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EFFECTIVENESS OF E-LEARNING RESOURCES IN PHYSICAL CHEMISTRY TEACHING

Abstract. Implementation of electronic learning resources into the teaching of chemical disciplines in higher school does not always lead to an improvement in students' mastery of the material. Therefore, the optimal choice of effective electronic resources for the teaching of basic chemical disciplines is an urgent task. The purpose of the work was to identify the resources that are relevant to the teaching of physical chemistry from the point of view of both teachers and students. Specific questionnaires were developed to achieve the goal, and a survey of pedagogical process participants (students and faculty members) was conducted, followed by statistical processing of the survey results. The expediency of usage of 41 e-resources was investigated, and 21 resources were identified as suitable for the study of a university course in physical chemistry. Among them, eight e-resources were found to be important for teaching most topics of the discipline, and so are attributed to universal resources. Another thirteen resources are important for teaching some topics and ineffective for others (specific resources). At the same time, only five universal and eight specific resources are currently used in the practice of the Faculty of Chemistry of Olesj Honchar Dnipropetrovsk National University. Some discrepancies have been identified between teachers and students concerning resource preferences that create the preconditions for the loss of effectiveness of the use of such resources. Since the use of some electronic resources is sensitive to learning styles, existing styles for faculties and students were analysed. The main differences consist in the explicit preferences of the faculty for reflective and global styles, while students are characterised by predominantly active and sequential learning styles. The results obtained regarding the effectiveness of e-resource usage are discussed from the viewpoint of preferences in learning styles characteristic of students and teachers of natural sciences.

Keywords: chemistry teaching at universities; electronic learning resources; physical chemistry; preferred learning styles of students and faculties; universal and specific resources.

1. INTRODUCTION

The problem setting. The impact of information and communication technologies (ICT) has brought many changes in the education system. ICT, including computer applications, mobile technology or recording and communication systems, have become essential and highly relevant items in teaching [1, 2]. However, the efficient implementation of ICT into all areas of educational activities is still of the critical priority [3, 4]. Despite the undoubted advantages of ICT usage, such as visualisation of information, automation of computing, facilitation of students' independent work, etc., the issue of the efficiency of the ICT-based teaching of chemistry-related disciplines remains unsettled. The introduction of ICT into the teaching process at universities is complicated by both weak elaboration of the didactic basis and lack of practical recommendations for its efficient use in teaching chemistry [5].

An adequate, well-balanced and efficient selection of electronic learning resources based on the ICT is an essential stage of embedding of novel electronic technologies into traditional systems of teaching. The selected learning resources should match the content of the curriculum and simultaneously be readily perceived by students. The term "electronic learning resource" (or in short form e-resource) includes the following aspects of the concept:

a digital type of data registration, processing and presentation; computer hardware and software for simulation, planning and control; and electronic environment for communication including networks and communication facilities.

The analysis of recent studies and publications. Nowadays, the use of e-resources in science education enhances and supports the learning process because a person can acquire new knowledge in a more flexible and adaptable way than with the traditional method.

One can conclude from the literature data that lecturers are provided with a sufficiently large number of e-resources to be used for teaching physical chemistry. However, their use is often restricted to multimedia support of a lecture. Existing restrictions in the curricula, such as the limited number of hours allocated for laboratory and seminar classes, availability of computer equipment in chemical laboratories, etc., allow one only occasional using e-resources in practical work. For this discipline, ICTs are generally used in the form of penetrating technology which causes the most significant complications of material perception due to the discrepancy between the dominant style of student learning and teaching methods [6].

Application software packages (Table 1) are often nominated among the most effective e-resources for teaching physical chemistry [7-13]. For example, the MathCAD Rro environment is actively used in the educational process of the Department of Physical and Inorganic Chemistry of Olesj Honchar Dnipropetrovsk National University (DNU) during the teaching of special courses "Fundamentals of electrochemical kinetics", "Solving research tasks in integrated software environments", etc. [8].

Table 1

Application software used in learning physical chemistry

Software type	Examples	Source
Multipurpose	Microsoft Office	[6]
Special purpose	Chemical formula editors, visualizers, modelling programs, learning and training programs, etc.	[9, 10, 11]
Integrated programming environment	MathCAD, Maple, Mathematica, MatLab	[7, 8]
Software for quantum mechanical calculations	HyperChem, MOPAC, GAMESS, Gaussian	[6, 12]

The allocation of sufficient time for practical work in a classroom equipped with computer equipment, as well as for independent work of students is essential for mastering the software packages listed above. Dialogical forms of training, a considerable amount of time to perform tasks in a computer class, a step-by-step study of the functionality of programs, and a gradual elevation of the complexity of tasks create conditions that reduce the severity of the issue of harmonizing the styles of student learning with teaching methods.

However, most of these products are used for the in-depth study of some sections of physical chemistry in the special courses of the unit of vocational training, when the application of computer technology can be classified as the main or even the only monotechnology. At the same time, available e-resources are weakly investigated in relation to the completeness of the coverage of university curricula for physical chemistry.

There is a long-term debate on the relationship between teaching and learning styles and their impact on students' performance [6, 14]. A general problem of teaching-learning mismatching is partly connected with possible differences in the attitude of both parties involved in the learning process to the e-resources used. An essential difference between learning styles of students and teachers is often observed [15, 16]. Since a teaching style is a combination of teaching methods and techniques, that a lecturer/teacher prefers in his/her teaching, the above difference can promote the difference in attitudes to the resources used. Given that a level of preference consistency may affect learning effectiveness, this article focuses on the level of match/mismatch in students' and lecturers' attitudes to e-resources within basic chemistry disciplines, an area not previously researched for these characteristics.

The paper goal. The primary objective of this research was to determine the true potential for practical use of various e-resources in the teaching of a university course of physical chemistry and evaluate the students' and faculty's attitudes to these resources. More specifically the following questions will be considered:

- ✓ What e-resources are the most relevant in physical chemistry teaching from the viewpoints of both students and faculty members?
- ✓ Do the students' preferences in e-resources match the faculty's choice?

2. METHODOLOGY

Surveys of both students and faculty members were carried out at the Faculty of Chemistry of DNU during 2012-2016. The teaching of four basic chemistry disciplines, namely inorganic, organic, analytical and physical chemistry, was analysed from the viewpoint of suitability and effectiveness of the implementation of e-resources in teaching and learning practice. The results for physical chemistry are presented in the given paper.

Preliminary studies allowed the author to identify 41 e-resources which either can be used or are already employed at the Faculty of Chemistry of DNU [17, 18]. All these resources were included in a specially developed questionnaire. A total of 8 faculty members, who were involved in teaching physical chemistry and considered as experts, and 94 graduate students, who already took the physical chemistry course during their undergraduate studies, have participated in the survey. The curriculum of physical chemistry was divided into 18 units in correspondence with the actual curriculum. All interviewees were asked to evaluate their attitudes to the application of a given resource in the teaching of each unit from the viewpoints of necessity and rationality.

A two-score system was used. If a resource is considered as unnecessary, it takes score 0. If a resource is readily applied and facilitates digestion of chemical knowledge, it makes score 1. Faculties were asked an additional question to select only those resources which have been actually used by an interviewee in his practice.

All individual questionnaires were treated with the use of statistical package SPSS. Blank fields were not taken into account in a stage of data processing. The primary statistical procedures used in this study were descriptive statistics for various samples, Pearson's correlation analysis and Kendall's non-parametric tests for rank variables. The significance level of 0.05 was used in all hypothesis tests.

For each resource, the scores from the completed questionnaires were first averaged over all units to calculate the mean resource scores for each interviewee. The values of either students' or faculty's resource average score (RAS) were then calculated for each considered resource.

The individual responses of faculty members were additionally treated by calculation of Kendall's coefficient of concordance W to assess the agreement level among the participated experts.

Index of Learning Style (ILS) instrument developed by R. Felder and B. Soloman (Felder-Soloman method) [19] was used to find the LSs. The technique allows one to assess preferences on four complementary dimensions: active-reflective (act-ref), visual-verbal (vis-vrb), global-sequential (glo-seq) and sensitive-intuitive (sen-int). ILS categorizes individuals' choices regarding type and mode of information perception, approaches for the information processing and the progress rate towards understanding. The results obtained allow one to determine fractions of respondents which demonstrate preferences to certain LSs for each dimension.

3. RESULTS AND DISCUSSION

The practical value of particular resources was assessed on the base of faculty's responses. The value of Kendall's coefficient of concordance between their responses was calculated to be W=0.84 evidencing a very high level ($p < 0.001$) of unanimity among the experts' opinions. Therefore, the results of survey fairly and objectively represent the current state-of-the-art of implementation of e-resources in chemistry teaching at DNU.

Faculty's RAS was considered as the main indicator of resource relevance. A sample histogram in coordinates "number of resources versus faculties' RAS" plotted on the base of individual surveys exhibits bimodal behaviour with two peaks at RAS=0.22 and RAS=0.55 and a relative border between them at RAS=0.4. Both maxima obey the normal distribution. Similar distributions were observed for other basic chemical disciplines [18]. Bimodal distributions of e-resources allowed the authors to divide all e-resources into a group of universal resources, which are pertinent in the teaching of most topics, and a group of specific means, which are valuable for the learning of some themes but are unnecessary for others. Details of such a division were described elsewhere [18].

Non-zero scores were recorded for 27 resources among 41 e-resources listed in the questionnaires. The analysis of score distributions concerning individual course units allows one to identify 14 resources of universal type and 13 specific resources. The values of RAS for eight universal resources exceed the threshold RAS=0.4 so that all they are essential means for physical chemistry teaching. The rest of universal means with an average RAS~0.2 have a rather low practical value.

In contrast to the optimal kit, only five amid eight universal and eight amid 13 specific resources have been already introduced into the physical chemistry teaching at the Faculty of Chemistry of DNU. For example, the faculty members appreciate the importance of usage of educational software products and dynamic visualisations but in fact, do not use them. In reality, the use of static images, test control programs and data search engines dominate over other e-resources. Insufficient amount of educational software is offset by the extensive use of integrated software environments (Mathcad), the share of which is slightly higher than the optimal level defined by experts.

The map, illustrating relationships between students' and faculty's scores, is shown in Fig. 1. Resources with similar students' and faculty's RASs are located in a vicinity of the diagonal line which is symbolically depicted by a shaded belt. They are evidence of similar attitude to a given resource by both students and faculty, which creates the necessary prerequisites for its effective introduction into the teaching process.

Lack of conformity complicates the process of learning. A part of e-resources is located below the diagonal line and marked by a dashed curve. They have somewhat limited chances to be used because the faculties value them less compared with the students. The faculty members more appreciate resources located above the diagonal line and ringed by another dashed curve. For this reason, they can be used more frequently than others. University teachers of science disciplines typically have personal experience in the use of a limited number of electronic resources. At the same time, they consider themselves as experts in the usage of these resources. For this reason, they tend to use just these habitual and known resources. However, the aids located above the diagonal in Fig. 1 are not popular among students. Such a situation may complicate their perception by the audience and reduce the effectiveness of their use in the teaching process.

The use of e-resources in the process of teaching a university inorganic chemistry course was studied in our previous work [20]. Some conclusions can be drawn on the base of comparison of results for these two disciplines. In general, the numbers of requested resources are close to both subjects: 24 resources were defined for teaching inorganic chemistry and 21 for physical chemistry. However, the qualitative characteristics of these resources are significantly different.

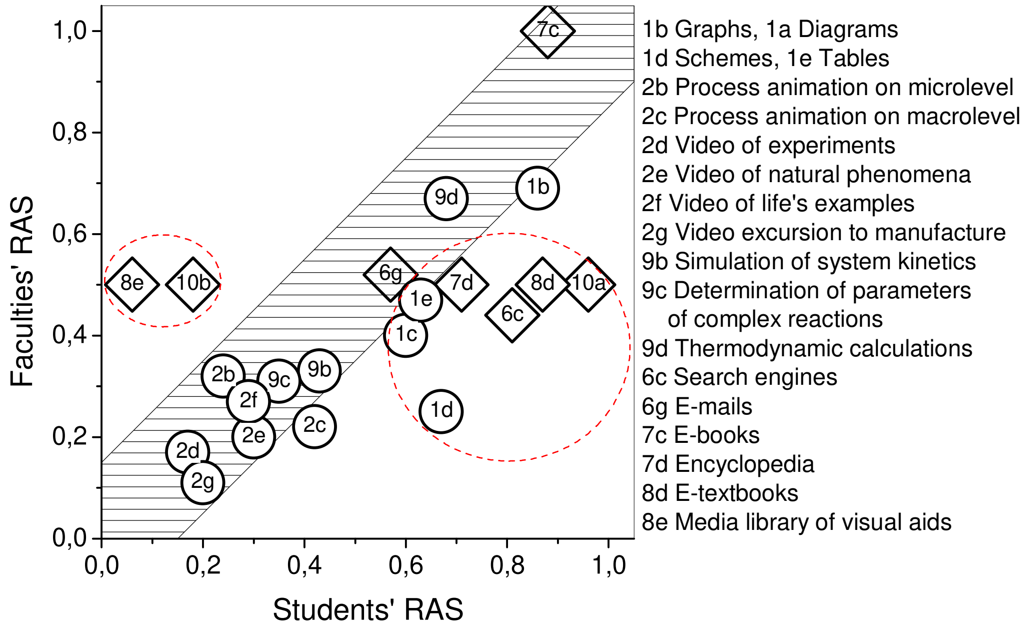

Fig. 1 Relationships between students' and faculty's RASs used in physical chemistry teaching. Universal and specific resources are marked with diamonds and circles respectively

More universal resources and half as many specific resources are nominated for teaching inorganic chemistry (Fig. 2). In contrast, specific resources dominate among those selected for physical chemistry. It should be noted that the course of inorganic chemistry is taught in the first year of study, while physical chemistry is learned in the third year. The content of disciplines taught at senior courses, in general, and physical chemistry, in particular, is devoted to a greater extent to the in-depth study of specific issues, whereas students study mostly more general topics in junior courses. Accordingly, the need for specific resources is increasing with study years, as is seen from Fig. 2.

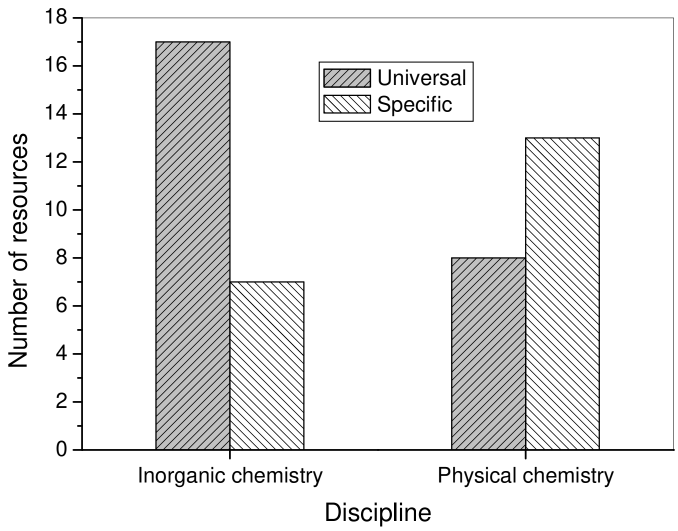

Fig. 2 Number of universal and specific e-resources which are used in teaching inorganic and physical chemistry

Another difference relates to the different structure of e-resources by purpose. If you allocate all resources to 4 groups according to their mission (visualisation, modelling, communication, and control and support means), the distribution of the number of resources by groups is shown in Fig. 3. The amount of e-resources for teaching inorganic and physical chemistry is approximately the same for three groups except for control and support means. For the latter case, the number of resources to learn inorganic chemistry is twice as many as those for physical chemistry.

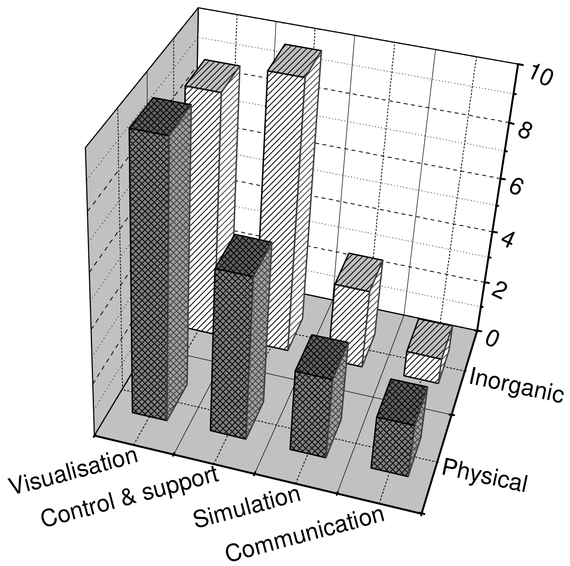

Fig. 3 In-purpose distribution of e-resources used in teaching of inorganic and physical chemistry

One of the possible reasons for the discovered difference in students' and faculty's attitudes to e-resources can be connected with the difference in their learning styles. Learning style is usually considered as typical, cognitive, emotional and psychological behaviour which serves as a stable indicator of the nature of the interaction of a student with the learning environment. More than 70 models are known characterising learning styles [21]. Various models concern various combinations of human activity and characteristics, such as thinking styles, comprehension type, intelligence structure, approaches to learning, decision-making methods, career type, etc. Only some of the available models focus on the educational applications, such as, e.g., identification and control of the potential problems that could appear during learning. In particular, the Index of Learning Style by Felder-Soloman is widely used in the context of engineering education [19]. This model categorises individuals' preferences in the following four dimensions: type (sensitive or intuitive) and mode (visual or verbal) of information perception, approaches to the information processing (active or reflective) and the progress rate towards understanding (sequential or global) [19, 22].

Students of different specialities were found to demonstrate fundamentally different preferences regarding the ILS [23, 24]. Moreover, the learning preferences of students and lecturers can also differ. For example, the learning preferences of the survey participants were averaged over all students and faculties respectively. As is seen from Fig. 4, the faculty members are much more reflective and also they are more inclined to global and intuitive modes compared with more active, sensitive and sequential students. The preferences in the learning styles depend strongly on the speciality. Approximately the same learning styles are observed for students of the same specialities in different universities and different countries [23, 24].

The revealed difference in students' and faculty's attitudes to various e-resources places in the forefront the question of matching teaching and learning styles. As mentioned before, a preferred learning style is a rather stable characteristic. However, it can be corrected under certain conditions [25, 26].

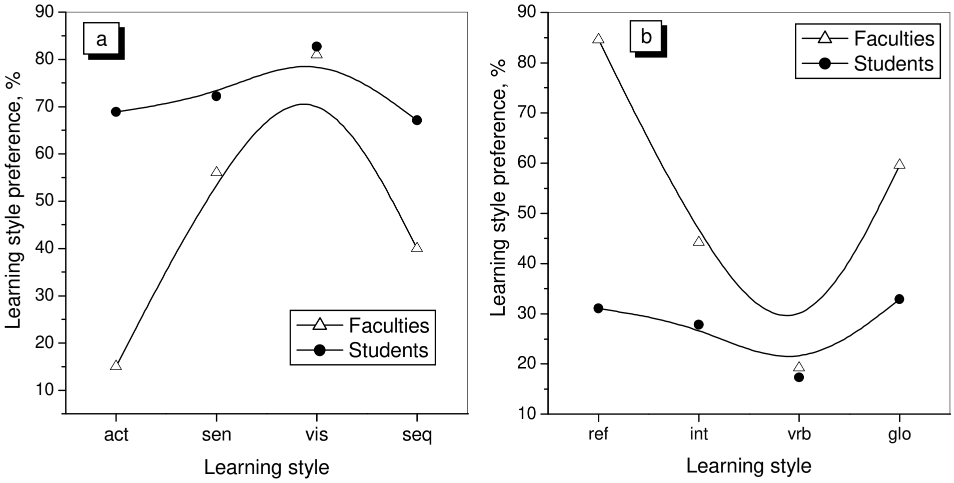

Fig. 4 Learning profiles for students and faculty members by Felder-Soloman ILS: a – act, sen, vis and seq dimensions, b – matching ref, int, vrb, glo dimensions

In our opinion, the optimal teaching style is a balanced one in which all students are sometimes taught in a manner that matches their learning preferences and sometimes in the opposite way. The optimal conditions can be achieved by incorporating a variety of teaching styles that, one the one hand, ensures the highest comfort of students and, on the other hand, allows the teacher to alleviate potential learning style conflicts. Preliminary diagnostics of students' learning styles in the group can provide additional support for the development of the efficient educational environment. For example, knowing that a vast majority of students are visual individuals motivates a teacher to enter visual ways of presenting material that would typically be given abstractly or verbally [27].

4. CONCLUSIONS AND OUTLOOK FOR FURTHER RESEARCH

Both expediency and the-state-of-the-art in the use of 41 electronic learning resources to teach university course of physical chemistry have been studied using an expert survey of Faculty of Chemistry of DNU. The utilisation of 8 universal electronic means, which cover more than 40% of all discipline themes, and 13 specific resources, which are of principal importance to teach a limited number of topics, were found to compose an optimal resource kit. The rest 20 resources have limited influence on the teaching. In contrast to the optimal package, only five universal and eight specific resources have been already introduced into the practice of chemistry teaching in DNU.

An essential difference exists between students and faculty members in their attitudes to individual e-resources. Some resources underestimated by faculty members but highly appreciated by students have limited chances to be implemented into educational practice. Other resources rate high by faculty members but are of a low value among students. Such a situation threatens with loss of effectiveness of the use of such resources in chemistry teaching.

A limited amount of e-resources is well perceived by both students and faculty. Those of the recognised e-resources, which are necessary for application from the viewpoint of faculty members, must be undoubtedly used in the pedagogical process. The following resources, although they do not constitute an exclusive list of compulsory teaching aids, can be recommended for use in the study of physical chemistry: integrated software environments (MathCad) for thermodynamic calculations; visualisation tools, such as graphs, tables and charts; e-books; search engines, and communication means.

One of the reasons for different attitudes towards e-resources is the differences in the learning styles that exist between faculties and students. Faculty's learning styles have distinct preferences towards reflectivity in active-reflective dimension and towards globality regarding global-sequential preference. On the contrary, students of chemical specialities are characterised by pronounced active and sequential learning styles.

The conducted research does not solve all the problems of ensuring the efficient application of ICT to teaching physical chemistry. However, it can assist teachers to optimise the choice of e-resources, taking into account student's learning preferences in a group. The outlook for further scientific research is seen in the development of educational technology for teaching physical chemistry using the means of ICT, as well as the appropriate teaching and methodological support for training of students of chemical specialities.

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ЕФЕКТИВНІСТЬ ЕЛЕКТРОННИХ РЕСУРСІВ У ВИКЛАДАННІ ФІЗИЧНОЇ ХІМІЇ

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Анотація. Впровадження під час навчання хімічним дисциплінам у вищій школі електронних навчальних ресурсів не завжди призводить до покращення показників засвоєння матеріалу студентами. Тому оптимальний вибір ефективних електронних ресурсів для викладання базових хімічних дисциплін є актуальним завданням. Метою роботи було визначення ресурсів, що є релевантними для викладання фізичної хімії з точки зору як викладачів, так і студентів. Для досягнення мети було розроблено спеціальні анкети та проведено опитування учасників педагогічного процесу (студентів та викладачів) з наступною статистичною обробкою результатів опитування. Було досліджено доцільність використання сорока одного електронного ресурсу, та визначено двадцять один ресурс у якості доцільних для викладання університетського курсу фізичної хімії. Серед них вісім ресурсів є важливими для викладання більшості тем курсу дисципліни, і тому віднесено до універсальних ресурсів. Інші тринадцять ресурсів є важливими для викладання певних тем, та малоефективні для інших (специфічні ресурси). У той же час у практиці хімічного факультету Дніпропетровського національного університету імені Олеся Гончара використовується лише п’ять універсальних та вісім специфічних ресурсів. У ряді випадків винайдено невідповідність у відношенні до деяких ресурсів між викладачами та студентами, що створює передумови для втрати ефективності застосування таких ресурсів. Оскільки використання деяких електронних ресурсів є чутливим до стилю навчання, проаналізовано наявні стилі для викладачів та студентів. Основні відмінності полягають у явно виражених перевагах викладачів до рефлективного та глобального стилів, тоді як студентам притаманні переважаючі активний та послідовний стилі. Отримані результати щодо ефективності застосування електронних ресурсів обговорюються з позицій особливостей переважаючих стилів навчання, характерних для студентів та викладачів природничого напряму навчання.

Ключові слова: викладання хімії в університетах; електронні навчальні ресурси; фізична хімія; переважаючі стилі навчання студентів та викладачів; універсальні та специфічні ресурси.

ЭФФЕКТИВНОСТЬ ЭЛЕКТРОННЫХ РЕСУРСОВ В ПРЕПОДАВАНИИ ФИЗИЧЕСКОЙ ХИМИИ

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Аннотация. Внедрение в процесс обучения химическим дисциплинам в высшей школе электронных учебных ресурсов не всегда приводит к улучшению показателей усвоения материала студентами. Поэтому оптимальный выбор эффективных электронных ресурсов для преподавания базовых химических дисциплин является актуальной задачей. Целью работы было определение ресурсов, которые являются релевантными для преподавания физической химии с точки зрения как преподавателей, так и студентов. Для достижения цели были разработаны специальные анкеты и проведен опрос участников педагогического процесса (студентов и преподавателей) с последующей статистической обработкой результатов опроса. Была исследована целесообразность использования сорока одного электронного ресурса, и определен двадцать один ресурс в качестве целесообразных для преподавания университетского курса физической химии. Среди них восемь ресурсов важны для преподавания большинства тем курса дисциплины и поэтому отнесены к универсальным ресурсам. Остальные тринадцать ресурсов являются важными для преподавания некоторых тем и малоэффективны для других (специфические ресурсы). В то же время в практике химического факультета Днепропетровского национального университета имени Олеся Гончара в настоящее время используется только пять универсальных и восемь специфических ресурсов. В ряде случаев обнаружено несоответствие в отношении к некоторым ресурсам между преподавателями и студентами, что создает предпосылки для потери эффективности применения таких ресурсов. Поскольку использование некоторых электронных ресурсов является чувствительным к стилю обучения, проанализированы обнаруженные стили у преподавателей и студентов. Основные отличия заключаются в явно выраженных предпочтениях преподавателей к рефлективному и глобальному стилям обучения, тогда как студентам присущи преимущественные активный и последовательный стили. Полученные результаты относительно эффективности применения электронных ресурсов обсуждаются с позиций особенностей преобладающих стилей обучения, характерных для студентов и преподавателей естественного направления обучения.

Ключевые слова: преподавание химии в университетах; электронные учебные ресурсы; физическая химия; преобладающие стили обучения студентов и преподавателей; универсальные и специфические ресурсы.