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The Experience of BMSTU's Teachers on Remote Teaching Chemistry of Hearing Impaired Students in the Pandemic

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Abstract

This paper considers the experience of Bauman Moscow State Technical University (BMSTU) teachers on remote teaching chemistry hearing-impaired students under pandemic conditions. The key challenge for these students in a general-type university with a verbal form of teaching is the content accessibility of fundamental engineering disciplines, including chemistry. The statutory activity of BMSTU guarantees vocational rehabilitation for this category of students through inclusive education programs and special learning conditions, taking into account the individual limitations due to hearing impairment. Special face-to-face conditions provide an accessible learning environment through digital transformation of classrooms, the use of individual and group audiological facilities as well as supplementary cognitive-technological chemistry course accompanying the basic chemistry discipline. In the pandemic conditions, teachers were faced with the challenge of transferring face-to-face chemistry courses into a content-accessible format of webinars. Principles of designing webinars in chemistry for these students include taking into account their cognitive features of information perception in virtual environment; creating multimodal developmental environment in webinars; designing special teaching materials for classes using cognitive technologies and an interdisciplinary approach considering UDL guidelines. It is shown that the process of teaching chemistry to deaf and hearing impaired students in specially designed conditions for webinars develops their cognitive abilities and does not reduce their motivation to effectively acquire the university program in the discipline. Webinar technology provides them with the opportunity to master new relevant skills. These findings have been confirmed by the students' results in chemistry in distance learning conditions compared to the results in face-to-face learning conditions.

Keywords: hearing impaired students, cognitive limitations, content accessibility, cognitive technologies, interdisciplinary approach, multimodal virtual environment.

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1. Introduction

Bauman Moscow State Technical University (BMSTU) is a general-type university with a verbal form of education. BMSTU has been training engineers with hearing impairments of varying severity (deaf and hard-of-hearing) since 1934. The key challenge for these students is the limited content availability of educational resources on fundamental engineering disciplines, including chemistry. This problem is mainly caused both the level of basic training of these students due to the lack of special conditions in general education institutions, and the level of their individual cognitive development due to hearing loss (Stanevsky, 2017). According to the International Classification of Functioning, Disability and Health (International classification, 2001), cognitive or perceptual skills include the ability to understand, integrate and process abstract information; analyze and generalize; to draw appropriate conclusions. These complex processes cause difficulties in deaf and hard-of-hearing students. They depend on a set of cognitive functions important for learning process, including the ability to perceive and remember information, concentrate, learn, and communicate verbally, and all of them are limited among these students due to a hearing impairment.

In order to support students in their educational process, the statutory activities of BMSTU include vocational rehabilitation and rehabilitation services (GOST, 2010) for them. This means that any student with disabilities (hearing impairment) becomes a subject of educational activities and adaptive rehabilitation services in order to realize his/her professional educational needs (Oreshkina, Slitikov, 2020). Such services include the education of the deaf and hearing-impaired students through inclusive (adaptive) higher education programs and the creation of special learning conditions taking into account their individual cognitive limitations due to hearing impairment.

In face-to-face learning conditions, the problem of content accessibility of fundamental engineering disciplines can be solved by creating an accessible multimodal environment through special digital organization of classrooms, individual and group audiological (sound-amplifying) means, additional cognitive and technological subject courses accompanied by sign-language interpreting (Oreshkina, 2020). In destabilizing pandemic conditions, it became necessary to transform classroom studies in academic subjects, including chemistry, into a distant format with effective remote (online and offline) working conditions for deaf and hard-of-hearing students.

The purpose of this study to reveal the experience of BMSTU teachers on remote learning chemistry of the deaf and hard of hearing students in the pandemic. This experience is based on following:

- considering individual cognitive limitations and peculiarities of information perception in students with hearing problems of varying severity;
- special preparing educational materials for classes and presenting them to students taking into account their individual cognitive peculiarities and limitations;
- organizing an effective interaction between students and teacher while classes.

2. Literature review

The prerequisite for inclusive education in Russia and in the whole world has been the modern advances in science and technology. The UN Convention on the Rights of Persons with Disabilities ratified by the Russian Federation on 15.05.2012. (Federal Law 46-FZ), obliges States Parties to "ensure inclusive education at all levels", "with effective measures for providing individualized support", in educational conditions which facilitate knowledge acquisition and social development as much as possible through "reasonable accommodation"[1] and/or "universal design"[2] of the educational environment. In this regard, according to (Alekhina, 2016), professional education becomes inclusive when universities and colleges create conditions to support any student. In the Russian Federation, all FSES of higher education include requirements for the

[1] "Reasonable accommodation" means making necessary and appropriate modifications and adjustments, where necessary, to ensure that persons with disabilities enjoy all human rights and fundamental freedoms equally with others (Convention on the Rights of Persons with Disabilities, Section 2).

[2] "Universal design" means the design of objects, environments, programs and services in order to make them as usable as possible for all people without the need for adaptation or special design. It does not exclude, where appropriate, assistive devices for specific groups of persons with disabilities (Convention on the Rights of Persons with Disabilities, Section 2).

implementation of inclusive programs (IP) such as increasing the period of study, adapting forms, special procedures for mastering certain disciplines, providing adapted online educational resources, etc. This raises a crucial question about the methods and technologies for implementing these requirements.

A comparative analysis of approaches to creating an accessible environment for hearing-impaired students at BMSTU and technical universities in Germany, USA and Japan is discussed in (Oreshkina, 2016). It is shown that technical and technological solutions prevailed in technical universities of these countries, the basis for implementation of which was created by legal support, the most consistently and systematically developed in the USA. The Vocational Rehabilitation Act of 1973 established the right of people with disabilities to equal access to vocational education. The Americans with Disabilities Act of 1990 extended equal access to all aspects of American life. In 1988 the Technology Related Assistance Act of 1988 was passed. Its 1998 version introduced the term "universal design for learning (UDL)", and in the 2004 version, it guaranteed a technology support for people with disabilities in every state when receiving an education. In 2004 the Individuals with Disabilities Education Act (IDEA) was adopted. In 2008, the Higher Education Opportunity Act (HEOA) took into account the UDL principles. At the same time, information and technical support networks for people with different disabilities have been formed in universities and colleges nationwide to improve the accessibility of educational resources for this category of learners in online and offline formats. 21st Century Communications and Video Accessibility Act of 2010 and the FCC Code of Practice of 2013 and the FCC Code of Practice of 2013 solve these challenges by making a wide range of electronic devices and software more accessible to people with hearing and visual impairments. Microsoft has carried out a number of technological developments to make software accessible to people with disabilities of various nosologies. For example, (Accessibility in education; Products and services; Special education…) are designed to provide individualized support to learners with disabilities, including hearing and visual impaired, as well as support to their teachers and parents in distance learning conditions. In (Accessibility…), a set of technologies is provided to increase the accessibility of content for learners with disabilities of different nosologies, including hearing impaired learners. For the latter, the main technologies are presentations with real-time captioning and automatic generation of video subtitles. The development includes ways to create content that is accessible to all students, and tips for students to ensure their transition to distance learning. Six UDL principles for distance learning are discussed in (Rappolt-Schlichtmann, 2020). It is shown that online distance learning is a very special teaching environment. The use of digital materials and the connection to the learning process by virtual conferencing is essentially a digital transformation of the learning process. Both teachers and students may need additional time and support to learn how to teach, study and interact effectively in a virtual conditions. According to (Hodnett, 2020), when designing effective online learning, it is important to focus on making content accessible to all learners. In this regard, guidelines are provided. In (Posey "Lesson") the following options of distance learning in accordance with the principles of UDL are outlined: consideration of students' individual features, flexible optional approaches to each student; multiple ways of providing learning content, barrier-free didactics. As mentioned in (Posey "Universal"), UDL is a powerful approach to learning that allows the teacher to anticipate and plan the activities of all his/her learners from the very beginning of the class with the confidence that online educational resources are available for each student and all students are involved in the learning process. The leading principles of UDL such as participation, presentation, action and expression are focused on developing 'skilled', motivated, resourceful, ingenious, knowledgeable, strategic and goal-oriented learners. In (Elliot et al., 2013), online tutoring for hearing impaired students in engineering training programs in a virtual academic community is considered. Critical barriers in virtual mastering fundamental engineering disciplines for these students are highlighted. According to (Watson et al., 2007), deaf and hard-of-hearing students experience serious problems due to the limited accessibility of educational content. Advances in technology provide them with a substantial choice of support services, but individual differences still play an important role in how clearly students understand the information. Therefore, all students receive a comprehensive expert diagnosis, which identifies their individual differences and provides recommendations for their individual support and guidance in the learning process. A modern approach to organizing their learning includes digital transformation of the learning environment as well as academic support for students using cognitive technology. Flexibility and creativity are important aspects of creating an accessible environment.

The partnership in the Project of creating Postsecondary Education Network International (PEN-International 2001–2010) of universities and colleges in the USA, Russia, Japan, China, etc., training hearing impaired people, promoted the unique experience of technological support of such students from universities and colleges of the USA to foreign universities and colleges. BMSTU was a founder of this unique Project along with the USA, Japan and China and its active participant. The Project created conditions for the exchange of local experience and technology transfer, which contributed to the development of Bauman approaches.

3. Materials and methods

Results in chemistry of BMSTU hearing impaired students from 2018 to 2021 have been used as the research material. Comparative analysis of results in face-to-face learning (from 2018 till autumn 2019) and distance learning (from spring 2020 till autumn 2020, autumn 2021) has been used as the research method.

The hearing-impaired students have been divided into two large groups: the hearing impaired and the deaf (a hearing loss of more than 90 dB in the main speech frequencies is defined as deafness). Some students focus on verbal communication, while others prefer sign language. Some students use both depending on the situation. Hearing-impaired students may use sound amplification devices (primarily hearing aids, cochlear implants) and/or lip-reading. The choice of communication method does not always depend on the degree of hearing loss; sometimes it is determined by the level of rehabilitation as well as previous phases of socialization. Thus, in terms of special educational needs, each student with a hearing impairment is unique.

Different degrees of hearing impairment among students with disabilities lead to limitations in the main life activity areas, including reduced ability to communicate, learn, self-control, orientation in the learning environment, etc. (Ministry of Labor). The relationship between the severity of hearing loss and the type of activity limitations is shown in Table 1.

Table 1. Relationships Between the Severity of Hearing Loss and the Type of Disability

No	Hearing Impairments, the Possibility of Correcting and Combining Them with a State of Speech Function	Type of Activity Limitation	Type of the Life Activity
1	Moderate hearing loss with the possibility of sufficient correction	Ability to: 1. Communicate; 2. Learn; 3. Navigate within education process;	1. The ability to communicate between people through the perception, processing, storage, reproduction and transmission of chemical information
2	Moderate hearing loss with insufficient correction		2. The ability to purposefully organize activities to acquire knowledge, abilities, skills and competencies, to gain experience in activities (including professional, social and cultural ones), to apply chemical knowledge in everyday life and develop chemical abilities.
3	Combination of hearing impairment with a moderate speech impairment unrelated to voice disorder		3. The ability to adequately perceive the personality and the environment, and to assess the situation in the learning process.

4	Severe hearing loss with insufficient or impossible correction	Ability to: 1. Communicate; 2. Learn; 3. Navigate; 4. Control behavior independently	4. The ability to self-evaluate and behave appropriately, taking into account social and legal, moral and ethical norms.
5	Combination of a hearing impairment with a severe speech impairment unrelated to voice disorder	Ability to: 1. Communicate; 2. Learn; 3. Navigate; 4. Control behavior independently; 5. Self-care (while learning) process)	5. An individual's ability to carry out every day learning activities independently.
6	Deafness		

As shown in Table 1, the mentioned types of disabilities are cognitive in nature, have varying degrees of severity and have a significant impact on the learning process of students with hearing impairment at a general-type university, both in normal and remote conditions. The level of pre-university training of these students in chemistry, largely due to the lack of special learning conditions in general educational organizations, also affects the acquisition of chemistry in higher education (Oreshkina, 2020).

The problem of content accessibility of both face-to-face and remote chemistry classes for hearing-impaired students at BMSTU is being solved using results of comprehensive expert diagnostic testing of students at the stage of their enrollment in inclusive programs (Oreshkina, 2018). Based on diagnostic results, cognitive disabilities and special educational needs of students are identified and, according to GOST R 53873-2010 and GOST R 53874-2017, individual packages of professional rehabilitation and habilitation services to support students in the learning process are formed, and adjusted as the students' progress along their educational trajectory (Oreshkina, Gurov, 2020). The methodological approach to solving the problem of content accessibility of distance learning in "Chemistry" is shown in Table 2. The development takes into account the guidelines for creating an accessible environment (Guide...) as well as guidelines of Universal Design for Learning (UDL). The proposed approach allows teachers to identify the cognitive needs of students with hearing impairment and to develop special educational services considering their individual characteristics and preferences.

Table 2. Methodological Approach to Solving the Problem of Content Accessibility of Remote Classes in Chemistry for Hearing Impaired Students at BMSTU

Cognitive Functions	Manifestation of Students' Disabilities	Special Educational	
		Students' Needs	Services for Content Accessibility
The ability to perceive information: the ability to recognize and interpret information	Difficulties in: - perception of information (recognizing words/terms quickly and accurately); - interpreting information; - limited vocabulary, rapid reading and writing skills.	High degree of perception and understanding of chemical information from a screen in a webinar format.	- Multi-sensory digital learning environment. - Assistive technical tools. - Cognitive learning technologies. - Techniques to enhance the perception of information in virtual environment. - A high level of literacy in chemical training texts. - Providing a thematic glossary.

Attention: ability to concentrate, switch, distribute attention.	Reduced ability to focus on important signals and information while ignoring distractions.	Providing information in advance about upcoming events and the time of action; availability of signals indicating the beginning and the end of an action.	- Providing enough time to perceive and respond to information adequately. - Providing information, commands and instructions in a form that attracts attention.
Ability to learn: ability to acquire knowledge, skills and competencies.	Reduced ability to perceive and reproduce chemical knowledge, skills and competencies as required by the educational standard.	Considering individual peculiarities of information perception and processing. Possibility to perceive educational information from screen by the most convenient way for a student. Semantic accessibility of educational materials in virtual environment.	Developing special conditions for webinars, including the creation of a multi-sensory learning environment through various methods of providing educational information; use of special teaching methods and technologies, teaching modes; assistive technical means and technologies; assistance of other persons (besides teaching staff): sign-language interpreter, technical specialist, psychologist.
Ability to remember information: ability to register, store and/or retrieve information if necessary.	Difficulties in: - memorizing and reproducing information; - weak actualization skills; low "survival" of knowledge; - reduced level of mental performance.	The ability to choose methods to obtain information from the screen (text, audio, video, sign language translation).	- A variety of ways and formats of providing information in a virtual environment (text, audio, video, sign language translation). - Work at an individual pace. - Cognitive education technologies: formation of operational thinking; transfer of information from one form of its presentation to another, etc.
Ability to verbal communication: the ability to reproduce and understand information.	Reduced ability to establish contacts between people by perceiving, processing and transmitting speech information (including Russian sign language).	Ensuring the proper level of understanding and self-expression by taking into account the peculiarities of communication, speech activity; literacy of written speech, understanding of symbols, terminology, and nomenclature.	- Service software, tablets, smartphones with speech recognition function, etc. - Assistive technical means and technologies of training and communication. - Providing educational information and instructions in a form that is easy to understand in the virtual environment.

4. Results and discussion

The problem of content accessibility of "Chemistry" for hearing-impaired students in both face-to-face and distance learning conditions has been achieved by taking into account their individual cognitive abilities and limitations identified during expert diagnostics of students at the stage of enrolment in inclusive programs (Oreshkina, 2020; Oreshkina, Gurov, 2020) as well as their pre-university training level in chemistry.

Organization of distance learning classes in webinar format. During the pandemic period, remote teaching Chemistry for students with hearing impairment was carried out in online and offline formats. Students and teachers were provided with access to the electronic educational literature of the MSTU publishing house, to materials developed by teachers for online classes and independent work, posted on the digital platform "Electronic University" in the "Distance Learning" module.

Online classes in chemistry have been given in webinar format using the domestic "TrueConf" platform (TrueConf). Webinar is an effective multi-sensory digital environment, which realizes both hearing and visual perception of educational information due to the possibility to use different ways of presenting it to the students. Lectures and practical classes such as laboratory works and seminars on chemistry have been conducted in webinar format. All types of classes have been realized in oral and written form, supported by technicians and sign language interpreters, with a balance between the presentation of theoretical knowledge and its practical application (drawing up the results of laboratory experiments, solving problems on the topic).

Principles of designing effective webinars for hearing-impaired students include:

- taking into account individual cognitive peculiarities of students' perception of information;
- multimodality: a variety of sources for providing educational information (text, articulation, audio, video, sign language interpreting) and the correctness of their switching;
- effectiveness of communication between the teacher and students;
- content accessibility of learning materials to all students.

Taking into account the individual peculiarities of the perception of educational information by hearing impaired students provides for a variety of sources for its supplying to students in the classes (multimodality), including:

1) The teacher (his or her speech, facial expressions, articulation)- the main source of chemical knowledge at webinars;
2) A sign language interpreter who transmits the teacher's speech literally through Russian sign language, fingerspelling and articulation;
3) Text with equations and illustrations accompanied by the teacher's explanatory speech;
4) Video demonstration of selected pieces of thematic information with built-in subtitles and audio support.

Deaf and hard of hearing students rely mainly on the visual channel of information perception, through which they process all the information that comes to them not only in the educational process, but also in everyday life. In webinars, different forms of visual information can be presented at the same time: visual linguistic information (interpreting in RSL), visual teaching materials and participants' comments in "chat". In this case, students are under increased cognitive load due to the need to switch visual attention from a teacher or a sign language interpreter to presented educational materials that leads to a decrease of lessons' effectiveness (Online learning…).

In this regard, switching information sources by the teacher was carried out taking into account the possibility of such students to focus an attention simultaneously only on one preferred way to obtain information from the screen , such as:

- teacher (his sonorous speech, facial expressions and articulation);
- sign language interpreter (his hands and lips: gestures, fingerspelling and articulation);
- an educational text with formulas and illustrations or video with subtitles supported by sonorous teacher's comments, - without sign language interpreting.

Special significance on webinars was given to sound as a stimulus for hearing perception and the need for its processing by the brain to better understand the meaning of the provided educational information.

The teacher voices everything that he shows, writes, and draws. In this case, the content of the teacher's sonorous speech coincides both with the content of the text on the electronic materials presented by him, and with the content of all explanatory notes, inscriptions, formulas and drawings that he makes when analyzing students' works.

Experience has shown that synchronous voicing the information given by the teacher significantly increases its uptake by hearing-impaired students.

Communication of students and teachers in training sessions.

Involving students in the process of online classes began with the procedure for testing the "TrueConf" system for its readiness for holding webinars: checking by the teacher the quality of broadcast of audio, video, texts and presentations; as well as the possibility to use chat (text, video) and group online discussions under the teacher's guidance.

Communication during webinars with the participation of deaf and hard-of-hearing students is an effective multisensory experience in which the mechanisms of their hearing and visual perception are implemented.

Communication between the teacher and students has been doing through voice and written speech, using chat or email, the "Whiteboard" application, and the sign language interpreter, if it was necessary.

At the webinar, the student was given the opportunity to complete assignments at an individual pace and style. He could send the completed task to the teacher after the end of the webinar and in this case, he always received a prompt response with a detailed analysis of the errors. To send educational materials, assignments and instructions to students and receive completed assignments from them, a digital platform was used, developed at BMSTU, which ensured uninterrupted communication between the teacher and students both during webinars and after them.

Clearly organized communication between the teacher and students during webinars contributed to the effectiveness of the classes. It included a strict sequence of checking completed individual tasks of students with their demonstration on the screen for analysis of errors and their subsequent correction by students. At the same time, the teacher's communication with both hard-of-hearing and deaf students has been carrying out mainly in the "chat"; the statements of each of the parties were reinforced by bringing clarifying formulas and reaction equations. It turned out that sign language interpreting in this situation was not a support: it distracts students' attention.

Psychological and cognitive unpreparedness of some deaf and hard of hearing students to work in the webinar format was revealed. As a rule, insecure students with poor reading and writing skills, poor basic training in chemistry, rapid fatigability, poor self-organization skills, suffering from the "scattered attention" syndrome, "dropped out" of group classes process and there was a need in additional individual lessons with them. It was found that the effectiveness of teacher-student communication is influenced by the students' reading and writing skills, their psychological readiness to communication with the teacher; the teacher's ability to promptly communicate with a particular student in the form of concise and single-digit oral and written statements, as well as the qualification of sign language interpreter (Online learning…).

The role of sign-language interpreter in a webinar.

The role of sign-language interpreter in a webinar is to facilitate communication between the teacher and hearing impaired students by interpreting sonorous speech into sign language and vice versa. The restrictive aspects of sign language interpreting in subject areas STEM disciplines are considered in (Oreshkina, 2018; Braun et al., 2018; Grooms, 2015; Marschark, 2005). During the chemistry webinars, the following restrictive features of sign language interpreting were noted.

1) The quality of the demonstration of gestures, dactyl and articulation of a sign language interpreter in online format is being affected by the speed of the Internet on the user's computer. If the speed is not high enough, gestures on the screen are "blurred" into a "tail" and are not perceived by the user.

2) A student who relies on sign language interpreting must simultaneously perform several actions:

- To recognize information from a sign language interpreter;
- To analyze it and record important points;
- To read quickly and perceive text information from the screen;
- To follow participants' comments in "chat".

As noted above, a student finds it difficult to simultaneously look at the interpreter and perceive the educational text from the screen. He/she is able to focus attention on preferred for him/her source of information on the screen with the possibility of losing significant information from the main source.

In this regard, special requirements for work of sign language interpreters in webinars' conditions have been determined.

The main source of chemical knowledge at webinars is a teacher.

Interpreters should request copies of training materials from the teacher in advance to be able to familiarize with the content of the lesson and coordinate with him/her their inclusion in the study process. The following situations should be taken into account. If on screen:

a) Only a teacher and a sign language interpreter, the sonorous teacher's speech is being accompanied by sign language interpreting;

b) Video clips with embedded subtitles and sonorous comments, participation of a sign language interpreter is not required;

c) Text materials with formulas and illustrations against background of the sonorous teacher's speech that explains their content, participation of a sign language interpreter is not required.

Features of preparing didactic material for webinars in chemistry with the deaf and hard-of-hearing students

Analysis of the problems of hearing impaired students in both face-to-face and distance learning in chemistry showed that the main difficulties are related to the general problem of perceiving and understanding the semantics of chemical information, including complex symbolism, terminology and nomenclature, which is exacerbated by their individual cognitive features and limitations. In online learning process, both voiced and textual information perception impairments are particularly pronounced due to reduced speed of perception and comprehension of incoming information, limited vocabulary, reading and writing skills, communication skills and mental work capacity (Oreshkina, 2020). In this regard, a key feature of webinars in chemistry for these students is their support by cognitive technologies, the main of which are (Oreshkina, 2019):

- developing operational (algorithmic) thinking skills;
- transferring information from one form of presentation to another;
- formation of conceptual apparatus in chemistry subject area (glossary technology), etc.

These technologies are used in the development of content-accessible study materials for classes in virtual environment.

Features of preparing didactic material for chemistry webinars. When preparing for the lesson, the teacher performs:

- conversion of classroom chemistry course material into visual content for webinars, taking into account the planned student activities in the classroom;
- online search and creation of video resources with subtitles for lectures and laboratory work;
- embedding videos of chemical experiments and subtitles, illustrations, photos in lesson content;
- developing materials for practical exercises using cognitive technology and an interdisciplinary approach.

Features of preparing teaching materials for lecture classes. Lectures' materials contain the main course outlines and concepts. They have been prepared and implemented by a teacher in the format of short (10-15 min) segments-quanta. The text fragments accompanied by sonorous teacher's explanations with sign language support are being combined with video fragments with built-in subtitles revealing the semantic content. In this way, transferring information from one form of its presentation to another are being realized. Each quantum begins with a glossary and ends with test questions that students must write answers within a specified period of time.

Features of preparing teaching materials for laboratory work. Laboratory work, as a fundamental part of many science disciplines, is particularly important for the experimental sciences, such as chemistry. It requires sufficient basic knowledge of the topic being studied for understanding mechanism of chemical reactions behavior.

Description of laboratory works include two parts: theoretical part, which contains necessary and sufficient description of theoretical basics on the study topic, and practical one, which includes instructions on how to carry out a series of experiments. Teachers have developed special workbooks to prepare students for works, their practical realization and registration of the results. Each workbook contains template of report form, which include a front sheet with the list of basic concepts on the research topic that a student has to define while preparing for the work, and a practical part, which the student fills out while doing laboratory work. The latter consists of a series of experiments with a title and an algorithm for carrying out each experiment, including making equations of the ongoing reactions, observations, completing result tables, graphing, drawing conclusions, etc. The theoretical material on the topic of the upcoming laboratory work is sent to students in advance to prepare for the lesson. During the webinar, the teacher consistently demonstrates video clips of the experiments with subtitles and his/her own comments on them. Students record their observations, write down the equations of reactions, and formulate conclusions on the experiment results in the relevant sections of the worksheet. This is followed by a group discussion of the results.

Features of preparing teaching materials for chemistry seminars. Teacher's preparing for seminars includes developing practical tasks in “Chemistry” using cognitive technologies and interdisciplinary approach. An extremely significant technology for practical mastering chemistry by solving problems (as well as for doing laboratory work) turned out to be the technology of developing operational thinking: forming skills and abilities to algorithmize the process of solving a task.

From the course of computer science students know that an algorithm is a logical sequence of certain actions, leading to the problem solution, and the process of algorithm creation (algorithmization) is the decomposition of the problem into elementary actions or operations. In this regard, the formation of logical-algorithmic thinking abilities includes (Leskovets, 2006):

a) Solving the task according to the algorithm offered by the teacher;

b) Solving the task according to the familiar algorithm (dynamic recognition of the situation);

c) Solving the task according to self-created algorithm;

d) Creating several possible algorithms to solve the task and choosing the best one.

As a result, the skills expressed in the relevant competence, are being formed in students and implemented in carrying out and design of laboratory works, home works, project-research activities, etc. Applying this technology implements an interdisciplinary approach in which students use two or more disciplines to extend their understanding of a subject or problem beyond the limits achievable through a single discipline (Nyamapfene, 2020; Holley, 2017). This approach enables students to integrate their skills, knowledge, experience and procedures from different disciplines (chemistry, mathematics, computer science) to acquire new knowledge, understanding and skills that allow explaining and solving problems in chemistry. Such approach also promotes active, developing, independent learning (Ivankina, 2018).

Consider the use of the above-mentioned technology while preparing educational material for a seminar that includes the analysis of tasks on the topic “Electrochemical processes in solutions. Corrosion and protection of metals”. Task’s condition as follows:

“Determine the possibility of electrochemical corrosion of tin (Sn) in aerated aqueous solution at T = 298 K, at pointed values of the activity of corroding metal ion $a_M{}^{Z+} = 10^{-6}$ mol/l, pH = 8.4, and standard electrode potential $\varphi^0_{\frac{Sn^{2+}}{Sn}} = -0{,}136$ V by calculations of electromotive force (EMF) of corroding element and Gibbs energy $\Delta_r G_{298}$ of corrosion process. Give the equations for the anodic and cathodic processes and the current-producing reaction. Take the partial pressure of oxygen over the solution as standard” (Golubev et al., 2013).

According to (Golubev et al., 2018; Gurov, 2017) the possibility of electrochemical corrosion is determined by following factors:

1) The change in Gibbs energy: corrosion is a spontaneous process accompanied by its loss ($\Delta_{r\,corr} G_{298} < 0$);

2) The sign of the electromotive force (EMF) of the corrosive galvanic cell (E_{cgcell}), which is the potential difference between the cathode and the anode ($E_{cgcell} = \varphi_K - \varphi_A$). It is related to the Gibbs energy of the reaction by the following equation: $ZFE_{cgcell} = -\Delta_{rcorr} G_{298}$. Where Z is the number of electrons involved in the corrosive current-producing reaction (the lowest total multiple of the number of electrons in the anodic and cathodic processes); F is Faraday constant (96500 Cl/mol Eq.). As Z and F > 0, corrosion is possible if $E_{cgcell} > 0$;

3) Comparing the cathode φ_K and anode φ_A potentials: corrosion is possible if the cathode potential is greater than the anode one: $\varphi_K > \varphi_A$.

Electrochemical corrosion of metal in an aqueous medium is possible if the following conditions: 1) $\Delta_{r\,corr}G^o_{298} = -ZFE_{cgcell} < 0$; 2) $E_{cgcell} > 0$; 3) $\varphi_K > \varphi_A$.

Based on the above wording of the assignment, hearing impaired students will experience difficulties in completing the task due to the uncertain sequence of operations. It is not possible to calculate the EMF of the corrosion element and the Gibbs energy of the corrosion process without prior calculation of the electrode potentials of the cathode and anode, and for this purpose, it is necessary to write the equations of the anodic and cathodic processes. Therefore, it is important to start the solution by writing these equations. The verbal algorithm for solving problems meeting the above conditions includes the following logical sequence of actions:

1. Write the equations for the anodic process.
2. According to the corrosion conditions, write the cathodic process equation.
3. Write the equation for the total (current-producing) reaction.
4. Calculate the potentials of the anode and cathode electrodes under the given corrosion conditions using forms of the Nernst equation adapted for T = 298 K.
5. Calculate the EMF of the corrosive element.
6. Calculate the Gibbs energy Δ_rG_{298} of the corrosion process.
7. Determine the possibility of metal electrochemical corrosion.

Students can easily follow this algorithm if they represent the semantic content of each action. In this regard, the algorithm shown in Table 3 is useful. One column of the table presents the verbal sequence of actions depending on the conditions, and the other column presents the description of the content of each action in the chemistry language.

Table 3. Algorithm for Task Performance

No	Sequence of Actions	Content of Actions
1	Write the equation for the anodic process (–)A	Oxidation of the reducing agent (tin) (–)A(Sn): $Sn - 2e \rightarrow Sn^{2+}$
2	According to the corrosion conditions, write the cathodic process equation (+)K. As the medium is aerated and pH = 8.4 (alkaline), the cathodic process in the aqueous solution will proceed with oxygen depolarization:	Oxidant (oxygen) reduction (+)K(Sn): $O_2 + 2H_2O + 4e \rightarrow 4OH^-$
3	Write the equation for the current-producing reaction (CPR), taking into account the coefficients:	CPR: $2Sn + O_2 + 2H_2O \rightarrow 2Sn(OH)_2$; Z = 4
4	Calculate the anode potential (metal electrode) according to Nernst equation adapted for T = 298 K, taking into account the activity of the corroding metal ions:	$\varphi_A = \varphi_{\frac{Sn^{2+}}{Sn}} = \varphi^0_{\frac{Sn^{2+}}{Sn}} + \frac{0,059}{2}\lg a_{Sn^{2+}} =$: $= -0,136 + \frac{0,059\lg 10^{-6}}{2} = -0,313\,B$
	Calculate the cathode potential (oxygen electrode) according to the Nernst equation adapted for T = 298 K, taking into account that the medium is aerated, pH = 8.4 and the partial pressure of oxygen over the solution is standard (1 atm):	$\varphi_K = \varphi_{\frac{O_2,H_2O}{OH^-}} = 1,229 - 0,059pH + 0,0147\lg p_{O_2} =$ $= 1,229 - 0,059\cdot 8,4 + 0,0147\lg 1 = 0,733\,B$
5	Calculate the EMF of the corrosive element:	$E_{cge} = \varphi_K - \varphi_A = 0,733 - (-0,313) = 1,05\,B > 0$
6	Calculate the Gibbs energy Δ_rG_{298} of the corrosion process, considering that Z = 4:	$\Delta_rG_{298} = -ZFE = -4\cdot 96500\cdot 1,05 = -405300\,J = -405,3\,kJ < 0$

7	Draw a conclusion about the possibility of electrochemical corrosion of tin by fulfilling the criteria: 1) $\Delta_{r\ corr}G_{298} < 0$; 2) $E_{cge} > 0$; 3) $\varphi_K > \varphi_A$	Conclusion: electrochemical corrosion of tin is possible because the following conditions are met: 1) $\Delta_{r\ corr}G_{298} < 0$; 2) $E_{cge} > 0$; 3) $\varphi_K > \varphi_A$

This algorithm realizes the technology of transferring information from one form of representation to another and helps students understand the content of particular actions. Then a verbal algorithm can be offered to students. They recognize commands and are able to execute them in the chemistry language. Algorithmization of solving process is based on the students' knowledge/understanding of terminology, which is facilitated by glossary technology (Oreshkina, 2019).

These technologies proved the effectiveness in teaching chemistry in a webinar format during the pandemic. In all types of classes, students' cognitive problems have been identified and successfully solved. The teacher performed a multifunctional mission, acting as a teacher, moderator, tutor, consultant and team leader. The teacher created and supported a positive environment in which all participants acted as a team and shared responsibility for the final results, confirming (Karpov, 2017; Patton, 2020).

These technologies meet the principles of universal design: they enhance the acquisition of information in chemistry, not only for hearing impaired students, but also for non-disabled students.

Approaches to assessing the progress of hearing-impaired students in a distance learning environment are similar to approaches used in traditional learning conditions. The BMSTU has a module-rating system for monitoring and evaluating students' knowledge. It provides evaluation of students' progress in all modules of chemistry course by summing up the points set for each type of required activities within the modules in accordance with the curriculum:

Carrying out and defending:

- laboratory work (3-5 points);
- homework assignments (10-15 points);

Activity during webinar (1-3 points), etc.

Assessing compulsory tasks performed by hearing impaired students is being carried out according to generally accepted criteria and taking into account the peculiarities of the developing their speech activity (Oreshkina, 2020). Intermediate certifying based on the results of semesters in the discipline takes in the form a credit (1st semester) and distributed examination (2nd semester). As the assessing scale it is adopted a 100-point system with a gradation of marks in accordance with the Regulations on current control and intermediate attestation of BMSTU. A student who has completed all the scheduled tasks and tests receives a final grade for the semester according to the scale in Table 4.

Table 4. Module-Rating System for Monitoring and Assessing the Knowledge of Hearing Impaired Students in Chemistry

Rating	Credit score	Distributed exam score[1]
85 – 100	pass	excellent
71 – 84	pass	good
60 – 70	pass	satisfactory
0 – 59	fail	poor

[1]A distributed examination is a type of intermediate assessment in which a student receives the entire set of points (100 points) for the current control activities.

Students' participation in webinars and their performance results are stored in the unified information system of BMSTU "Electronic University" (Moskalenko, 2010) and are available to students. The comparative results of academic performance in chemistry in face-to-face (2017–2019) and distance (2020–2021) learning conditions during the pandemic are presented below:

Table 5. The comparative results of academic performance in chemistry in face-to-face (2017–2019) and distance (2020–2021) learning conditions during the pandemic

Academic year	2016/17	2017/18	2018/19	2019/20 (spring)	2020/21 (autumn)
Average sum of points	74,0	79,0	82,0	82,0	80,0
Average score	4	4	4	4	4

Analysis of learning outcomes showed that effective webinars in chemistry with hearing-impaired students require the comprehensive solution: taking into account their individual perception of information in a virtual environment; creating content-accessible multimodal environment for all students by preparing special study materials based on cognitive technologies and interdisciplinary approach; involving all students in online learning process and keeping them active throughout the session by taking an optional approach to each student and ensuring a positive, creative atmosphere. According to the students themselves, this approach to remote learning the discipline "Chemistry" fully justified itself: students were able to understand goals, objectives and content of the classes, the teachers' guidelines, were able to understand the meaning of tasks and perform them according to established requirements. They felt steady help and support from the teacher and perceived all webinar' participants as a single team. A positive atmosphere and mutual support contributed to the success.

5. Conclusion

Distance learning is a very specific environment for teaching and learning "Chemistry". Using digital materials and integrating them into the learning process through a virtual conference in webinar format is essentially a digital transformation of the learning process. Both teachers and learners need to be able to teach, learn and interact effectively in a virtual environment. Organizing learning process of "Chemistry" in webinar format for hearing impaired students is a forced measure that imposes a number of limitations. Students are not able to perform real laboratory works in a chemistry laboratory under the teacher's supervision, thus preventing them from developing skills to make experiments. For hearing impaired students, direct contact with a teacher to guide and correct their steps in the chemistry learning process is essential. Face-to-face classes, where students work within sight of the teacher and each other, create a "cumulative" effect in the acquisition of new knowledge, which is not sufficient in the distance format.

BMSTU's experience confirms that development of accessible training materials for all types of classes and for all involved students based on considering their peculiarities of information perception from the screen is very important for conducting effective webinars on chemistry for this category of students. However, checking students' laboratory works and practical assignments with analysis and correction of mistakes is a significant additional load for the teacher, and supporting positive and creative atmosphere in webinars causes psychological stress. In general, the effectiveness of remote learning is being determined by the ratio of achieved results and labour input of all participants involved in the process.

Creating accessible multimodal environment in webinars for hearing impaired students by taking into account individual cognitive features of information perception and using cognitive learning technologies, based on interdisciplinary approach, does not reduce their motivation to study chemistry, develops their cognitive abilities and thus helps to make their performance in chemistry in remote learning equal to their performance in face-to-face classes. Current cognitive learning technologies based on interdisciplinary approach are an innovative development of BMSTU professors. They comply with the principles of UDL: facilitate the acquisition of information in chemistry not only by hearing-impaired students, but also by non-disabled students.

Webinars provide students with the opportunity to learn new professional skills that they can later use in their academic and professional careers.

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