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CHEMISTRY TEACHING BY MEANS OF ICT-BASED RESOURCES WITH THE REGARD FOR PREFERRED LEARNING STYLES OF UNIVERSITY STUDENTS

Expediency and effectiveness of the use of various ICT-based learning resources in teaching of basic chemistry disciplines was studied. Preferred learning styles of 46 graduate students were assessed by the Felder-Soloman Index of Learning Styles. More than a half of 45 considered resources were found to be dependent on students' preferred learning style. Certain corrections in the use of style-dependent resources are necessary to improve conformity with students' learning preferences.

Keywords: *ICT-based learning resources; university chemistry teaching; Felder-Soloman preferred learning style*

Introduction

Active incorporation of information communications technology (ICT) into traditional systems of teaching of chemistry disciplines calls for optimization of educational process because the active use of ICT does not automatically increase the efficiency of learning. A large number of domestic and foreign researches were devoted to the problems of implementation and effective usage of ICT. An important contribution to the solution of these problems was made by V.Yu. Bykov, A.F. Verlanj, B.S. Gershunskiy, P.S. Gurevich, M.I. Zhaldak, Yu.O. Zhuk, V.I. Klochko, M.P. Lapchik, A.F. Manako, YU.I. Mashbits, N.V. Morze, S.A. Rakov, Yu.S. Ramskiy, I.V. Robert, O.V. Spivakovskiy, P.V. Stefanenko, S.A. Semerikov, Yu.V. Trius, and many others [1-4]. Various aspects of the application of ICT to learning process and ways for improvement of the effectiveness of learning with the use of novel techniques and modern hardware were discussed. However, the substantiation of expediency and the study of conditions for efficient usage of ICT in educational process are still the topical problems.

Nowadays, the use of electronic 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. However, available learning resources are weakly investigated with relation to coverage of the content of university curricula for basic chemistry disciplines. An adequate, well-balanced and efficient selection of a set of electronic learning resources based on the ICT is an important stage of the optimization of process of chemistry learning. The selected learning resources should match in the best way the content of curricula and simultaneously be easy perceived by students. As used here, the term "an ICT-based learning resource" (or in abbreviated form ICT-LR) includes the following aspects of the concept: a digital form 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.

Preferred learning styles of students are among the most important psychological and pedagogical aspects of optimal selection of a resource set to be used in learning. Students learn in different ways and the approach they prefer may be an important determinant in their academic performance [5, 6]. However, it remains to be seen whether a preferred learning style can influence preferences in resource selection as was supposed in some published works [7, 8]. Educators need to adopt approaches to teaching and assessment that enable students with different learning styles to learn effectively. Optimal selection of ICT-LRs is one of possibilities for the educators to improve their course design, modes of delivery and assessment.

Objectives

The main objective of this research was to determine the real potential for practical use of various ICT-LRs in teaching of university chemistry courses and appreciate the students' attitude to the identified resources. More specifically the data gathered for this paper were used to address the following questions:

- What ICT-LRs are the most relevant in chemistry teaching from the viewpoints of both students and faculty members?
- Is there any correlation between students' attitude to ICT-LRs and their preferred learning styles?

Methods

All experiments were performed at the Faculty of Chemistry of Dnipropetrovsk National University (DNU) in Ukraine. Frequency and expediency of the use of a number of electronic resources in teaching of basic chemistry disciplines, namely inorganic, organic, physical and analytical chemistry, was studied. A total of 46 graduate students and 12 faculty members participated in the study. All these students have already taken the aforementioned basic courses during their undergraduate studies. All participated faculties are involved in chemistry teaching. The experiment consisted of two main parts. The first one focused on the evaluation of attitude of both students and teachers to individual ICT-based resources used for chemistry teaching. The second part was devoted to the testing of preferred learning styles of all project participants.

Preliminary studies allowed the author to identify 45 individual resources which either can be used or are already used in chemistry teaching at the Faculty of Chemistry of DNU. Special questionnaires, which include all tentatively identified resources, have been developed to cover the contents of four basic disciplines. Each course has been divided into 15 to 25 units in correspondence with the actual curricula. All interviewees were asked to evaluate their attitudes to the application of a given resource in teaching of each unit from the viewpoints of necessity and rationality. The score system and related criteria used are shown in Table 1. Lack of response was considered as either impossibility or unwillingness of a respondent to define his/her attitude to a given resource. Blank fields were not taken into account in a stage of data processing.

Table 1.

Score system used in the questionnaires

Score	Criteria
0	The use of this resource is either unnecessary or it does not improve the learning process
1	I like this resource because its application can facilitate digestion of chemical knowledge. However, it has no essential advantages over other resources of similar function
2	This resource is highly recommended and readily used because its application provides additional benefits compared with other resources of similar function

There was a certain difference between students' and faculties' questionnaires. The main goal of students' survey was to investigate personal attitudes to all individual resources. Each student got four questionnaires aimed at the evaluation of expediency of resource usage for all chemistry disciplines under studying. Since each faculty member was involved in teaching of a particular chemistry discipline, he/she received only one questionnaire related to a discipline of his/her competence. As a result, the number of faculties' responses was less than the total number of survey participants. For example, only 5 of 12 faculties taught inorganic chemistry, so that only 5 questionnaires were completed to evaluate faculties' attitude to resources meant for inorganic chemistry.

The faculties were asked two questions. The first one was similar to that in students' questionnaires. The second question was to mark only those resources which are actually used by an interviewee. The individual results of faculty members were statistically treated to assess the agreement level among the participated experts. The treated figures of faculties' questionnaires

were valuable and considered as an expert opinion. They allowed the author to fix the current situation with application of particular ICT-based resources in chemistry teaching, select most relevant resources for further analysis and evaluate their necessity in practical work.

For each resource, the scores from the completed questionnaires were first averaged over all units to calculate the mean scores for each participant in the context of each discipline. Various samplings of respondents, e.g. a sampling of all students with a particular proffered learning style, were made to compare the survey results with characteristics of learning styles. Then the values of students' or faculties' resource average scores denoted hereinafter as RASs were calculated for interesting samples on the base of averaging of individual data in a sample.

The Index of Learning Styles (ILS) was created in 1991 by Felder and Soloman [9] as a self-scoring questionnaire for assessing preferences on four complementary dimensions (Table 2). This model categorizes individuals' preferences in terms of type and mode of information perception, approaches for the information processing and the progress rate towards understanding. A few studies listed at the dedicated Web-site [9], examining the independence, reliability, and construct validity of the four instrument scales, concluded that the ILS meets standard acceptability criteria for instruments of its type.

Table 2.

Dimensions of Felder-Soloman model

Dimension	Types (abbrev.)	Description
Perception	Sensitive (sen)	Concrete thinkers, oriented towards facts and procedures
	Intuitive (int)	Abstract thinkers, oriented towards theories and meanings
Input	Visual (vis)	Prefer visual representations of presented materials
	Verbal (vrb)	Prefer written and spoken explanations
Processing	Active (act)	Learn by trying things out, enjoy working in groups
	Reflective (ref)	Learn by thinking things through, prefer working alone
Understanding	Sequential (seq)	Linear thinking process, learn in small incremental steps
	Global (glo)	Holistic thinking process, learn in large leaps

The ILS instrument is conveniently available on the Internet [9]. The index contains 44 questions, 11 each for four dimensions of learning. The questions are coupled with two responses in which the respondents chose one answer which best fits their preferred learning mode. The total of the "a" and "b" responses for each question associated with a given dimension are combined to give a total score for each dimension. Therefore, the intensity of a dimension can vary from 1 to 11.

The primary statistical procedures used in this study were descriptive statistics for various samples, correlation analysis with standard Pearson correlations, and non-parametric tests to calculate Kendall's coefficient of concordance W for rank variables. All statistics were calculated with the use of statistical package SPSS. The significance level of 0.05 was used in all hypothesis tests with appropriate p-values reported, if necessary.

Results and Discussion

Correlations between ICT-based resources and preferred learning styles

All separate electronic resources were combined into 13 conventional groups in accordance with their function (Table 3). Pearson's correlation coefficients for RAS – ILS pairs were calculated for all learning style dimensions to find any correlation between students' attitude to individual resources and preferred learning styles.

Table 3.

Classification of ICT-based learning resources by function

Groups of ICT-based resources (number of resources in a group)	Resource function	Influencing learning styles showing positive correlations
Static images (5)	Data visualisation	Ref, glo, int
Dynamic images (7)	Data visualisation	Vis – for 4 of 7 res.
Audio recording (1)	Audio accompaniment	No influence
"Virtual" chemical laboratories (3)	Simulation of experiments and imitation of chemical phenomena	Vis
Integrated programming environment (5)	Computer simulation, planning and optimization of experiments	No influence
Software for quantum chemical simulation (3)	Computer simulation	Ref, int
Laboratory complexes with gage sensors (1)	Experiments with computer-aided data processing	Ref
Internet and communication (8)	Communications and collaboration	Ref, int – for 2 of 8 res.
Object retrieval systems (1)	Data search	Ref
Educational databases (1)	Data search	No influence
Learning materials (5)	Methodical support	Ref – for 3 of 5 res.
Learning software (3)	Methodical support	Vis – for 2 of 3 res.
Software for knowledge control (2)	Knowledge control	No influence
TOTAL: 45 resources		

As follows from the results obtained, some resources are equally perceived by students with different learning styles. In other words, the results of application of such resources are not influenced by preferred learning styles. This can be considered as an essential advantage because incorporation of such resources in a chemistry teaching process requires no special precautions regarding the audience. The use of other resources is influenced by students' learning styles. A level of preferences to such resources either increases or decreases with an increase of the ILS for a certain style dimension. In other words, either positive or negative significant correlations at $p<0.05$ exist between the preferred learning styles and propensity for particular resources.

A total of 20 resources were found to be independent on the students' learning styles while the rest 25 resources exhibit a pronounced dependence (Table 3).

Dependent and independent on learning style resources

Figure 1 illustrates the revealed correlations between average students' ILS and RASs for some style-dependent resources. The average scores of the ILS for the studied sample of respondents are shown as an octagon outlined by solid straight lines and shaded inside. For clarity, the dotted line illustrates the regular octagon at the ILS=5.5 formed by the equilibrium lines in an 11-point scale. If an average ILS for a particular learning style is located outside the equilibrium octagon, therefore the given style dominates over corresponding anti-style in the considered student group. As follows from the positions of the dotted and solid segments, the act, sen, vis and seq learning styles dominate over complementary ref, int, vrb and glo styles respectively. This result is in good agreement with the data from other studies and is typical for natural science students [10].

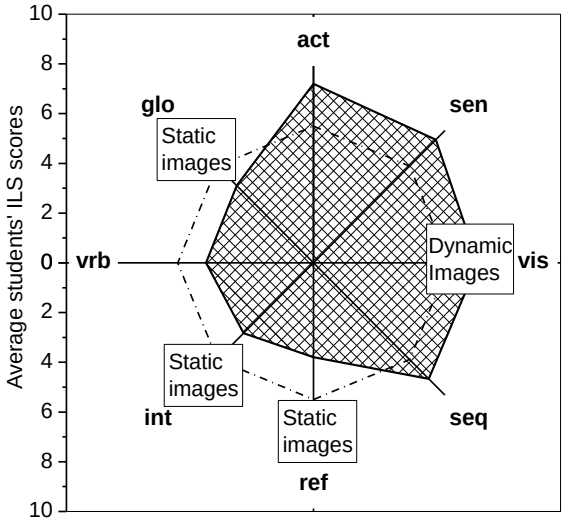

Fig. 1. Average students' ILS scores are depicted as a shaded octagon. A dotted regular octagon illustrates the equilibrium points for each of four bipolar dimensions of learning styles. The data are averaged over four basic chemistry disciplines.

Two groups of style-dependent resources, namely static and dynamic images used for data visualization, are illustrated in Fig. 1 as labels located on the axes of those dimensions which demonstrate significant positive correlations with the above-mentioned two resource groups. Negative correlations with complementary to the marked axes dimensions are not shown to simplify the graph. Pearson's correlation coefficients are shown in Table 4 to demonstrate the available correlations between the selected RAS – ILS pairs.

Table 4.

Pearson's coefficients to describe available correlations between the indexes of individual learning styles and resource average scores for two resource groups

Resource group	Individual resource	act	sen	vis	seq
Static image	Picture	-0,406*	-0,489*	0,014	-0,116
	Graph	-0,627**	-0,428*	-0,3	-0,359
	Diagram	-0,461*	-0,471*	-0,221	-0,461*
	Table	-0,113	-0,556**	-0,06	-0,441*
	Scheme	-0,428*	-0,38	-0,08	-0,493*
Dynamic image	3D models	-0,316	-0,239	0,067	-0,365
	Micro animation	-0,415*	-0,101	0,467*	-0,198
	Macro animation	-0,480*	-0,139	0,478*	-0,048
	Video of experiments	-0,221	-0,09	0,042	-0,032
	Video of processes	-0,11	-0,198	0,124	-0,423*
	Video of real world	-0,07	-0,135	0,417*	-0,327
	Video of industry	-0,026	-0,022	0,571**	-0,087

* $p<0.05$, ** $p<0.001$

As follows from the available positive correlation shown in Fig. 1, respondents with preferred global style like to select static images. On the contrary, students with dominating sequential style do not usually select this resource, as follows from the available negative correlation. Nevertheless, in the context of static images both preferred sequential and global modes can be considered as influencing styles. A majority of students are characterized by dominating sequential style compared with global one because the ILS of sequential style is higher than the

equilibrium value 5.5. Therefore, admirers of static images are in minority compared with the number of respondents who do not accept positively the given resource.

An act-ref dimension was found to demonstrate the highest number of correlations with electronic resources among all learning styles. Students with dominating active style exhibit the highest number of cautions with respect to some ICT-LRs because all correlations with resources are negative for active students. In contrast to active-reflective students, a seq-glo dimension exhibits the lowest number of correlations with individual resources.

The values of RAS assessed by the survey can be considered as an indicator of popularity for a given resource. There are two parameters, describing the popularity of a resource and also imposing certain limitations on its practical application. They are the value of RAS and the number of influencing learning styles. The higher the RAS is, the more valuable the resource. An increase of the number of influencing learning styles imposes more limitations on the application of a given resource to teaching.

Available figures for resources with different numbers of influencing styles are mapped in Fig. 2 in coordinates "students' RAS versus influencing style number".

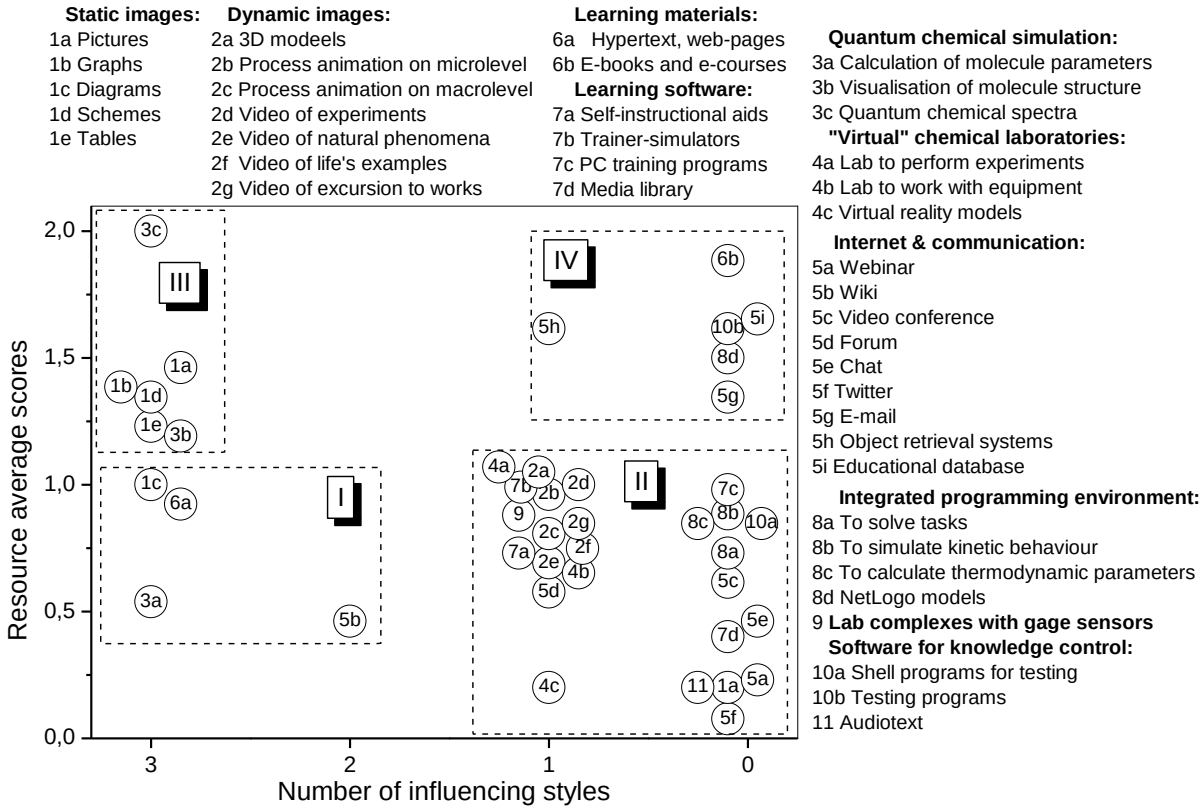

Fig. 2. Resource average scores by students' questionnaires plotted as a function of the number of influencing learning styles. The data are averaged over four basic chemistry disciplines.

The results for individual resources seem to be decomposed into 4 clusters. Cluster I, located in a lower left corner of the plot, combines resources with RAS≤1 and with 2 or 3 influencing learning styles. Evidently, these are high-risk resources. On the one hand, students frostily perceive them as follows from their low RAS values. On the other hand, their use is complicated by the presence of a few restrictive correlations with some learning styles.

Cluster II is the most numerous. It also includes resources with rather low RASs but they either style-independent or have only one influencing learning style. Therefore, optimization of the use of such resources may be somewhat easier than in the previous case.

Cluster III contains resources with RAS>1 that evidences their wide popularity. However, their use is complicated by the presence of a pronounced dependence on three learning styles.

Only six resources assigned to cluster IV. All they are characterized by a high RAS and correlate with one learning style at the worst. One may suggest that the use of these resources may be the least problematic among all others.

From the practical viewpoint, the correlations revealed can be used to correct teaching process. Such a correction would focus on the optimal selection of teaching resources to minimize contradictions with preferred learning styles typical for a given student group.

Possible algorithms for optimal resource selection

The experts have defined a set of resources necessary for inorganic chemistry teaching. Agreement among experts was estimated by calculation of Kendall's *W*. The value $W=0.837$ was obtained that evidences a very high level ($p<0.001$) of unanimity among the experts' opinions. This allows one to conclude that the results of expert survey fairly and objectively represent the current state-of-the-art of implementation of electronic resources in inorganic chemistry teaching.

Let us consider possible algorithms for the optimal selection of an electron resource set by the example of the theme "Chemical Reaction Rate" within the module "Basic Mechanisms of Chemical Reactions". A total of 16 resources were identified to be necessary for optimal teaching of this theme. Samplings of students on the base of learning style preferences were made to calculate the mean values of RAS for each sample in the context of all four Felder-Soloman style dimensions. The results for one selected theme "Virtual" chemical laboratories to perform laboratory works" are shown in Table 5.

Table 5.

Determination of the mean RAS effective for samples with different preferred styles by the example of ICT-LR "Virtual" chemical laboratories to perform laboratory works"

Learning styles	act	ref	sen	int	vis	vrb	seq	glo
Calculated RAS for a given preferred style	1.0	0.7	1.0	1.0	1.2	1.0	1.0	1.0
Actual profile of students' group	act + sen + vis + seq							
Effective mean RAS for a given student group	$(1+1+1.2+1)/4 = 1.05 \geq 1$							

As is seen from Fig. 1, the given students' group is characterised by the preferred act, sen, vis and seq learning styles. Therefore, the effective value of RAS, which characterizes the preferences of the group as a whole, can be calculated as the arithmetic mean of four preferred styles (Table 5). The calculated effective mean $RAS=1.05\geq1$ that evidences positive attitude of a majority of the students to a given resource to be used for the teaching of chemical reaction rates in inorganic chemistry. Thus, the considered resource can be recommended for the usage but the ultimate learning goal and the main resource-aided advantages should be explained for the audience.

As is seen in Fig. 3, only 9 ICT-LRs among 16 resources selected for the teaching of chemical reaction rates have $RAS\geq1$ by the students' questionnaires or, in other words, are desirable for the student audience. A few possible ways to organize effective learning in a group with the use of selected ICT-LRs are discussed in the literature. The most promising variants are listed in Table 6.

A majority of researches supposes that the teaching style with ICT-LRs may mismatch with students' preferences. Moderate mismatching can help students to overcome weaknesses in their learning styles and develop a more integrated approach to their learning. However, the discomfort level should not be too large because a serious lack of matching between preferred learning styles and teaching methods could result in lower motivation and poorer performance.

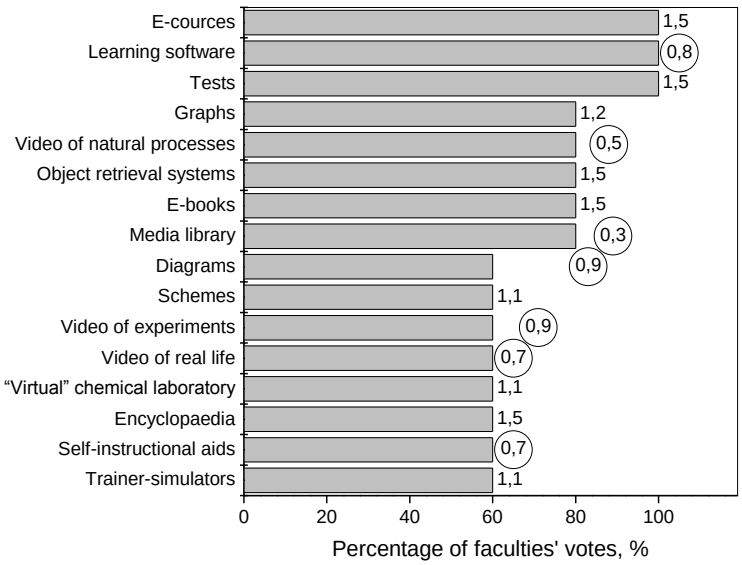

Fig. 3. Ranking of resources to teach the theme “Chemical Reaction Rate” by faculties’ questionnaires. The values of effective mean RAS by students’ questionnaires are separately shown for RAS≥1and RAS<1 (circled).

The development of new techniques for effective application of ICT-based electronic resources to teach students with different learning styles is a very important field of research to improve the quality of university chemical education.

Table 6.

Prospective ways to optimize the use of ICT-based electronic resources in chemistry learning

Variants	Implementation ways	Drawbacks
Bringing of all elements of the learning process to conformity with students’ preferences	Grouping of students with similar styles and using of most suitable ICT-LRs and teaching techniques	Difficulties in realization due to teacher/student regulated ratio, lack of suitable ICT-LRs, etc. No conditions for the development of ill-defined students’ styles
Development of learning environment which provides opportunities for all students to select a learning line showing the best correlation with particular preferences	Work with adaptive ICT-LRs	No conditions for the development of ill-defined students’ styles. Development of special software is necessary; no domestic ICT-LRs are available.
3. Identification of an effective, unified style for a group and optimal selection of ICT-LRs on this basis	The use of a package of different ICT-LRs matching the identified group style	Moderate discomfort for some students but it should not throw obstacles in effective learning

Conclusions

Influence of individual learning styles on the preference in use of ICT-based resources in chemistry teaching was studied. A total of 45 resources were analyzed and a majority of them (25 of 45) were found to be dependent on learning styles.

Active versus reflective style, on the one hand, and global versus sequential style, on the other hand, are the most and the least influential learning style dimensions, respectively.

Preferred active, sensitive and sequential learning styles, which are the most typical for science students, show negative correlations with some resources. Therefore, certain corrections in use of these resources are necessary to improve conformity with students' learning preferences.

Visual learning style exhibits positive correlations with some electronic resources, such as e.g. dynamic images, virtual laboratories etc, that simplifies their use in chemistry teaching for students with preferred visual style.

The development of techniques of teaching and teacher's guides to teach the basic chemistry disciplines with the use of electronic resources of various types to students with different learning styles is the promising direction for further research.

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ВИКЛАДАННЯ ХІМІЇ ІЗ ЗАСТОСУВАННЯМ ЕЛЕКТРОННИХ ОСВІТНІХ РЕСУРСІВ З УРАХУВАННЯМ СТИЛІВ НАВЧАННЯ СТУДЕНТІВ УНІВЕРСИТЕТУ

Проаналізовано ставлення викладачів та студентів до використання електронних освітніх ресурсів під час вивчення хімічних дисциплін. Стилі навчання респондентів визначено за методом Р. Фелдера та Б. Соломан. Сприйняття окремих ресурсів оцінено за результатами анкетування студентів 5-го курсу хімічного факультету. Для вибору більше половини з проаналізованих 45 видів ресурсів встановлено існування сильних кореляційних зв'язків з певними стилями навчання студентів. Отримані дані можна використовувати для вдосконалення методик навчання.

Ключові слова: електронні освітні ресурси; викладання хімії в класичному університеті; стилі навчання за методом Р. Фелдера та Б. Соломан

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ПРЕПОДАВАНИЕ ХИМИИ С ИСПОЛЬЗОВАНИЕМ ЭЛЕКТРОННЫХ ОБРАЗОВАТЕЛЬНЫХ РЕСУРСОВ С УЧЕТОМ СТИЛЯ ОБУЧЕНИЯ СТУДЕНТОВ УНИВЕРСИТЕТА

Проанализировано отношение преподавателей и студентов к использованию электронных образовательных ресурсов в изучении химических дисциплин. Стили обучения респондентов определены по методу Р. Фелдер и Б. Соломан. Восприятие отдельных ресурсов оценено по результатам анкетирования студентов 5-го курса химического факультета. Для выбора больше половины из проанализированных 45 видов ресурсов установлено существование сильных корреляционных связей с определенными стилями обучения студентов. Полученные данные можно использовать для совершенствования методик обучения.

Ключевые слова: электронные образовательные ресурсы; преподавание химии в классическом университете; стили обучения по методу Р. Фелдер и Б. Соломан