Information Visualization in the Educational Process: Current Trends

https://doi.org/10.3991/ijet.v15i13.14671

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Abstract—The rapid development of computer visualization techniques as well as virtual and augmented reality has led to the possibility of perfect data visualization and the creation of a special virtual space for educating new generation. Simultaneously, the increase in the amount of data to be processed requires a proper selection and presentation of data for solving specific problems. Education sets such tasks as 1) improving the efficiency of presenting information and its assimilation by students, and 2) increasing the convenience and quality of the teachers’ work. The purpose of this study is to test an acceleration and improvement of the teacher’s response to students studying with more productive visualized learning material. Meanwhile, the created visualization system was based on minimizing the efforts and costs of its preparation and constant support. Only free cloud-based services and visualization tools were used. Students were given the opportunity to constantly, in real time control their learning process and create education markers with the help of perspicuous visual environment. To create a visualization system, already existing works on the implementation and verification of the system was used. The study was based on the results of applying this technology. A survey of 300 students from three universities in China, Russia and Kazakhstan was conducted. The control group consisted of 150 students from the same universities who did not use visualization to master the same educational material. According to the results of the study, students who used information visualization showed a sharp increase in the subjective assessment of the speed and quality of their learning (58.58% and 37.73%, respectively, of the total number of participants gave a high rating, while in the control group – only 12.25%). Further, the level of anxiety associated with an assimilation of new language material was significantly decreased (13.54% in the study group did not feel anxiety, while only 7% – in the control group).

Keywords—Emerging technologies; foreign language learning; information visualization; knowledge visualization; visual representation.
1 Introduction

In last decades display resolution is closely connected with 1) An exponential increase of processors’ and video processors’ speed, as well as subsystems for processing visual information in general 2) With the widespread use of distributed computing technology that allows you to split image processing between many separate computers in Networks [1,2].

The rapid development of computer graphics has led to the possibility of creating virtual and augmented reality of various types [3,4]. Modern mobile gadgets already have sufficient processing power to reflect a sophisticated and complex AR and to use them in systems integrated to VR with a partial presence effect. Such systems are already used to educate and train specialists whose activities are associated with a high risk or decision making (rescue services, military organizations, the aerospace industry, navigation, management of nuclear reactors and power plants, etc.) [4-6]. Likewise, complex environment visualization systems are increasingly used in order to provide the possibility of virtual communication with great opportunities for transferring and converting data. Augmented reality systems are widely used in training specialists who need a direct representation of hidden processes (doctors, architects, builders, repairmen, workers in large mechanical engineering, rocket, aerospace engineering, shipbuilding industries, etc.) [7]. The information visualization and knowledge visualization are main visual technologies equally demanded in all types of modern education systems [8].

The information visualization usually represents data in the form of an organized set of graphic symbols, spatial location, as well as graphic markers of which (colour, size, space etc.) carry an information load. The knowledge visualization represents information in the form of an organized set of graphic symbols in a more complex structure of the relationship between individual information nodes [9,10]. Generally, the information visualization is the transformation of a tabular data, usually numerical, in the form of graphs, charts, diagrams, drawings, and even animated sequences. Conversely, the knowledge visualization involves the transformation of any, not only numerical data, as well as the presentation of complex relationships between individual types and sections of the general information field represented by a graphical method.

The knowledge visualization is already very important for teaching a foreign language [11,12]. A study of the use of different forms of visualization shows that the involvement of the visual component leads to several consequences in the learning process:

1. Activation and stabilization of students’ attention on the information provided for a longer time and with greater intensity
2. Improvement of the information perception and memorizing
3. Increase of the learning motivation and the interest in further study of a subject

There has been a series of studies devoted to the psychological consequences of knowledge visualization applying and how its contribute to the creation of conditions for the learning individualization over the past five years [11, 13-15]. Today, generation
called digital native enters high school and universities, that is, people who were born and raised surrounded by communication devices and subject to constant access to information. Researchers point out that the nature of perception and learning of this generation differs from previous generations, and requires radical changes in higher education, as well as specific teaching methods. In particular, representatives of this generation rarely read spontaneously and for a long time (their reading method is more often defined as skimming – quick browsing). Additionally, they require independence from the teacher in the learning process and constant access to the digital environment to which they are accustomed, and which they constantly use. Thus, the requirement for the visual presentation of educational content becomes decisive for modern education.

Learning a foreign language requires the formation of very diverse and complex skills, which, in modern condition, takes less time as before. Thus, the quality features of information visualization are very important for this area [16]. Learning a language is now associated with constantly changing living conditions, the influx of new words and expressions, the development of new domestic and social phenomena. A person learning a foreign language is required not only to learn a certain set of knowledge, but to integrate some constructive skills that will help to quickly “build” new elements into his knowledge system in the future. The most of standard type of training should involve constant support of the learning process by digital methods [17]. This refers to both the collection and use of information about the learning process, and the use of new methods for providing educational content, in particular, visualized information and visualized knowledge.

A constant increase of processed data leads to a need of skills in the competent analysis of large volumes of online data for most specialties in higher education institutions [12,18]. Today, even medium-sized enterprises are actively using big data technologies as a means of improving marketing efficiency and flexible adaptation to consumer requirements.

2 Materials and Methods

The study involved 300 students from GuangXi Normal University (China), KIMEP University (Kazakhstan) and Peoples’ Friendship University of Russia (RUDN University). 100 people were selected from each university. Groups were selected according to the level of the Russian language as a foreign language (level A1, A2); the gender composition of the groups represented an equal ratio of men and women (50 people in each group), age – 18-21 years. 50 people from each of the universities (150 people in total) were selected for a survey as a control group. They were also allocated in the same representative group and simultaneously trained according to the same program, but without the use of information visualization tools.

The study was carried out for 3 months as standard training programs, which were brought together by agreement between researchers from three countries for the purpose of coordination of efforts. The study was conducted using infographics and special means of data visualization in two directions at the same time. Students received
training material with visualized information. Students could also keep a constant record of their own information assimilation and educational effectiveness with the help of cloud-based network services. Meanwhile, teachers had daily access to visualization of data on the assimilation and understanding of the material by students and their current success with the help of streaming data visualization at cloud-based network services.

In order to improve and facilitate the perception of information and communication skills in a foreign language as well as reduce anxiety in speaking and reading [19], there were used building tools as diagramming and memory card, with the help of which semantic and associative connections between words were created, and stable grammar of elementary level used. Thus, researchers used three types of infographics:

1. **Consolidating** of speech and recorded form of words and expressions with visual images, including animated ones. For animation, there was used simple animated gifs based on the superposition of two or three drawings in an animation sequence. Such animations advantaged an easier and faster understanding of verbs and expressions indicating actions or directions.

2. Memory cards, **consolidating** associative and semantic connections between lexemes and phraseological units, ways of expressing thoughts and representing the grammatical material of the Russian language. The opportunity of quickly inflecting of visual images on the memory card, as explained above was used. Thus, there was provided an easy connection of a simpler base material with a more complex one.

3. The use of charts and graphs for forming sustainable speech strategies in everyday speech. Having mastered such a scheme, students were able to independently form a rather complex structure of the expression, questions or answers to them within the framework of the learned material.

All types of visual information were closely connected with each other by special directly indicated connections, by which it was easy to move from one visual scheme to another. Teachers posted all schemes in “cloud” services all along with the working material of the training course. The materials were also provided to the study group on social networks for immediate use on smartphones, tablets, or laptops. The entire visual information was duplicated three times:

1. It was transmitted with projector to canvas or screen in the classroom, so as to be accessible for the group during training the material. The teacher also carefully explained the meaning and content of the diagrams and instructed how to use them.

2. The training material along with visual material was provided on the social networks (Facebook VKontakte, Instagram) to all participants in the study group so that they would use these schemes directly during classroom lessons as well as personal time.

3. All visual information has been available since the end of the classroom on a special resource of the cloud-based service “Google Drive” (free service).

Actually, the elements of visualized data are special means of tracking the success of students’ assimilation of information in the form of graphic data that was generated using the Tableau Public network service (Fig. 1).
Tableau Public was chosen because of its high popularity and objectively the broadest possibilities of constructing different types of visualization.

Data for building flow charts and data visualization was extracted from two sources. On the one hand, the user-student himself could mark on the diagrams hard to remember points or hard to recreate on his own during the classes. On the other hand, the teacher recorded the results of students’ intermediate work and grades for them. Both types of information were recorded simultaneously from both the teacher and the student in the form of visualization of the current success and visualization of the current state of training (Fig. 2).

Fig. 2. Visualization of the learning process current state
Based on the visualization of the learning process current state, the teacher could further focus on problems that caused the most difficulties for students and provide them with additional information. Students, relying on both types of visualizations, could receive more information about where pay more attention or find additional information.

Additional surveys were conducted in order to reveal the hypothesis of the study. It consisted of a survey of study participants and a control group about attitudes toward learning and subjective feelings associated with the learning process, and also included an assessment of their own knowledge and motivation for learning. The parameters “anxiety”, “learning speed” and “learning outcomes” were studied. All data are presented as a percentage of the number of participants in the study and control groups.

- “Anxiety” – a subjective indicator of the stress level, which students evaluated on a scale from 0 (absence of tension and stress, maximum efficiency and speed of work and thinking) to 10 (maximum painful anxiety and deep distress with loss of ability to adequately perform tasks and think coherently);
- “Learning speed” is a subjective indicator, based on the speed of mastering the training material up to the time of readiness to move to the next section of the training material, on a scale of 0 (very slow, there is a need to constantly repeat the material and use the training materials to support) to 10 (very quickly, information is acquired after the first lesson, there is no need in repeating);
- “Quality of training” – a subjective feeling of complete mastering of materials without difficulties, it was also evaluated on a scale from 0 (complete misunderstanding of the material and its forgetting) to 10 (fluency in materials, there is no need to recall the material in order to use it).

The study did not use the materials of personal visualization modules for students with ethical reasons, since they contain relevant personal information about the development of certain topics, existing difficulties in learning, teachers’ corrections, etc. Additionally, this information is not of interest for the hypothesis of the study and its subject matter. The information presented in the visual examples was created specifically for the presentation, but the average data for many students of the study group was used.

### 3 Results and Discussion

Fig. 3 shows a sharp decrease in the level of anxiety among students, who studied using information visualization methods, that’s fully correspond to the data obtained during the study [19]. Meanwhile, the number of students who practically experience no anxiety increased (13.54% in the study group and 7% in the control group) and the number of those who experienced maximum anxiety decreased in rapidly (3.56% in the study group and 18.42% in the control group). The indicators are more than three times lower in the study group for those who experienced the highest anxiety. However, the average indicators of anxiety remained almost equal for both groups (38.92% in the study group and 36.42% in the control group). The advantage of visual perception of
information and its easy decoding [20,21] is that students’ no longer perceive learning process as dangerous and threatening, that reduces stress [19,22]. Obviously, this is due to the fact that the average level of tension, acceptable from the subjective point of view, corresponds to the level of positive mobilizing stress.

![Anxiety evaluation, %](image)

**Fig. 3.** Subjective evaluation of anxiety level (in% of the number of participants)

Source: developed by the authors

Fig. 4 shows the evaluation of learning speed, in the control group, which is distributed among students studied within the normal distribution, which is typical for subjective assessment in large groups [23]. The difference in the estimates of the learning speed in the control group is more consolidate while, in the study group, there is a significant prevalence of those who rated the learning speed as high (58.58% of the study group students rated with 5 points or higher; while only 30% – in the control group). 37.17% of students in study group and 27.34% in the control rated the learning speed as average, the most comfortable. Thus, in the study group with the use of information visualization, the perception of the learning speed significantly increased in comparison with the control group.
A subjective evaluation of the quality of training (Fig. 5) also has the same tendency as for learning speed. The number of students who rated the quality of training as high as possible is critically greater in the study group than in the control group (15.25% and 2.5%, respectively). The total range of those who rated the quality of training as high as possible (7 points and higher out of 10 points) is 37.73% – in the study group, while only 12.25% – in the control group. Meanwhile, the range of students rated the quality of training as low is much fewer – 5.94% – in the study group, and 13.50% – in the control group.

It’s worth emplacing that the quality of training evaluation was less subjective, since students constantly monitored not only teachers’ assessment of their activities, but also their own actions and objective level of their material mastering, students could note what they know and what not. Most likely, self-evaluation was influenced by the high expectations and an overly optimistic view of their capabilities. However, an increase in optimism towards quality of one's training and learning speed is already a positive indicator in academic education and contributes to an increase in its quality, according to a number of works on information visualization [11,15].

![Fig. 4. Subjective evaluation of the learning speed (in % of the number of participants)](http://www.i-jet.org)
The study shows that the use of information visualization in the form of interactive, updated online content that allow you to monitor the educational process, conduct self-testing and control the quality and speed of training, dramatically reduces students’ anxiety and incertitude, and also helps to increase confidence, self-esteem and motivation for learning.

The results of our study generally confirm the results obtained by other researchers, in particular, works on reducing students' anxiety with the help of knowledge visualization [19]. Atabekova [24] also indicates that the use of knowledge visualization helps to improve students' social skills, mostly because of the reduction in competitive tension, which is somehow present in the group. Lots of works indicated an increase in motivation for learning along with the use of knowledge visualization and an increase of interest in the subject studied, moreover, for long periods not once [25-27]. A number of researchers also note that stable changes in relation to the knowledge gained and increased motivation grow up over time. Instantaneous effect or sporadic use of information visualization causes steady and quite prolonged interest, but do not change the motivation for language learning, as shown in the study [21,28,29]. One of the important areas for further research should be the establishment of an experimental time frame for the effectiveness and duration of the knowledge visualization effect on the cognitive capabilities of students with different levels of education.

Over the past three years, several options have been described for creating fairly complex integrated knowledge visualization systems that use specialized software both to provide a visual representation of material for students and to provide an opportunity to analyze the learning process individually [30,31]. Ge and Li [13] provide an analysis for the significance of individual elements of knowledge visualization systems. There are such types of visual representation as text, graphics and diagrams, static images, edited video, as well as VR. The study showed that VR has the least effect on the
cognitive abilities of language learners. Meanwhile, static images and systems of graphs and diagrams are the most significant, according to experimental evidence [8,32].

Li et al. [26] describe one of the best, in our opinion, integrated systems for visual training and presentation of information. The system is focused on new generation students’ needs; it allows easily select visualized data, go deeply into and release new levels of presentation simply by contact with elements of visual data presentation. The problem of implementing such systems lies in the need of additional costs for programming as well as integrating several complex data processing systems at once. In addition, such a system is less focused on the needs of the teacher, who must monitor student progress and make adjustments to the learning process, focusing on updating data.

It should be noted that in the field of knowledge visualization almost all works are devoted to the use of integrated complex visualization programs. This is due to the high requirements for their effectiveness, as well as the fact that free open visualization platforms require special skills and the development of special protocols for their correct use, which must be explained to students and teachers. Integrated specialized systems have interface that can be used without special training or with minimal training. However, the creation of such systems for most universities, for example, in Russia, Kazakhstan and many other countries interested in improving the quality of education, is not possible. Thus, the limited capabilities of free visualization tools can be used. We also consider that they can be integrated into the use of virtual learning systems, which are increasingly provided in systematic university courses [33,34].

More and more attention is also being paid to the use of virtual and augmented reality mechanisms, as the availability of these technologies is rapidly increasing [35]. The problems of using AR mechanisms for teaching a foreign language, especially at the initial level (A1, A2) should be left open for further study. According number of authors [22,36-38] the use of VR largely limits the subconscious resistance to mastering new skills, which is especially important at the initial stage of training. However, language learning does not require skills in three-dimensional reality orientation and is not associated with the use of objects or finding the optimal route, comparing to other specialties [6,39]. Therefore, the use of information visualization in the form of static or limited animated images shown on a monitor or its analogue seems to be a more effective and cheaper method of improving the quality of training. The study does not describe methods involving VR and AR, that’s the source for further study.

4 Conclusion

Learning a foreign language is an area in which the most advanced computer data visualization systems are applicable less. Even though, over the past decade, researchers have done a lot for creating and studying systems for applying information visualization and knowledge visualization in foreign language learning. The use of integrated, programmable knowledge visualization systems is more often described, as it helps the learning process to be intensified in a digital environment. This type of training is more suitable for a new generation of students, so-called digital native.
During the study, we tasted the effectiveness of applying the knowledge visualization system to provide educational content for students studying Russian as a foreign language, as well as data visualization systems for students and teachers to improve control over the process of mastering knowledge and control over it. As a result of the survey, the use of information visualization technologies leads to a number of positive sustainable results: 
a) increased interest in the subject and increased student motivation; 
b) reduce stress and distress due to unfamiliar language learning; 
c) accelerate learning and increase its effectiveness and involvement of students in the learning process.

Practically, the results of the study can be used to increase the effectiveness of teaching Russian as a foreign language, as well as teaching foreign languages at the initial level using the simplest methods of visualizing knowledge in most higher education institutions.

5 Acknowledgement

The first author was supported by Project of Innovation Project of GuangXi Graduate Education (No. JGY2018020; JGY2019031); Project of Vietnam Research Center of GuangXi Normal University (YN2017004); Funding of Pearl River-Xijiang River Economic Belt Development Institute, GuangXi Normal University (ZX202008); Undergraduates Teaching Reform Project of Guangxi Higher Education (2016JGA142).

The second author was funded by Russian Foundation for Basic Research according to the research project No 19-013-00627.

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proceedings of the V International Interdisciplinary Science Conference. Peoples' Friendship University of Russia, pp. 236-249.


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