this problem is related to the social conditions in the country. Traditional methods are indicated as being the most effective methods and approaches for teaching: problem-solving, laboratory work, discussion, visualization through experiments and models. The teachers which participated in the questionnaire survey did not clearly outline specific strategies for overcoming students' difficulties. The role of ICT-assisted learning in organic chemistry training is not fully taken into account. The critical attitude of the majority of experienced teachers results from recent educational reforms, that are not met with complete approval.

CHAPTER 6. CONCLUSION

The implementation of the methods, outlined in the Introduction, made it possible to answer the research questions as follows:

RQ: *Which topics from the chemistry curriculum students perceive as difficult?*

The topics perceived by students as most difficult are *Organic Chemistry*, *Chemical calculations*, *Reaction rates*. *Catalysis and Chemical Equilibrium*. These are the topics that for the most part contain abstract concepts, specific chemical logic and terminology, require mathematical skills and a fair amount of basic knowledge.

RQ: *Which topics from the chemistry curriculum students perceive as interesting?*

Particularly high levels of interest are not observed for any of the topics in the chemistry curriculum. Relatively interesting are: *Organic Chemistry, Electrolyte Dissociation Theory. Acids and Bases*, *Thermochemistry*, *Atomic structure* and *Periodic Table and periodicity*. The first three topics are directly related to students' lives, while the last two – easy for students to learn.

RQ: Is there a connection between levels of perceived difficulty and interest towards a topic?

No correlation was found between levels of perceived difficulty and interest. Topics perceived as difficult by students are also indicated as interesting, like *Organic Chemistry* for example. Among the interesting ones we can find topics perceived as easy – Atomic structure and Periodic table and periodicity. There are also those that are difficult and at the same time uninteresting, e.g., *Chemical calculations*.

RQ: *Which topics from the chemistry curriculum teachers perceive as difficult/interesting for their students? Do students' and teachers' opinions differ?*

The topics most often indicated as difficult by students were also indicated by the teachers, namely: *Organic Chemistry*; *Chemical calculations*; *Chemical equilibrium* and *Reaction rates. Catalysis*. This shows teachers exhibit high levels of pedagogical knowledge of difficulties their students encounter.

Regarding the interesting topics – there's a significant discrepancy in the perceptions of students and teachers. The topics indicated by the teachers as interesting for the students - *Metals, non-metals and their compounds* and *Redox processes* - are not among the most preferred by the students themselves. At the same time, the topic students pointed most often as interesting – organic chemistry – has been chosen as such by just a few teachers. This indicates that teachers are not sufficiently aware of their students' self-interest motives.

RQ: *What are the important skills needed to be successful in chemistry class according to students and teachers?*

Self-training and understanding of scientific concepts, principles and laws are important skills according to both students and teachers. But while most students believe it is very important to memorize chemical formulas and facts, only a minority of teachers say this is the case. At the same time, for almost half of the teachers, the skills of gathering and comparing information from different sources and sharing it with others are important, they are not considered as such by any student. This indicates a difference in perceptions of Bulgarian teachers and students.

RQ: *What are the causes of difficulties in learning chemistry according to teachers and students? Is there a difference in their viewpoint?*

Students' and teachers' opinions on this matter differ. As reasons for student difficulties, teachers point to the small number of instructional hours, the abstract concepts and the fact that learning the subject requires effort and systematic preparation. For students, the reasons for their difficulties are mainly in the large amount of information and the need for them to memorize it, as well as lack of connections to everyday life. Teachers' and students' understanding of ways to minimize difficulties in the subject also differs. For students, they are mainly in practical activities, in improving school discipline, better written textbooks, more instructional hours for practice, use of ICT in class and group work. Some teachers believe the problem lies in students' lack of study habits and interest, their bad discipline in class, and poor school environment.

RQ: *What are the actual difficulties students face when learning Organic chemistry at the basic level?*

In the first cycle of research organic chemistry was found to be the most difficult topics for Bulgarian students. The second cycle of research revealed most of their difficulties are in the areas of competence Chemical processes and Experiment and research. The following actual difficulties were identified: a) representing organic compounds using structural formulas; b) establishing a connection between structure and properties; c) representing organic reactions using chemical equations or reaction schemes; d) classifying types of organic reactions; e) planning chemical experiments to distinguish organic compounds by functional groups and draw conclusions from them.

RQ: *What are students' perceptions of difficulty in organic chemistry at the basic level?*

In terms of perceived difficulty, the areas of competence *Chemical processes*, *Structure and properties of organic compounds* and *Experiment and research* are the most problematic. Surveyed students find it most difficult to: a) establish a relationship between structure and properties; b) represent chemical using chemical equations or reaction schemes; c) plan chemical experiments to distinguish organic compounds; d) classify types of organic reactions; e) represent organic compounds using structural formulas. Analyzing chemical information and describing the application of organic compounds is considered easy.

The problems in the area of competence *Chemical processes* are indicated as most difficult and indeed were the ones mostly solved incorrectly. The problems in the competence area *Structure and properties of organic compounds* are also viewed as difficult, although actual performance on the test is not that poor. The problems requiring analysis of information were highly underestimated and considered easy when in fact most students got them wrong. Those that require planning an experiment were adequately rated as difficult, as indicated by test results. Students with low test scores (high levels of actual difficulty) perceived the problems in the diagnostic test as particularly difficult (high levels of perceived difficulty).

RQ: *What are students' perceptions of self-efficacy in organic chemistry at the basic level?*

Students have different self-efficacy (belief that they will cope with the study problems) in organic chemistry at the basic level. They are the least sure in their abilities to: a) explain chemical properties of organic compounds from their structure; b) plan a chemical experiment and draw conclusions from it; c) represent organic reactions using chemical equations or reaction schemes. Students feel most confident in their abilities to: a) name organic compounds; b) analyze chemical information; c) describe application of organic compounds.

There was a significant discrepancy between students' belief that they are able to successfully process and analyze chemical information and actual test results. A plausible explanation is the students' perception that retrieving and processing provided information is easier than solving tasks requiring certain knowledge.

In general, low-achieving students (high levels of actual difficulty) are convinced that they cannot successfully solve the problems (have low self-efficacy).

RQ: *What do teachers know about the difficulties in teaching and learning organic chemistry at the basic level, the causes of these difficulties and which teaching methods/approaches they consider effective?*

Teachers perceive *Chemical processes* and *Experiment and research* as most difficult content areas for students and, based on students' performance on the diagnostic test, they truly are. Compared to students, teachers consider organic chemistry to be more difficult. The topics on physiological action, practical application of organic compounds and their impact on the environment – perceived by students as important and interesting – are indicated by teachers as easy to learn and also interesting.

The majority of high school chemistry instructors believe students' difficulties are related to specifics of organic chemistry: complex nature of organic compounds and their interconversions, significant amount of information to comprehend, specific logic and terminology, bulky formulas, complex names, equations and ways of representation.

Another main reason for the difficulties, according to them, is the small number of instructional hours in the reformed curricula and syllabi, combined with the significant amount of teaching material.

The learning environment is another obstacle to consider. Few educators look for the causes of students' difficulties in teaching: the teachers themselves fail to engage students' attention, and experience difficulties in understanding the new learning content.

Teachers find organic chemistry enjoyable to teach. They share that the difficulties in teaching are most often due to the students themselves: they are not consistent in their preparation, lack study habits and motivation and are unable to analyze information. Rote learning does not yield good results.

For the purposes of training, teachers mainly use direct methods (lectures, explanations, questioning and visualization related ones) and to a lesser extent indirect methods (problem solving, modeling), interactive methods (discussion, group work) or experience related methods (laboratory work) as well as students' independent learning (project-based learning and ICT-assisted learning). The most effective methods, according to them, are the practical methods – problem solving, laboratory experiments – and also visual and interactive methods. Bringing learning into context, wider use of ICT in class and home experiments are necessary in order to increase students' interest in the subject. Teachers also give recommendations related to changes in educational policy, curricula and syllabi, providing a suitable learning environment, and conducting teacher training courses on a regular basis, for further improving education quality.

LIMITATIONS OF THE STUDY

As a limitation of the study, it should be noted that, given the COVID-19 pandemic, it took place during the period of online learning. This necessitated adapting the employed research tools, and made it difficult to assess procedural knowledge such as writing chemical equations. The extraordinary health situation did not allow us to conduct in-depth interviews with students. The small number of teachers surveyed in the first cycle of research can also be attributed to the limitations of the study.

CONTRIBUTIONS OF THIS RESEARCH STUDY

The current study fills the gaps in the empirical studies in Bulgarian secondary chemistry education by:

1. Identifying the topics in the secondary chemistry curriculum perceived as difficult and as interesting by Bulgarian students, the reasons for students' difficulties, as well as the important skills needed to be successful in chemistry class;
2. Identifying Bulgarian students' subjective perceptions – of difficulties and self-efficacy – and actual learning difficulties in organic chemistry at the basic level;
3. Identifying Bulgarian teachers' pedagogical content knowledge of students' difficulties in learning the basics of organic chemistry, the sources of difficulties and effective ways to overcome them.

SUGGESTIONS ON PRACTICAL APPLICATION OF RESEARCH FINDINGS

The research findings in this work are applicable on a national level and may be of use to teachers, textbook authors, curriculum developers and educational researchers.

Curriculum developers could take into account the teachers' views reflected in the study and reduce teaching load, giving students time to grasp key ideas and practice the material. Curriculum should put greater emphasis on developing thinking skills and establishing logical connections between separate topics.

Current research findings may benefit textbook authors in their attempt to present educational content in an appropriate and accessible way, with more examples of real-life applications.

Teachers could rethink and adapt the methods, approaches or strategies applied in their work in light of students' perceived and actual learning difficulties in organic chemistry (at the basic level) reported in the present study. The effective ways to overcome them, outlined here, could also be taken under consideration.

Our research findings will also benefit university specialists in the field of chemical education engaged in delivering training courses for prospective teachers and additional qualifications for current ones.

PROSPECTS FOR FUTURE RESEARCH

The current research could be extended further by identifying the difficult and interesting topics in profiled chemistry training, once again from students' and teachers' point of view.

It would be interesting and useful for the training of future teachers to identify students' perceived and actual learning difficulties in the advanced organic chemistry course, covered in profiled chemistry classes.

Pursuing this line of research, perceived and actual learning difficulties could be investigated in other content areas of the chemistry as well. The content area *Chemical calculations* deserves special attention given the fact that it is indicated by the most students as both difficult and uninteresting.

It would be interesting to investigate the change in students' perceptions of difficulty in chemistry with each passing grade.

The issue of difficulties encountered in various branches of chemistry, studied at the tertiary level of education, also remains open to research.

PUBLICATIONS

Publications in scientific journals approved by NACID:

1. Gendjova, A., Markova, N., & Chakarov, K. (2022). Pedagogical content knowledge in science education: difficulties in organic chemistry. *Pedagogika-Pedagogy*, *94*(6), 764-778. ISSN 0861-3982

Other publications:

2. Chakarov, K., Gendjova, A (2021). Difficult topics in the chemistry curriculum – Bulgarian students' view. *Natural Sciences and Advanced Technology Education*, *30*, 613-629. ISSN 2738-7135
3. Chakarov, K. (2022). Difficult topics in the chemistry curriculum – Bulgarian teachers' view. *Natural Sciences and Advanced Technology Education*, *31*, 531-551. ISSN 2738-7135
4. Gendjova, A., Chakarov, K. (2023). Learning difficulties of 9^{th} grade Bulgarian students in organic chemistry at the basic level. *Natural Sciences and Advanced Technology Education*, *32*, 59-75. ISSN 2738-7135

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1. Chakarov, K., Gendjova, A. *Students and teachers about the areas of conceptual difficulties in studying chemistry*. XIX National Chemistry Conference for students and PhD students, 2.06 - 4.06.21, of the Faculty of Chemistry and Pharmacy at the Sofia University "St. Kliment Ohridski";
2. Chakarov, K., Markova, N., & A. Gendjova, A. *Difficulties in teaching organic chemistry at the basic level according to teachers*. National conference with international participation "Natural Sciences 2021" (NCNS2021), 1.10 - 3.10.21 at University of Shumen "Konstantin Preslavsky".

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