Development of educational video materials collection as a part of special conditions for hearing impaired students while studying chemistry at technical university

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Abstract. BMSTU trains hearing impaired persons as engineers on inclusive programs. The subjects of the inclusive educational process are students with hearing impairment of varying severity. The key need of this contingent of students is the content accessibility of educational resources in the disciplines of fundamental engineering, including chemistry. BMSTU solves the problem of accessibility of such disciplines as chemistry for hearing impaired students through creation of special educational conditions during study, taking into account individual characteristics of restricted information perception, restricted life activities and degree of their severity in students. Special conditions form a special accessible multimodal educational environment learning process in chemistry for students with hearing impairments. An element of forming such an environment was the development of a collection of educational multimedia video materials on the chemistry course topics. Involving deaf and hard-of-hearing students themselves in development of demonstration experiments as part of the educational process in chemistry and creation of a complex of video materials are important cognitive and social factors that increase their motivation to study chemistry.

1. Introduction.

Ratifying the “Convention on the Rights of Persons with Disabilities” by Russia and amending Russian legislation in the context of this document made it crucial to solve various problems in the field of vocational education of disabled people, including those with hearing impairments, by creation of inclusive vocational trainings and special conditions to provide its availability at all education levels. Inclusive education involves providing equal access to educational resources to all students in an educational institution on the basis of taking into account their special educational needs and individual capabilities. Creation of special conditions includes development and implementation of special educational programs and teaching methods, writing new textbooks, teaching aids and didactic materials as well as other solutions that will increase the accessibility of educational content and thereby enable students with disabilities to master educational programs. These activities are aimed at solving the problem of equalizing the training opportunities of students with health disabilities with the capabilities of regular students. Bauman Moscow State Technical University (hereinafter referred to as “BMSTU”) has been training hearing impaired persons as engineers since 1934. In 1994, the Head Education and Research and Methodological Center has been established for development and implementation of inclusive engineering training programs for people with hearing disabilities. Today, more than 200 students with hearing impairments from 36 regions of the Russian Federation and 3 CIS countries are enrolled in these programs at 10 faculties of the
university in 11 specialties. At the same time, about 50 trainees undergo training in the pre-university cycle programs. Since 2016, the Center has been training students with other disabilities on inclusive programs. Currently, inclusive programs of BMSTU Center are recognized as model for use in higher vocational education of people with other disabilities.

2. Methodology
According to the Federal Law “On Social Protection of the Invalids in the Russian Federation” (Article 1), a student with disability is a young person aged 18-35 years, who has violation of health with stable functions’ disorder due to diseases, consequences of injuries or defects, leading to restrictions of his life activities, including abilities to learn and communicate. In this connection he needs in special education conditions in an educational institution of a general type.

The purpose of this work is to develop a collection of educational video materials on chemistry as a part of special conditions for students with hearing impairments while studying this discipline within inclusive training programs at a technical university of general type.

Students with hearing impairments who study in inclusive programs at BMSTU depending on hearing loss degree are being divided into the following four categories:

1. Deaf students. As a rule, these are students with severe hearing impairments who use sign language as the main form of communication. In deaf students, the main perception is visual. They are divided into 2 groups:
   • those who lost hearing or congenitally, or before forming speech, that is up to 2-3 years. Their number at BMSTU annually ranges from 30 to 50% of the total number of students with hearing impairments. If towards them in their childhood timely habilitation and further adequate rehabilitation have not been carried out, they represent the heaviest contingent of students at a higher educational institution of general type;
   • those who lost hearing after forming speech; on condition timely and adequate rehabilitation, such deaf students may even have a sufficiently developed sonorous speech.

2. Hard-of-hearing students. Mostly, these are hearing impaired students who use hearing aids and use sonorous speech as the main form of communication. They are being divided into three categories:
   • hearing: they use predominantly auditory perception of information (its volume does not reach 100%) with the help of various individual hearing aids and have relatively well or satisfactorily developed speech;
   • auditory-visual: these students have partial auditory perception (which is not enough for complete information perception) with the addition of visual (lips reading); in such students auditory perception does not play a leading role; their complex perception can make up to 75-80% of normal perception; with that its effectiveness depends on the teacher's speech quality (clear, slow, with sustained intervals between phrases);
   • Visual -hearing: these students also use hearing aids; but they have only orientating hearing perception, which allows them to determine the source of sound information and perceive the latter as separate words; their main perception is the visual one; in learning process they use sign language interpreting.

3. Late-deafened students represent a special category of students with severe hearing impairments. In these students centers for auditory information perception were formed; their speech is saved; they have a stock of auditory information and well orient in visual written information; they use hearing aids; but at the same time, psychological trauma prevails in these people, as they are “knocked out” from ordinary life. They are not able to master lip reading or sign language in order to communicate freely; the only possible communication form for them is the written one.

4. Students with a cochlear implant (as the rule they are implanted in their adult life): for these students there is a problem of recognition new sound images, so they often use hearing aids along with the implant.

Thus, each student with a hearing impairment is unique, both as a result of specific hearing problems and the presence of other concomitant disorders of body functions, as well as due to specific “listening”
and learning strategies. The prevailing visual perception in students with hearing impairments requires “visual” accompanying of their learning process.

As a rule, hearing impairments of varying severity lead to restrictions of life activities the main of which are given in Table 1.

**Table 1.** Correspondence between the main restrictions of life activities, their manifestations and the special educational needs in students with hearing impairment

| Kind of restriction | Manifestation of restriction                                                                 | Special education needs                                                                 |
|---------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Restriction of      | Reduction of the pace and volume of received and transmitted information.                    | The need in assistive technology, including speech-to-text translating one, and in sign language interpreter services |
| his/her ability to  | The use of assistive technology, non-verbal communication and sign-interpretation services    |                                                                                         |
| communicate         |                                                                                              |                                                                                         |
| Restriction of      | Low level of the ability to perceive, memorize, assimilate and reproduce knowledge; to master skills, abilities, competencies. | The need in meaningful accessibility of educational content and creation of special conditions for the acquisition of knowledge, including visualization of educational material |
| the ability to      | Low level of developing abilities, the acquisition of experience in the application of knowledge in everyday life |                                                                                         |
| learn               |                                                                                              |                                                                                         |
| Restriction of      | Low level of the ability to expand knowledge and active cognitive interest in chemistry for further professional activity | The need to perform work in partnership with teachers in the framework of design and research (practical) activities |
| the ability for     |                                                                                              |                                                                                         |
| labour activity     |                                                                                              |                                                                                         |
| Restriction of      | Low level of ability to control his/her behavior in difficult situations; the difficulty of performing role functions in the educational process | The need in taking into account his/her psychological characteristics; the need in cooperating in design and research (practical) activities; in participating in student conferences |
| the ability to      |                                                                                              |                                                                                         |
| self-control behavior|                                                                                             |                                                                                         |

*Classifications and criteria used in the implementation of medical and social expert evaluation of citizens by Federal state institutions of medical and social expertise in the Russian Federation (Approved by the Order of the Ministry of Labor and Social Protection of the Russian Federation N 1024n (2015)).

As an example, below is a list of the types of manifestations of life activities’ restrictions according to the level of communicative skills in a typical hearing-impaired student, most pronounced within first or second years of study. These restrictions are due to the specific psycho-physiological characteristics of the disabled person, and in the first education stage they most strongly influence the process of mastering main professional educational programs:

- underdevelopment of oral and writing speech;
- limited vocabulary;
- weakly developed long-term memory
- weakness of skills of knowledge actualizing;
- low level of abilities to establish and understand temporal, spatial, and cause-effect relationships and relations between conceptual objects;
- slow forming an extensive system of concepts;
- limited social contact skills.
Due to the above restrictions, students with hearing impairments, including those with disabilities, have special educational needs and need an individualized approach across all disciplines in engineering training programs, including the disciplines of fundamental engineering, such as chemistry, physics, mathematics, etc. (hereinafter referred to as "STEM" - disciplines).

It is recognized that the key need of all the above categories of students with hearing impairment is the content accessibility of educational resources in STEM disciplines, including chemistry, physics, etc. Chemistry is the most important component of engineering education. Its studying forms the basis for mastering a number of other disciplines in modern engineering training programs. In the absence of special educational conditions in high school chemistry classes, graduates with hearing impairments show an extremely low level of chemical knowledge of the school course. This is confirmed by the results of annual testing of residual knowledge of the school chemistry course in BMSTU students with hearing impairments, who begin to study the university course. Test results of students with hearing impairments for the 2013-2019 school years are shown in Table 2.

**Table 2.** The test results of BMSTU second year students with hearing impairments within the school chemistry course for the 2013-2018 school years.

| №  | Theme from school course which testing has been carried out | % unsatisfactory answers of hearing impaired students according to school year |
|----|----------------------------------------------------------|--------------------------------------------------------------------------------|
|    |                                                          | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017 | 2017-2018 | 2018-2019 |
| 1  | Inorganic compounds: main classes, names and chemical formulas | 60 | 75 | 80 | 90 | 94 | 92 |
| 2  | Stoichiometric calculations | 60 | 75 | 80 | 90 | 100 | 100 |
| 3  | Determination of an oxidation degree of an element in a compound | 60 | 75 | 100 | 93 | 94 | 92 |
| 4  | Electrolytes: composition and equations of electrolytic dissociation | 80 | 80 | 80 | 100 | 100 | 100 |
| 5  | Selection of stoichiometric coefficients in the equations of redox reactions by electron balance method | 90 | 90 | 80 | 100 | 94 | 92 |
| 6  | Calculatory task on excess – lack of reagents | 90 | 100 | 100 | 100 | 100 | 100 |

The test results show the almost complete lack of basic knowledge of certain sections of chemistry among students with hearing impairments, especially among graduates of inclusive schools. This testifies to the lack of a cognitive basis for perception and understanding chemical information at the university by such students. In this regard, solving the problem of accessibility of the discipline "Chemistry" for this special contingent, as well as other STEM disciplines, is carried out at BMSTU through the creation of special conditions for its studying and is based mainly on the taking into account of:

- an individual features of limitations of information perception;
- restrictions of life activities and the degree of their severity in students, which are identified during their comprehensive expert diagnostic testing at the stage of enrollment in inclusive programs.

BMSTU has created and continues to improve a special accessible multimodal educational environment for teaching students with hearing impairments in the disciplines of fundamental engineering, which is formed by creation of special educational conditions for this contingent. Special conditions for studying chemistry (as well as other STEM disciplines, by the way) include the following:

- organization of educational space in the form of specialized system-integrated multimedia information complexes of educational resources and technologies;
-adaptation of basic educational programs in STEM-disciplines, including Chemistry, in hours, but not in the content: the term of mastering the course of Chemistry by students with hearing impairments is two semesters instead of one given to ordinary students;
-introduction of supplementary supporting adaptive course in chemistry which includes mastering the discipline content using a number of cognitive technologies;
-writing textbooks and teaching aids of a new generation that meet the principles of universal educational design [1,2];
-developing multimedia educational resources in chemistry with participation of students themselves;
-supporting classes in chemistry by demonstrating chemical experiments on the main topics of chemistry course, developed with the involvement of students, etc.

As the material of the study served as indicators of academic performance in chemistry of BMSTU students with hearing impairments for the period from 2011 to 2018. As a research method, a comparative analysis of results of academic performance in periods of absence (2011-2013) and creation (2014-2018) of special education conditions while studying chemistry.

3. Results and discussion

Chemistry is being studied by BMSTU hearing impaired students who study on following inclusive bachelor's training programs: 03.15.04 "Automation of technological processes and production"; 03.22.01 “Materials Science and Materials Technology”; 03.27.01 “Standardization and Metrology”.

The chemistry course, which they study in accordance with the prescribed training programs, corresponds to the same programs and the same educational materials used by ordinary students [1–4]. When studying chemistry, deaf and hard-of-hearing students face great difficulties connected with the low level of their pre-university training in this subject due to the individual characteristics of information perception caused by hearing defects and insufficiently effective organization of educational and rehabilitation processes [5]. This applies not only to students - graduates of specialized schools and vocational training centers for children with hearing impairments, but also graduates of mainstream schools. As a rule, students from these categories of graduates do not know the symbols and terminology, do not know the basic laws of chemistry, do not know how to make up the equations of chemical reactions, do not have the skills to analyze experimental data and to formulate conclusions [6].

The main problem for deaf and many hearing impaired students is the understanding of chemistry teaching texts in both oral and written forms. In order to acquire needed knowledge and practical skills in the field of chemistry, students should understand everything that is being offered to them at lectures and practical classes (laboratory works and seminars) and be able to convey the sense meaning of what they understand "by their own words". This problem directly concerns those faculty members who teach chemistry deaf and hard-of-hearing students: they should be confident that both they and their students are in the same content sense field.

Chemistry is well known as an experimental science. Many phenomena and processes in it become clear to students only after conducting experiments and subsequent analysis of obtained results. Chemical formulas that seemed previously abstract are in this case are linked together with their physical and chemical incarnations. Chemistry lectures for ordinary BMSTU students are accompanied by demonstration experiments and are held in a specially equipped room. For the deaf and hard-of-hearing students, such lectures are held in the specialized multimedia classrooms, which are not intended for carrying out chemical lecture experiments there. Laboratory works in chemistry performed by students of this category, firstly, do not cover the entire spectrum of the material under study, and secondly, most of the experiments performed are carried out by the drop method, which does not provide a complete and clear understanding of the chemical process. Taking into account the fact that in hearing impaired students dominate visual perception, they require visual support of their educational process. In this regard, development of a collection of visual educational multimedia video materials on the main topics of the chemistry course with a step-by-step explanation of the occurring phenomena and processes for
these students is a very, very important task. These video materials become a very effective means to increase the content accessibility of educational resources in chemistry, and therefore, a part of special educational conditions for this category of students [7], contributing to a deeper understanding and assimilating chemical course topics.

The involvement of deaf and hard-of-hearing students themselves in the development of demonstration experiments as part of the educational process in chemistry and the creation of a complex of video materials in this regard are significant cognitive and social factors that increase their motivation to acquiring knowledge in chemistry. Partnerships that arise during joint project-research activity, without which the functioning and development of subjects of vocational (technical) education is impossible, implies developing emotional self-regulation and constructive cognitive activity in students with hearing impairments in interaction with other actors in this activity. A prerequisite for partnership, as a type of emotional relationship, is the ability and desire to be useful in achieving a common goal, skills of positive self-regulation, acceptance of common goals, interaction and variability of solutions ways and, ultimately understanding the necessity of self-restriction in his/her desires and emotions. The object of design and research activities to create a collection of educational video materials are both the material objects (chemical reagents, laboratory equipment) and the technologies used. All this work activates the cognitive processes of perception and understanding chemical phenomena and transformations in these students [8].

The first video experiments developed on the course of chemistry were three fairly simple to implement, but very visual and spectacular experiences on the topic "Energetics of chemical reactions." These are:

1) "Bettger volcano" - thermal decomposition of ammonium dichromate \((\text{NH}_4)_2\text{Cr}_2\text{O}_7\), described by the following stoichiometric equation:

\[(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \rightarrow \text{Cr}_2\text{O}_3 \downarrow + \text{N}_2 \uparrow + 4\text{H}_2\text{O} \uparrow\]

2) “thermite mixture” - aluminothermic reduction of iron from its oxide of composition \(\text{Fe}_2\text{O}_3\);

the stoichiometric equation for this process is following:

\[\text{Fe}_2\text{O}_3 + 2\text{Al} \rightarrow 2\text{Fe} + \text{Al}_2\text{O}_3\]

3) "purple genie" - the interaction of aluminum with iodine in the presence of water as a catalyst which can be reflected by the following equation:

\[2\text{Al} + 3\text{I}_2 \xrightarrow{\text{cat. H}_2\text{O}} 2\text{AlI}_3\]

Performing these experiments require the following:

- a) using sufficiently dry reagents; therefore, ammonium dichromate, aluminum powder, and iodine are permanently stored in a desiccator in a fume hood;
- b) careful selection of the weight ratios of reagents to initiate reactions, such as, the reactions of aluminum with iodine and aluminothermy, since these reactions are complex;
- c) conducting experiments exclusively in a fume hood in a special classroom, since during their performing, volatile substances and toxic substances are formed ("Bettger volcano," the reaction of aluminum with iodine).

These requirements make it impossible to demonstrate such experiments in a multimedia classroom.

To show the connection of theory and practice, these three reactions were previously described by equations. According to the latter, thermodynamic calculations of the thermal effect of \(\Delta r\mathbf{H}^{\circ}_{298}\) and the entropy \(\Delta r\mathbf{S}^{\circ}_{298}\) of each reaction were performed. In the calculations, either new or refined values of the standard enthalpies of formation of substances were used, which have not yet been included in reference publications either abroad or in Russia [9, 10]. Using the obtained values of these two thermodynamic characteristics, the Gibbs energy of the reaction \(\Delta r\mathbf{G}^{\circ}_{298}\) was calculated. It turned out that all reactions are spontaneously proceeding, as their \(\Delta r\mathbf{G}^{\circ}_{298} < 0\), and in addition being exothermic, in which \(\Delta r\mathbf{H}^{\circ}_{298} < 0\). Attention should be paid to the fact that decomposition of ammonium dichromate \((\text{NH}_4)_2\text{Cr}_2\text{O}_7\) ("Bettger volcano"), as it turned out, also is being exothermic process, although it is
known that most decomposition reactions are endothermic reactions. This is a characteristic feature of given reaction. This reaction belongs to the type of intramolecular redox reactions, whereas other two reactions relate to intermolecular redox reactions. The description of the processes under study, as well as the subsequent analysis of the results obtained, contribute to a deeper perception and understanding by students of the semantics of chemical learning texts, while increasing the content accessibility of the subject area of chemistry. Thus, the result of this work was multimedia educational video material, which illustrates such sections of the Chemistry course, as redox reactions, thermodynamics, and catalysis. It includes:

- preparing a video experiment;
- conducting the video experiment itself;
- analysis and explanation of the observed phenomena and processes;
- description of the processes by stoichiometric equations;
- confirmation of the obtained results by thermodynamic calculations.

Listed sequence of actions is an important methodological component of chemistry classes for students with hearing impairments.

The effectiveness of the educational process in chemistry is assessed by the results of students' progress achieved while they receive and assimilate educational information from various sources in accessible multimodal environment, including the environment of the experimental BMSTU chemical laboratory. The design and research activities of students in such an environment greatly contribute to their understanding studied chemical phenomena and processes. Comparative results of academic achievement in chemistry of students with hearing impairment as actors of inclusive programs and ordinary students, studying in the same areas of training are presented in Table 3.

| Cipher and field of education | Students' categories | Average academic performance results |
|------------------------------|----------------------|-------------------------------------|
|                              |                      | Total academic score | Grade for semester |
| 03.15.04 “Automation of technological processes and production” | With hearing impairments | 72.0 | 4.0 |
|                              | With normal hearing  | 79.0 | 4.0 |
| 22.03.01 “Materials Science and Materials Technology” | With hearing impairments | 65.0 | 3.0 |
|                              | With normal hearing  | 82.0 | 4.0 |
| 03.27.01 “Standardization and Metrology” | With hearing impairments | 71.0 | 4.0 |
|                              | With normal hearing  | 82.0 | 4.0 |

4. Resume

Involving deaf and hearing impaired students in developing demonstration experiments as part of the educational process in chemistry is a kind of education project-research activity [11], which refers to the creative process aimed at identifying and satisfying students’ cognitive needs through creation of some material or ideal product of subjective or objective novelty increasing their motivation to study chemistry.

Video materials created with the participation of the students themselves is considered as an educational resource naturally integrating into educational process in chemistry for students with hearing impairment in multimedia classrooms and is an important part of special educational conditions for such a category of students at technical university of general type. Application in the educational process in chemistry for students with hearing impairments of this type of design and research activity contributes to its cognitive flexibility [12], manifested in the didactic orientation of the content and teaching methods on both individual and collective peculiarities of students' cognitive activity.
According to [13], the project-research activity of students at a university of general type contributes to the expansion of their cognitive abilities and the social and cultural interaction between the deaf, hard-of-hearing and ordinary (hearing) students.

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