UDC: 378.016:[54+004] +159.9

Tetiana Derkach,
Doctor of Pedagogy, associate professor,
Department of Industrial Pharmacy,
Kyiv National University of Technologies and Design,
2, Nemirovicha-Danchenko Str., Kyiv, Ukraine

ELECTRONIC RESOURCES IN TEACHING BASIC CHEMICAL DISCIPLINES AT UNIVERSITIES

The article goal is to examine the actual state of the use of electronic resources in teaching chemical disciplines, as well as to justify common approaches to the expedient choice of means of information and communication technology for learning. To achieve this goal, the following methods were used: questionnaire, survey of experts to determine the real state of the use of electronic resources in teaching chemical sciences; classification of available electronic resources to rank their expedience; computer testing to determine personal characteristics of the educational process participants and statistical methods using SPSS software package to interpret the experimental data obtained. The statistical analysis included a comparison of samples, data validation, dispersion tests for statistical significance difference (ANOVA package), and correlation analysis for metric (Pearson's statistics) and rank (W Kendall's statistics) variables. The actual state of the use of e- resources in teaching chemical disciplines was studied. Various parameters, such as functionality, demand for the use of a given resource in accordance with expert's opinion and correlations with students' preferred learning styles, were used for the classification of e-resources and for the identification of several groups for further analysis. A significant discrepancy between the necessary provision of learning process with e-resources and the real state of the problem was established on the base of experts' opinions. Two important aspects of the contradictions were revealed, namely the teachers recognize the need of usage of different types of e-resources but do not use some of them in their practice. The appraisal of expediency of the use of certain e-resources is significantly different from the viewpoint of students and faculty. This creates prerequisites for reducing the effectiveness of the use of e-resources.

Keywords: higher education, basic chemical disciplines, learning style, information and communication technology, electronic resources.

Introduction

Nowadays the educational community faces the ambitious goal to ensure the high quality of higher education. The implementation of information and communication technologies (ICTs) into all areas of educational activities is still of the key priority. Despite the undoubted advantages of ICT, such as facilitation of understanding and learning, visualization of information, automation of computing processes and creating the conditions for students' independent work, the issue of the efficiency of learning chemical disciplines with the use of ICT still remains understudied. 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 effective use in teaching Chemistry.

The pace of technological expansion passes ahead of processes of psycho-pedagogical understanding of the consequences of ICT implementation. Reorganisation of traditional teaching forms based on ICT faces the problem of teachers' unpreparedness and lack of skills. Therefore, the opportunity for improving the efficiency of ICT-based teaching process is not entirely realised yet.

Researchers pay a lot of attention to the issue of improving the quality of education in the field of chemistry. The role of informatisation of the educational process was discussed by many researchers in their scientific papers [1-5]. The organisation of ICT-based learning was intended to create the necessary prerequisites for strengthening the fundamental component in teaching Chemistry and providing professional orientation of content of chemical disciplines. Various opportunities to improve students' understanding of chemical materials through the use of ICT were considered in the studies of both domestic and foreign scientists [6-14].

However, many studies deal with contradictory aspects of the effective application of dynamic visualisations, interactivity dual effect, etc. For example, the contradiction between advanced opportunities to comprehend complex chemical concepts with the use of computer modelling and impossibility of using these resources in the course of learning chemistry were revealed [15].Therefore, the issue of effective application of ICT to training in chemical disciplines still remains unresolved.

The aim of the article is to clarify the current state and potential expediency of the use of electronic resources (e-resources) in teaching basic chemical disciplines as well as to develop a general approach to the optimal selection of ICT means for teaching Chemistry at universities.

To achieve the aims of the paper, the following methods were used: questionnaire surveys; expert survey to determine the real state of application of the e-resources for teaching chemical disciplines to students; classification for ranking the available e-resources; computer testing to determine personal characteristics of the educational process participants; and statistical methods with the use of SPSS software package to interpret the experimental data obtained. The statistical analysis included samples comparison, data validation, dispersion tests for statistical difference significance (ANOVA package), and correlation analysis for metric (Pearson's statistic) and rank (Kendall's W statistic) variables.

The work was performed at Oles Honchar Dnipropetrovsk National University (DNU). E-resources which seemed to be expedient for learning basic chemical disciplines, such as inorganic, analytical, physical, and organic chemistry, were defined on the basis of the interrogation of teachers and students. The expedient e-resources were compared with those ones which had been really used during previous years of learning each discipline. The results obtained have made it possible to determine the state of the progress in application of e-resources in teaching Chemistry. The comparison of expedient resources with the ones used before made it possible to select the most relevant e-resources for the further analysis of their necessity and effectiveness in the educational process.

In total, 46 fifth year and MA course students of the Faculty of Chemistry of DNU were involved in the survey. Simultaneously, 18 teachers, professors or associate professors of the Faculty of Chemistry, were questioned. All they have at-least 5-year teaching experience of the above-mentioned basic chemical disciplines.

The attitude of teachers and students towards different e-resources was assessed on the basis of the survey results. The survey involved answering two questions, namely to define the e-resources expedient for application in learning and to assess the state of the progress achieved after the real use of e-resources in teaching. The content of each basic discipline was divided into 15-18 educational units in accordance with its curriculum.

Both students and teachers were asked to rate their attitude towards the necessity and rationality of using a particular resource in teaching/learning each educational unit. The respondents had the opportunity to assess their preferences using two-point (0 or 1 point) system. The null result shows that the respondent does not consider the resource as a necessary means in learning of a given unit. One point shows that the resource is considered as the expedient one for the studying of a given unit. The questionnaires without any answers were not included into the processing of the survey results.

In addition to rating e-resource expediency, the teachers were asked to assess the current progress in resource use on the basis of their personal academic experience. The questionnaires of teaching staff were statistically processed with the use of Kendall's W test in order to determine the degree of consistency of experts' opinions. The values of concordance coefficients (W) were calculated with the use of the statistical package SPSS [16]. The calculated value $W = 0.837$ at significance level of $p < 0.001$ proves the presence of the very strong consistency between the responses of the surveyed. It makes it possible to consider the results of the survey to be objective evidence.

When processing the filled in questionnaires, the scores given to a resource by respondents were firstly averaged for each educational unit. Then the unit's average scores were repeatedly averaged for the discipline as a whole to calculate the grade point average for the given resource in relation to the given discipline. Students' expedience ratings and teachers' estimations for expedience and real use were processed separately. Therefore, the following grade point averages were calculated and used for the further analysis: Students' Average Score of Expediency (SASE), Teachers' Average Score of Expediency (TASE), and Teachers' Average Score of Usage (TASU).

In addition, the students were tested by Felder-Soloman's Index of Learning Styles Questionnaire [17; 18] to identify the preferred learning styles. The comparison of the results of Felder-Soloman's tests and resource's grade point averages has made it possible to divide all educational e-resources into two groups which are appropriate or inappropriate to preferred learning styles respectively. Available correlations between the revealed preferences in the learning styles and in e-resources are used for the resource selection optimisation for teaching Inorganic, Analytical, Physical, and Organic Chemistry.

The list of e-resources under consideration divided into 11 groups by similarity is shown in Table 1. In addition, the numbers of the students' preferred learning styles which demonstrate clear correlations with students' attitude to given resources are also shown in Table 1.

All characteristics of the studied e-resources were estimated separately for each discipline. The use of the common approach, which is described in detail for inorganic chemistry, allowed us to compare data obtained for different disciplines.

Discussion

Application of e-resources to teaching Inorganic Chemistry. In the questionnaire, the course of Inorganic Chemistry was divided into 16 topics compiled in accordance with the existing curriculum. Totally 41 e-resources, which can be used in classrooms, were identified in the course of preliminary analysis. The values of TASE were used as the key indicators of resource demand. These values reflected the relative numbers of subjects during the course in which a resource was considered to be expedient for teaching.

Table 1.

List of e-resources divided into groups with indication of the numbers of students' influencing learning styles

No	E-resource	No. of styles (*)
	Static resources	
1a	Pictures & photographs	3
1b	Graphs	3
1c	Diagrams	3
1d	Circuitry	3
1e	Tables	3
	Animation	
2a	3D models	1
2b	Process animation on microlevel	1
2c	Process animation on macrolevel	1
	Video	
2d	Video of experiment	1
2e	Video of natural process	1
2g	Video of real-world example	1
2h	Video excursion to works	1
	Audio	
11	Audio recording of text	0
	Quantum chemistry	
3a	Calculation of molecule parameters and energies	3
3b	Molecule structure visualisation	3
3c	Study of reaction mechanism	n/a
3d	Study of NMR, IR & UV spectra of compounds	3
	Virtual laboratory	
4a	Virtual lab to perform practical work	1
4b	Virtual lab to work with equipment	1
4c	Virtual reality models	1
	Data processing	
5a	Laboratory system with gage sensors	1
5b	Software-based statistical data manipulations	n/a
5c	Webinar	0
5d	Podcast	n/a
	Internet & communication	
6a	Wiki	2
6d	Video/audio conference	0
6b	Forum	1
6e	Chat	0
6g	Twitter	0
6h	E-mail	0
6c	Search engine	1
6f	Educational databases	0
	Information assistance	
7b	Digital journals	n/a
7c	E-books	n/a
7d	Encyclopaedia	n/a
7a	Hypertext, webpage	3
	Instructional materials	
8c	Instructional software	0
8d	E-textbook	0
8a	Manual for self-tuition	1
8b	Simulator (exercises, games, etc.)	1
8e	Media library of visual aids	0
	Educational software	
9a	Realisation of chemical problems	0
9b	Simulation of kinetic behaviour of system	n/a
9c	Determination of parameters of complex reactions	n/a
9d	Thermodynamic calculations	0
9f	Mathematical simulation of experiment	0
9h	Table processor	0
	Supervisory control system	
10a	Ready-to-use test for various topics	0
10b	Test shells	0

* n/a –not available

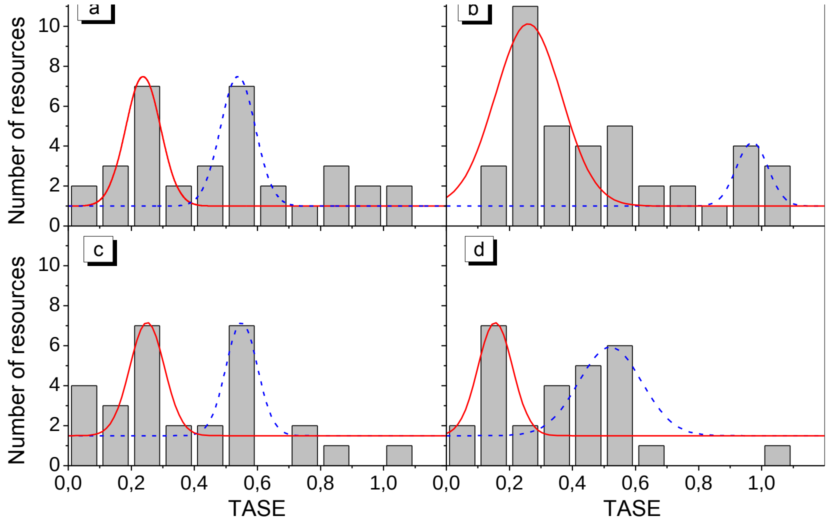

Fig. 1 Number of e-resources used in teaching Inorganic (a), Analytical (b), Physical (c), and Organic (d) Chemistry as a function of teachers' average scores of expedience (TASE)

Figure 1 shows a histogram illustrating the number of resources as a function of TASE. All curves demonstrate clear bimodal distributions. Each of the two modes can be approximated by the Gaussian curves of normal distribution. Thus, all the e-resources can be conditionally divided into two groups corresponding to the resources with high and low TASE. For example, the mean scores for these groups are 0.54 and 0.24 for Inorganic Chemistry. The border between these peaks is located near TASE = 0.4.

The first group includes the most popular resources used in the teaching of more than 50% of all subjects. Such resources can be called universal (Un). The rating of these popular resources in accordance with their TASE is given for Inorganic Chemistry in Fig. 2a.

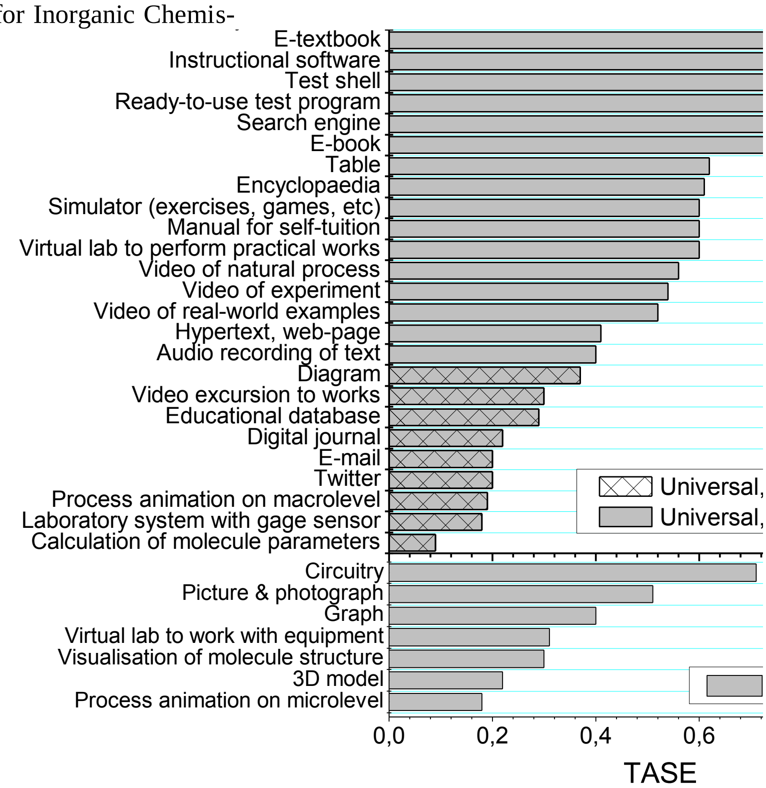

Fig. 2 Ranks of universal (a) and specific (b) e-resources use in teaching Inorganic Chemistry on the basis of teachers' average scores of expedience (TASE)

The second group consists of the resources with lower ratings. A more detailed analysis shows that they can also be divided into two subgroups. A number of the resources were given rather low experts' scores for all units of the discipline, which results in a low TASE. They can be considered as universal resources by their nature but all they are of low priority. They are represented at the bottom of the Fig. 2a. The use of these resources is not critical for teaching a given discipline. Therefore, they may not be considered when determining the optimum set of e-resources.

The rest of resources (Fig. 2b) also have a rather low TASE but they demonstrate different performance in individual educational units. For a number of topics, such resources gain low scores in accordance with experts' estimations. For other topics, they demonstrate a high priority. They can be considered as specific (Sp) resources which are of high importance in teaching some specific topics. Obviously, the importance of specific resources increases in going from teaching basic disciplines to teaching special courses.

Comparison of SASE, TASE and TASU for individual universal resources with TASE > 0.4 and all specific resources are shown in Table 2. The higher the differences between TASE and TASU are, the more problems in teaching are expected.

Table 2.

Grade point averages(SASE, TASE and TASU) for high-scored (TASE > 0.4) universal (Un) and all specific (Sp) e-resources in learning Inorganic Chemistry

No	E-resource	Type	SASE	TASE	TASU
11	Audio recording of text	Un	0.12	0.40	0.00
10a	Ready-to-use test	Un	0.94	1.00	0.62
10b	Test shell	Un	0.29	1.00	0.62
8c	Instructional software	Un	0.24	1.00	0.62
8d	E-textbook	Un	0.88	1.00	0.62
8e	Media library of visual aids	Un	0.06	1.00	0.62
7c	E-book	Un	0.89	0.80	0.61
7d	Encyclopaedia	Un	0.88	0.61	0.22
2a	3D model	Sp	0.45	0.22	0.06
2b	Process animation on macrolevel	Sp	0.49	0.18	0.01
2d	Video of experiment	Un	0.19	0.54	0.14
2e	Video of natural process	Un	0.26	0.56	0.02
2g	Video of real-world example	Un	0.28	0.52	0.00
4a	Virtual lab to perform practical work	Un	0.41	0.60	0.02
4b	Virtual lab to work with equipment	Sp	0.16	0.31	0.02
6c	Search engines	Un	0.83	0.80	0.03
8a	Manual for self-tuition	Un	0.24	0.60	0.02
8b	Simulator (exercises, games, etc.)	Un	0.24	0.60	0.02
1a	Picture & photograph	Sp	0.75	0.51	0.42
1b	Graph	Sp	0.47	0.40	0.23
1d	Circuitry	Sp	0.65	0.71	0.60
1e	Tables	Un	0.37	0.62	0.51
3b	Molecule structure visualisation	Sp	0.55	0.30	0.02
7a	Hypertext, webpage	Un	0.18	0.41	0.22

Comparative study of e-resources in teaching basic chemical disciplines. Similar to Fig. 2, ranks for universal and specific resources were built for all other disciplines. This makes it possible to determine the optimal structure of e-resources for teaching each of the basic chemical disciplines. E-resources of similar functionality were combined into 11 resource groups to simplify their analysis (Table 1). The structures of expedient resources and the ones really used in teaching are shown in Fig. 3a and Fig. 3b respectively.

According to the Fig. 3a', 5 of 11 available groups cover more than 98% of the total number of e-resources really used in teaching Inorganic Chemistry. A similar situation is observed in teaching Physical (Fig. 3c') and

Organic Chemistry (Fig. 3d'). Under conditions of expedient (optimal) resource use, the top five groups cover 79% in teaching Inorganic Chemistry (Fig. 3a), 82% in Physical Chemistry (Fig. 3c) and only 77% in Organic Chemistry (Fig. 3d).

In case of both real and expedient resource use, the total share of visualisations in the course of Inorganic Chemistry remains virtually unchanged (31-36%). However, the ratio of dynamic and static visualisations dramatically changes in favour of dynamic visualisations in case of optimal resource use (Fig. 3a).

The similar situation is typical for static and dynamic visualisations in teaching Physical Chemistry (compare Fig 3c' and Fig. 3c). The real use of the internet and communications, and static visualisations seems to be redundant in Physical Chemistry while dynamic visualisations and educational software are underestimated.

The use of the educational software together with supervisory test programs amounts to 30-34% in inorganic chemistry. In practice (Fig. 3a'), supervisory programs for control testing (21%) dominate over educational software (12.9%) while an inverse ratio is expected for optimal resource structure (Fig. 3a).

The use of e-resources in teaching Organic Chemistry is characterised by the domination of static images and lack of quantum simulation software compared to optimal structure (Fig. 3d and Fig. 3d').

In contrast to other disciplines, the difference between real and optimal resource structures is minimal for Analytical Chemistry (Fig. 3b and Fig. 3b').

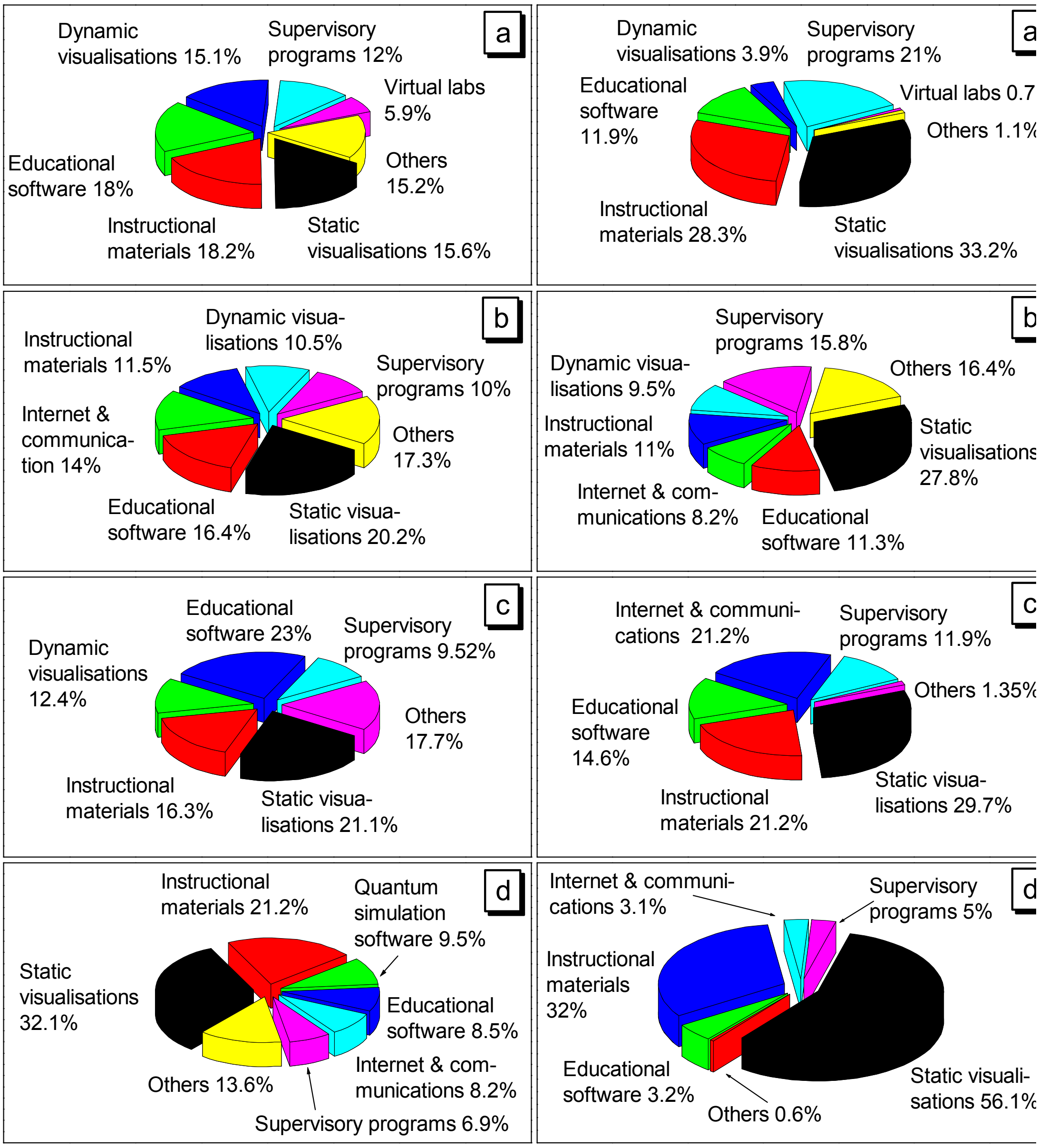

Fig. 3. Group structure of expedient (a, b, c, d) and real (a', b', c', d') use of e-resources in teaching Inorganic (a, a'), Analytical (b, b'), Physical (c, c') and Organic (d, d') Chemistry

The questionnaires were filled in by teachers and students, so if estimates of both sides coincide with each other, there is the possibility for the effective use of e-resources. If there is no consistency, some prerequisites for complications of educational process appear. The correlation between the responses of teachers and students is shown in Fig. 4 for specific e-resources with SASE, TASE > 0.05 and highly-scored (TASE > 0.4) universal resources. The data are presented separately for universal and specific resources.

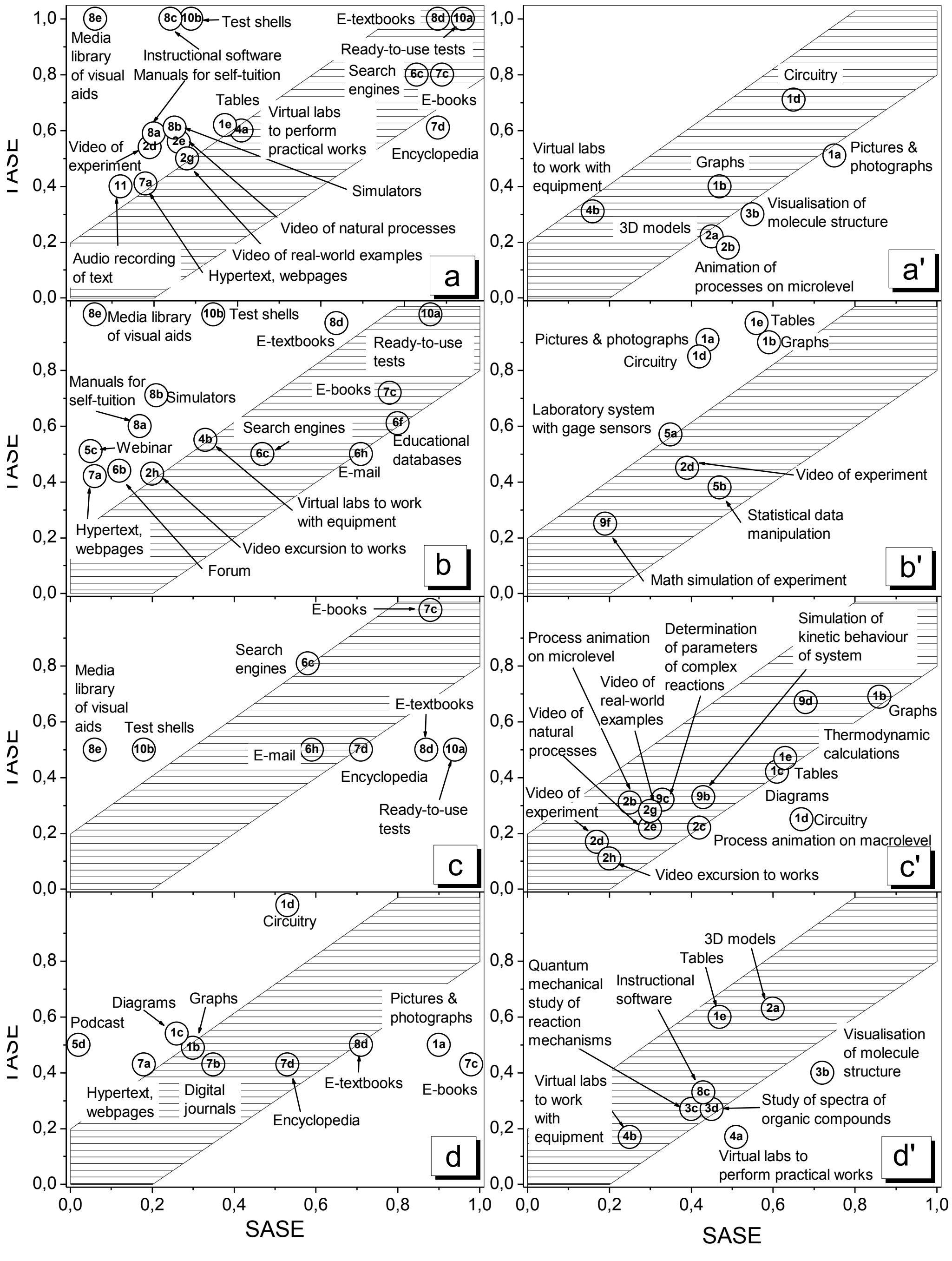

Fig. 4 Correlations between teachers' and students' average scores for universal e-resources with score >0.4 (a, b, c, d) and specific e-resources with score > 0 (a', b', c', d') used in teaching Inorganic (a, a'), Analytical (b, b'), Physical (c, c') and Organic (d, d') Chemistry

According to the teachers' opinion, all resources shown in Fig. 4 are expedient for use in the teaching process. Based on such an approach, 24 e-resources were identified as useful for the optimal teaching of Inorganic Chemistry. 17 of them are universal and necessary for teaching of almost all units (Fig. 4a), and 7 resources are specific by nature (Fig. 4a'). They are expedient in the learning of a limited number of topics. In contrast, only

10 universal and 4 specific resources are currently used in real educational process.

As follows form the comparative analysis of the survey results, the attitude of teachers and students towards the individual resources is quite different. This may lead to the reduction of their effectiveness.

The resources with similar attitudes of teachers and students are located in the vicinity of the diagonal that is conventionally depicted as a shaded band in Fig. 4. These resources are equally perceived by teachers and students that makes their application easier.

The resources located below the band are relatively less valued by the students than the teachers. Therefore, they have little chance of being applied in practice. On the contrary, the resources located above the band are more preferred by the teachers than the students. Therefore, in educational practice they are used more often than the other ones. However, they are not accepted by the students very well that can complicate their application and reduce their efficiency.

High scored (TASE > 0.4) specific resources and all universal resources can be defined as the important ones for learning. The comparison of the results obtained for various disciplines showed that the total number of important resources is relatively stable and for all disciplines it varies in a rather narrow range from 18 to 24 resources. However, there is a significant difference in their structure, namely the shares of universal and specific resources change pronouncedly (Fig. 5a). The largest number of universal resources is expedient for application in Inorganic Chemistry and this number decreases in going from Inorganic to Physical Chemistry.

As known from the structural and logical scheme of teaching, the level of specialisation is enhanced with time of studies. This is reflected in the logics of construction of chronological sequence of chemical disciplines teaching. The largest number of general theoretical problems is considered at the beginning of studying Chemistry in the course of Inorganic Chemistry which is often divided into two parts entitled General and Inorganic Chemistry. On the contrary, Physical Chemistry curriculum contains much more lessons dedicated to specialised subjects. With enhancement of specialisation of basic disciplines, the demand for specific resources is also enhanced, as is seen from Fig. 5a.

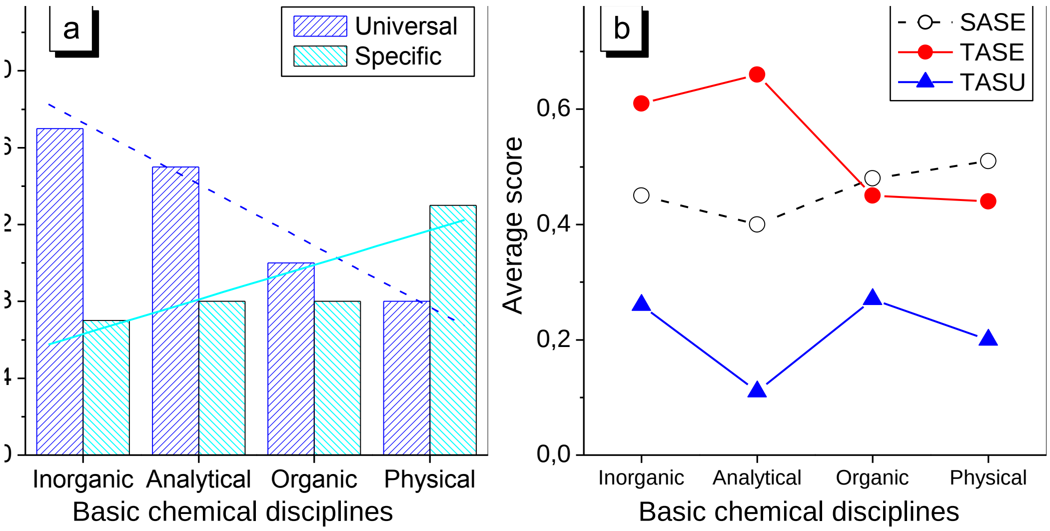

Fig. 5. The numbers of universal and specific e-resources (a) and teachers' and students' grade point averages (SASE, TASE and TASU) (b) in learning basic chemical disciplines

Figure 5b compares the average scores of e-resources on the basis of the students' and teachers' surveys. A high degree of compatibility of the students' and teachers' assessments of SASE and TASE is observed for Organic and Physical Chemistry while a pronounced difference is seen for Inorganic and Analytical Chemistry.

The difference between expedient and real use (TASE and TASU) is rather high for all disciplines that reduces the efficiency of applying e-resources in teaching chemical disciplines at universities. A technology dedicated to the integration of methods, forms and means of ICT, which takes into account students' preferences in both e-resources and learinig styles, was developed to prevent reducing the effectiveness of e-resources usage [19]. In particular, quantitative criteria for the optimal selection of ICT means were proposed to take into consideration the formed learning syle of a particular student group. These criteria include an average score of the preference to a given e-resource calculated on the base of sudents' estimations and a difference between students' and teachers' assessments of SASE and TASE. The developed technology was experimentally tested for teaching Inorganic Chemistry [20].

Conclusions

An essential discrepancy between the real and expedient usage of e-resources in the educational process was revealed. There are two important aspects of such a discrepancy. Firstly, the teachers accept the necessity of using various resource types but they do not use some of them in the least. Secondly, the perception of some e-resources is different for teachers and students.

The above-mentioned discrepancies form prerequisites for reducing the effectiveness of resource application in learning. Therefore, a special technology dedicated to the integration of methods, forms and means of ICT, which takes into account students' preferences in both e-resources and learinig styles, should be incorporated into a methodological system of teaching chemical disciplines.

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Тетяна Михайлівна Деркач,

доктор педагогічних наук, доцент кафедри промислової фармації,

Київський національний університет технологій та дизайну,

вул. Немировича-Данченка, 2, м. Київ, Україна

ЕЛЕКТРОННІ РЕСУРСИ У НАВЧАННІ БАЗОВИХ ХІМІЧНИХ ДИСЦИПЛІН В УНІВЕРСИТЕТАХ

Актуальність теми дослідження зумовлена недостатньою розробленістю дидактичних основ підготовки студентів із хімії в умовах інформатизації. Теорія та методика професійної освіти наразі не може відповісти на запитання, пов'язані із забезпеченням умов підвищення ефективності навчання із застосуванням засобів інформаційно-комунікаційних технологій. Метою статті є висвітлення реального стану використання електронних ресурсів у навчанні хімічних дисциплін, а також обґрунтування доцільності та загального підходу до вибору засобів інформаційно-комунікаційних технологій для навчання. Для досягнення поставленої мети було використано наступні методи: анкетування, опитування експертів для визначення реального стану застосування електронних ресурсів для викладання хімічних дисциплін; класифікація для ранжирування доступних електронних ресурсів; комп'ютерне тестування для визначення особистісних характеристик учасників освітнього процесу; а також статистичні методи з використанням програмного пакету SPSS для інтерпретації отриманих експериментальних даних. Статистичний аналіз включав порівняння зразків, перевірку даних, дисперсійні тести для статистичної значущості різниці (пакет ANOVA) і кореляційний аналіз для метричних (статистика Пірсона) та рангових (W статистика Кендалла) змінних. Досліджено реальний стан застосування електронних ресурсів у навчанні хімічних дисциплін. Різні параметри, такі як функціональність, попит на використання ресурсу у навчанні за оцінками експертів, наявність кореляцій з переважаючими стилями навчання, були використані для класифікації всіх ресурсів на кілька груп для подальшого аналізу. Встановлено наявність значних розбіжностей між бажаним забезпеченням електронними ресурсами процесу навчання та реальним станом цього питання. Виявлено два важливих аспекти протиріччя: викладачі визнають необхідність застосування у викладанні різних типів ресурсів, зовсім не застосовуючи деякі з них на практиці. Оцінка доцільності використання деяких електронних ресурсів викладачами і студентами суттєво відрізняється. Це створює передумови для зниження ефективності використання електронних ресурсів.

Ключові слова: вища освіта, базові хімічні дисципліни, стилі навчання, інформаційно-комунікаційні технології, електронні ресурси.

Татьяна Михайловна Деркач,
доктор педагогических наук, доцент кафедры промышленной фармации,
Киевский национальный университет технологий и дизайна,
ул. Немировича-Данченко, 2, г. Киев, Украина

ЭЛЕКТРОННЫЕ РЕСУРСЫ В ОБУЧЕНИИ БАЗОВЫМ ХИМИЧЕСКИМ ДИСЦИПЛИНАМ В УНИВЕРСИТЕТАХ

Актуальность темы исследования обусловлена недостаточной разработанностью дидактических основ подготовки студентов по химии в условиях информатизации. Теория и методика профессионального образования в настоящее время не может исчерпывающе ответить на вопросы, связанные с обеспечением условий для повышения эффективности обучения с применением средств информационно-коммуникационных технологий. Целью данной статьи является изучение реального состояния использования электронных ресурсов в обучении химическим дисциплинам, а также обоснование целесообразности и общего подхода к выбору средств информационно-коммуникационных технологий для обучения. Для достижения поставленной цели были использованы следующие методы: анкетирование, опрос экспертов для определения реального состояния применения электронных ресурсов для преподавания химических дисциплин; классификация для ранжирования доступных электронных ресурсов; компьютерное тестирование для определения личностных характеристик участников образовательного процесса; а также статистические методы с использованием программного пакета SPSS для интерпретации полученных экспериментальных данных. Статистический анализ включал сравнение образцов, проверку данных, дисперсионные тесты для статистической значимости разницы (пакет ANOVA) и корреляционный анализ для метрических (статистика Пирсона) и ранговых (W статистика Кендалла) переменных. Исследовано реальное состояние применения электронных ресурсов в обучении химическим дисциплинам. Различные параметры, такие как функциональность, спрос на использование ресурса по оценкам экспертов, наличие корреляций с предпочтительными стилями обучения студентов, были использованы для классификации ресурсов с выделением нескольких групп для дальнейшего анализа. Установлено наличие значительного несовпадения между необходимым, по мнению экспертов, обеспечением электронными ресурсами процесса обучения и существующим реальным состоянием этого вопроса. Выявлены два важных аспекта противоречия: преподаватели признают необходимость применения в преподавании различных типов ресурсов, при этом вообще не используют некоторые из них на практике. Оценка целесообразности применения некоторых электронных ресурсов преподавателями и студентами существенно отличается. Это создает предпосылки для снижения эффективности использования электронных ресурсов.

Ключевые слова: высшее образование, базовые химические дисциплины, стили обучения, информационно-коммуникационные технологии, электронные ресурсы.

Подано до редакції 19.12.2016