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INTERFACE LAYOUT VERSUS EFFICIENCY OF INFORMATION ASSIMILATION IN THE LEARNING PROCESS

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Abstract. *The purpose of this article is to study the impact of different ways of presenting educational content found on websites on the ability to assimilate information among elementary school students. To conduct the study, three websites with interface layouts different in terms of levels of complexity were prepared: a simple, a moderate and a complex one. Each site contained the same educational materials. Seventy-two students from elementary school grades IV-VI participated in the study. All the students were divided into 3 groups, each of which worked with one version of the website. At the first stage, students were tasked with familiarizing themselves with the content of the web pages within a given website. This was followed by a knowledge quiz, checking how much information the subjects had memorized. At the last stage, participants of the experiment completed a questionnaire collecting their opinions on their preferences regarding the form of presentation of educational content made available online. The obtained results and the conducted analysis show the interface with the moderate level of complexity, i.e. with a relatively simple layout and without an excessive number of elements, allows for the assimilation of the most information. The interface was also rated the highest by the participants of the study.*

Keywords: child-computer interaction, memorability, memorization efficiency, interface layout, website evaluation

UKŁAD INTERFEJSU A WYDAJNOŚĆ PRZYSWAJANIA INFORMACJI W PROCESIE UCZENIA SIĘ

Streszczenie. *Celem artykułu jest zbadanie wpływu różnych sposobów prezentacji informacji edukacyjnych zawartych na stronach serwisów internetowych na zdolność przyswajania treści wśród uczniów szkoły podstawowej. Dla zrealizowania badania zostały przygotowane trzy serwisy internetowe mające odmienne układy interfejsów, różniące się poziomem zaawansowania: prosty, średniozaawansowany i zaawansowany. Każdy serwis zawierał te same treści edukacyjne. W badaniach wzięło udział 72 uczniów z klas IV-VI szkoły podstawowej. Uczniowie zostali podzieleni na 3 grupy, z których każda miała do czynienia z jedną wersją serwisu. W pierwszym etapie uczniowie mieli za zadanie zaznajomienie się z treściami zawartymi na stronach www w ramach danego serwisu. Następnie został przeprowadzony test wiedzy, sprawdzający ile informacji badani zapamiętali. W ostatnim etapie uczestnicy eksperymentu wypełnili ankietę zbierającą opinię na temat preferencji dotyczących formy prezentacji treści edukacyjnych udostępnionych w trybie online. Na podstawie uzyskanych wyników i przeprowadzonej analizy można wysunąć wniosek, że interfejs średniozaawansowany, o stosunkowo prostym układzie i nie zawierający nadmiernej liczby elementów, pozwala na przyswojenie największej ilości informacji i był najlepiej oceniany przez badanych.*

Słowa kluczowe: interakcja dziecko-komputer, zapamiętywalność, efektywność zapamiętywania, układ interfejsu, ocena strony internetowej

Introduction

The 21st century is the age of the Internet so it should not be surprising to observe the gradual migration of teaching to the online space. Thirty years ago, no one would have thought that the first place to look for any information would be a web browser. It is a quick, more convenient and easier way to access knowledge than flipping through volumes of books that need to be also physically transported. The use of the Internet greatly facilitates access to information and education for people from poorer areas and those who do not have access to schools or courses that offer education in a particular field [12].

The usefulness of World Wide Web is self-evident. From an early age, children are motivated in many ways to use content posted online. Younger generations no longer know the world without the omnipresent Internet [6] which has become so popular and common that it is used subconsciously and instinctively.

Nowadays, the main concern of parents and teachers regarding the Internet is how to teach children to use it safely and how to limit the amount of time they spend online. The dangers found on the Web have been described by N. Krasteva [8]. The author stresses the importance of educating children about dangers of the Internet and teaching them how to use the websites properly. However, it is worth noting that a significant amount of time spent in front of the screen may stem from the difficulty of finding the desirable information on designed websites. The growing influence of the Internet on children's daily lives should also not be ignored. It is impossible to cut off young people from online content completely since they will inevitably need to learn to use it at some point in their lives. Modern technology enables fast access to information and therefore the way of presentation of the online content is also of high importance.

The sites are usually developed by adults and for conscious users who have no problem reading large portions of text at once and who are able to focus their attention on a particular element. Children, especially younger ones, are easily distracted and have trouble reading a "wall of text" in order to find the information that is needed [1]. Hence, if children are expected to be enthusiastic about and willing to use educational portals then these sites should look at least half as attractive as browser-based game websites. Unfortunately, the aspect of appropriate and user-friendly display of online content is frequently neglected.

The knowledge on what kind of interfaces are positively perceived by schoolchildren may help build more interesting and accessible sites for all Internet users. If popular information websites had interfaces built with the youngest users in mind, they would also be more readable for older users. Furthermore, a properly created and interesting interface may raise children's interest in a particular topic, attract attention to the site and encourage them to broaden their knowledge.

On the other hand, websites overloaded with redundant content containing various types of online distractors, which initially may look interesting and inviting, can negatively affect children's memorability of the information provided on the website and may weaken their focus on the material. According to a study by A. Osmulska et al. [13], icons were less understandable than text buttons, which reduced the number of correctly completed tasks and affected the time to reach correct solutions. Inclusion of too many unlabeled graphical items forces users to speculate about the functions of individual elements and leads to user errors, which may discourage many people from using the site. It is therefore critical to find the balance between the attractiveness of the site and its readability. When designing interfaces that are supposed to be friendly for young users, it is important to take into consideration the users' age, needs and capabilities.

The purpose of the study was to determine the degree of the interface complexity of educational websites in order to maximize the assimilation of the information contained therein and encourage users to utilize the websites. The study was designed to test the amount of information students assimilate during online learning through interfaces with varying levels of layout complexity and featuring different numbers of on-screen elements. The study used two surveys where the first one was intended to test the amount of information memorized by the participants, while the other was used to collect the users'

opinions on different aspects of designed interfaces. An experiment consisting of four stages was prepared. At the first stage, after being introduced to the aim and process of the study, the participants gave their consent to partake in the experiment. At the second stage the participants familiarized themselves with the website and the information contained within it. The third stage used a quiz to verify the amount of information memorized by the participants. Eventually, in the final part, a short survey was conducted to evaluate various aspects of the website used.

For the purpose of this study, based on the literature review, the following thesis was formulated: *website interfaces with a moderate level of complexity allow users to memorize the greatest amount of educational content*. Such a thesis suggests that the expected outcome of the conducted research is the search for a happy medium that compromises between graphic attractiveness and asceticism and that makes the transfer of knowledge effective.

1. Literature overview

Nowadays, traditional teaching is increasingly being replaced by or supported by online educational platforms and therefore it is crucial to study the effects of e-learning on knowledge assimilation and enthusiasm for learning. The effects of e-learning were examined in an article by I. Patra et al. (2022) [14]. In the study, the participants with similar knowledge and skills were divided into two groups: the first one was taught via e-learning and the second one via face-to-face learning. The study did not show significant differences, still the group that broadened knowledge by means of e-learning scored higher on average than the group taught in a traditional manner.

Some theories in the related literature primarily concentrate on the impact of individual interface components on the quality of learning among adult learners. The research of H. Nordin, et al. [9, 10] can be considered as such. Using surveys, the writers of both works gathered and examined opinions of college students from Z generation about colours and graphics on e-learning websites in Malaysia. The results of the research indicated that students prefer interfaces with bright colors and graphics not associated with any higher education institutions, but rather intended to increase motivation. Moreover, a preference for a variety of colours on individual pages rather than a preference for a uniform interface colour was observed.

In contrast, only one work focuses on how these aspects affect younger students. In their paper, M. Gasah, N. H. Mat Zain, A. Baharum [3], using a survey, analyze the problem of children's lack of interest in learning at the same time proposing interface design guidelines that focus on evoking emotions.

In a study conducted by A. H. Muhammad et al. (2020) [11] researchers examined factors affecting the quality of e-learning systems. The article proposes an effective evaluation model of those systems, but does not take into account individual differences or the specific needs of users. The study emphasizes the importance of safety of e-learning systems, the use of cloud computing technologies and the exploration of multi-criteria evaluation methods. According to A. S. Shibani et al. (2023) [17], the most significant elements in the e-learning process are: perceived usability of the system, flexibility, user preferences, enjoyment, self-efficacy, content quality, perceived ease of use, interface layout design, website quality and perceived accessibility. Among the elements listed, the perceived ease of use proved to be the most significant, while user preferences proved to be of least significance.

Although the majority of works does not seem to consider the individual needs of students, in the study done by L. M. Hasani et al. (2020) [5] the authors attempted to create an alternative interface design based on the learning style of the users. The authors used a variety of research methods, including analyzing similar scientific works and conducting user feedback surveys. The experiment uncovered significant differences between the preferences of each research group and the designs of the educational platforms being used. Likewise, in a different paper by L. M. Hasani et al. (2020) [4], the authors write about the user-centered interface design. Based on literature research it was determined, which UCD (User-Centered-Design) methods are most commonly used in designing user-computer interfaces and point to their positive impact on the interface quality.

As computers play an increasingly important role in people's lives starting with childhood, the field of child-computer interaction is becoming increasingly important. This field examines how to design interactive technology for young computer users and how they can use it to their advantage so that it has the most positive impact on their development. The rapid technological development has a huge impact on how children learn, play, and interact with others. When designing technology, it is very important to make it children-friendly. Adults are usually goal oriented and therefore for adults, the goal of usability of any technology is to enable to quickly and accurately do what needs to be done. For children, on the other hand, everything should be easy to do, however, there should be appropriate challenges so that it is possible to learn along the way. For young computer users, fewer functions can lead to better results. Therefore, simpler user interfaces, where only a few operations can be performed, will be better suited to children who are expected to be able to explore technology with minimal instructional support. A critical role in the development of software and technology aimed at the youngest computer users is played by visual design [7].

J. Nielsen and K. Sherwin (2019) conducted usability studies by observing a group of 125 users aged 3-12 as they used a wide range of websites and applications from different countries. The aim of this study was to develop usability guidelines for companies, government agencies and large non-profit organizations that want to design websites for children. An important conclusion from this study is the need to focus on very narrow age groups when designing content for children. Since each group has different behaviours, physical and cognitive abilities, it is necessary to distinguish between young children (3-5), middle children (6-8) and older children (9-12). Users become much more familiar with technology as they get older, and children are very aware of age differences [16].

Druin A. (2002) claims that children have much to offer in the design process. They can play 4 different roles in the design of new technologies: a user, a tester, an informant or a design partner. Each of these roles can shape the technology design process and influence the technologies being created. When children take on the role as users, their interaction with an existing technology is being studied to discover design aspects that can be improved. As informants, children can be involved at any time the design team believes it needs direction or support. As testers, children test prototypes of a technology before it is released onto the market. The role of a child as a design partner is similar to that of an informant, however, this role suggests children will be a part of the research and design process throughout the experience. With this role, the child is an equal stakeholder in the design of new technologies. In addition to these traditional roles, a role for the child as a designer of processes has recently been proposed [2]. This role is the result of research into authentic forms of participation, such as play, that give meaning to children's interactions with each other, adults, objects and their context [15].

2. Materials and methods

2.1. A research site and a research group

The experiment was performed in Elementary School No. 15 in Lublin with the permission of the school's administration. Each room where the study was conducted had workstations with Internet access and only one participant was allowed to sit at each workstation. The research was conducted in the presence of a school teacher.

All students participating in the study were from grades 4, 5 and 6 of elementary school. Each class was divided into 3 groups of 6 to 9 students. Each group was assigned one of 3 interfaces. A total of 72 people participated in the study. The study also included students with disabilities, like the autism spectrum disorder, including one student in a wheelchair requiring assistance from the teacher.

2.2. Research subjects

The study concentrated on three interfaces with different levels of complexity of the layout. Each of these interfaces contained the same information about a sea slug called Blue Sea Dragon. The interfaces differed in terms of the layout as well as their colours and graphics, but were identical in terms of the page order and titles. All sites had the same number of pages. The pages contained information divided into the same categories. The last page contained a link to a short test with a questionnaire used for rating a given type of the interface.

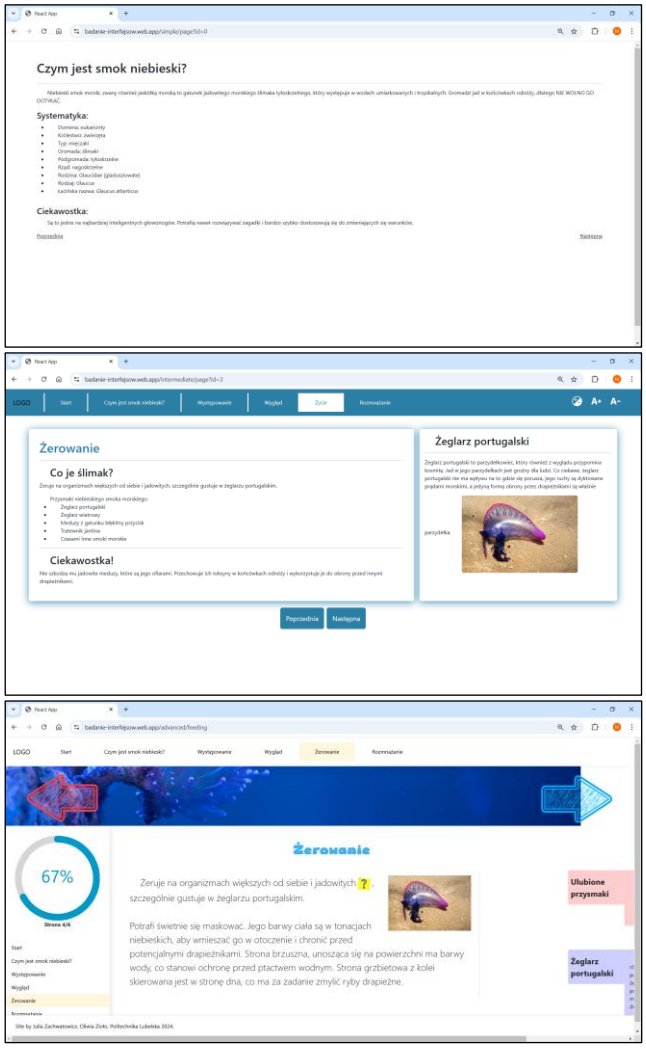

Fig. 1. Three versions of the educational website (from top): a simple, a moderate, and a high level of complexity

The simplest of interfaces consisted of a text arranged in a single column presented on a white background, divided into main information, additional information and some trivia, with corresponding titles and a link to the next and the previous page. All the information within a given category was immediately visible on the screen with no hidden segments. The interface featured no graphics, buttons or a navigation bar. The only way to navigate the site were the links underneath the text. No colours were used on the site except for the white background and a black colour of the text and the links.

The second interface had a slightly modified layout, but similarly to the simple interface, all the information was visible on the page immediately after it was loaded. In this case, the text was split into several columns, with each column located in a separate section on the screen. The site was based on a single blue interface colour and graphics relevant to the information being displayed were included in the subsections. The links were replaced with labeled buttons and a navigation bar was placed at the top of the page to allow the users to move freely between subpages. The site was designed and programmed on the basis of selected universal design principles, with the navigation bar featuring buttons that allowed the users to resize the text shown on the page and a tool allowing to change the contrast.

The third site used the interface resembling modern educational websites. A wide palette of colours and graphics was used, much of it unrelated to the information on the site. A large banner was added to the main page of the site, as well as three instructions on how to use the site (such as how to use the trivia icon). The buttons for moving between pages were replaced by graphical arrows without labels. In addition to the navigation bar, at the top of the page, a navigation panel on the left side of the page was added, causing the navigation component to be duplicated. This panel also included information on the current progress in the course. The only content available immediately after loading the page was the basic information, while additional information was hidden within a component that only appeared after pointing the mouse cursor at the bookmark located at the right edge of the page. The text detailing the trivia could only be seen after clicking the right icon in the text. Several elements on the page took the form of animations simulating motion to the left or right, shaking and scaling. The principles of universal design were not considered during the design and implementation of this version of the interface. As a result, this version of the interface was not equipped with text resizing or contrast changing features, which were available in the moderate complexity version of the site.

2.3. Research process

Once the class had started and the process of the study was explained, each student opened the version of the website assigned and read through the educational material contained therein. Upon getting to the last page of the website, the participant clicked on a link that took them to the next stage of the experiment, which was a quiz to verify their knowledge of the content on the website. The first question of the quiz checked whether the participants had previously been familiar with the information presented on the prepared educational website. Pupils answered this question with a brief yes or no answers. The next 6 single-choice questions covered the information found on the site. The third part of the quiz consisted of 5 questions asking to rate the site on a scale of 1 to 5, where 1 meant "definitely not" and 5 meant "definitely yes". During the study the authors recorded the participants' questions and observations about the site presented and any problems the participants encountered while using the website.

The amount of the information memorized by the participants was verified with seven simple questions listed below:

1) What is a Blue Sea Dragon?
2) Where can it be found?
3) What does it eat?
4) How does it obtain its toxins?
5) How does it defend itself against predators?
6) Do members of this species exhibit sexual dimorphism?
7) What is a Portuguese man o' war?

The interface of a given site was evaluated on the basis of grades from 5 questions directed to the users and related to their feelings expressed about the appearance, structure of the site and the way the information was presented.

The questions are listed below:

1) Do you think the site was interesting?
2) Would you like to return to the website for more information?
3) Did you have any trouble navigating the site? – For this question, the rating scale was reversed (i.e.: 1 meant "definitely yes" and 5 meant "definitely not").
4) Was the site easy to use?
5) Did you like the design of the website?

3. Results and discussion

The responses to the questions on the information memorized by the participants were scored on a scale of 0 to 3 points. The answer "I don't know and there was no such information on the site" corresponded to zero points, the incorrect answer to one point, the answer "I don't know but I remember this information was on the site" – 2 points, and the correct answer – 3 points. The ratings of individual aspects of the sites used numerical values on a scale of 1 to 5.

Table 1 and Figure 2 provide a combined statistical breakdown of the results of two parts of the experiment: an analysis of memorability of the content presented on the site and the ratings analysis of various aspects of the three versions of the sites. Each interface is marked with a Roman numeral, where I corresponds to the simple interface, II to the moderate interface, and III to the complex interface. The memorability is represented by a numerical value being the average of the sum of all test responses for all the participants. The interface rating is calculated by averaging all ratings of individual aspects of the services for all the test participants.

Table 1. The statistical summary of the results of two parts of the experiment: an analysis of the memorability and an analysis of the evaluations of the interfaces of three websites

Interface		I	II	III
Memorability level	Mean	15.33	16.83	15.54
	Median	15.50	17.00	16.00
	Std Dev.	2.37	2.73	3.36
Interface rating	Mean	3.92	4.24	4.00
	Median	4.00	4.30	4.00
	Std Dev.	0.61	0.51	0.64
Number of responses	Correct answers	86	110	95
	"I don't know but I remember ..."	40	20	30
	Incorrect answers	30	34	28
	"I don't know and there was no such information ..."	12	4	15
Average number of responses	Correct answers	3.58	4.58	3.95
	"I don't know but I remember ..."	1.67	0.83	1.25
	Incorrect answers	1.25	1.42	1.67
	"I don't know and there was no such information ..."	0.50	0.17	0.63

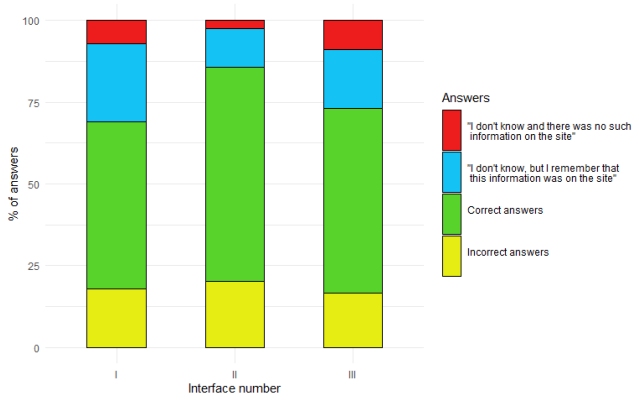

Fig. 2. The percentage of answers of each type for respective interfaces (I-III)

In the study the highest memorability shown by the highest score was observed in the case of interface II with the moderate level of complexity. The largest spread of results occurred in the case of interface III – a complex one (SD = 3.36), which received both the lowest and highest scores. The average memorability score for the simplest interface was lower than for the other two interfaces. On the other hand, the moderate interface achieved the highest mean and median scores. The memorability scores for the simple and the complex interface were similar. The participants using the moderate interface tended to answer more questions correctly than those using other interfaces. The fewest correct answers were usually given by the participants using the simple interface. The largest number of "I don't know but I remember that this information was on the site" responses was given by the participants using the simple interface and the smallest by those using the moderate interface. The number of wrong answers was similar for all interfaces, but the smallest number appeared where participants used the complex interface. The answer "I don't know and there was no such information on the site" was the least common for the moderate interface, while the numbers for the simple and the complex interfaces were comparable being 12 and 15, respectively.

The participants of the experiment rated the moderate interface the highest, with an average rating of 4.24. The average ratings for the simple and complex interfaces were similar, at 3.92 and 4.00, respectively. The complex interface received more varied ratings (SD = 0.64). The simple interface received the lowest ratings. Furthermore, each interface was also given the maximum rating by at least one user.

Figure 3 presents two graphs that reflect the results shown in Table 1 that demonstrate the levels of memorability and evaluation of the interfaces. The coloured boxes indicate values between the first and third quartiles, the vertical lines inside the boxes – medians, the "whiskers" connect the minimum (on the left side of the box) and maximum (on the right side of the box) values. The dots, on the other hand, represent the outliers.

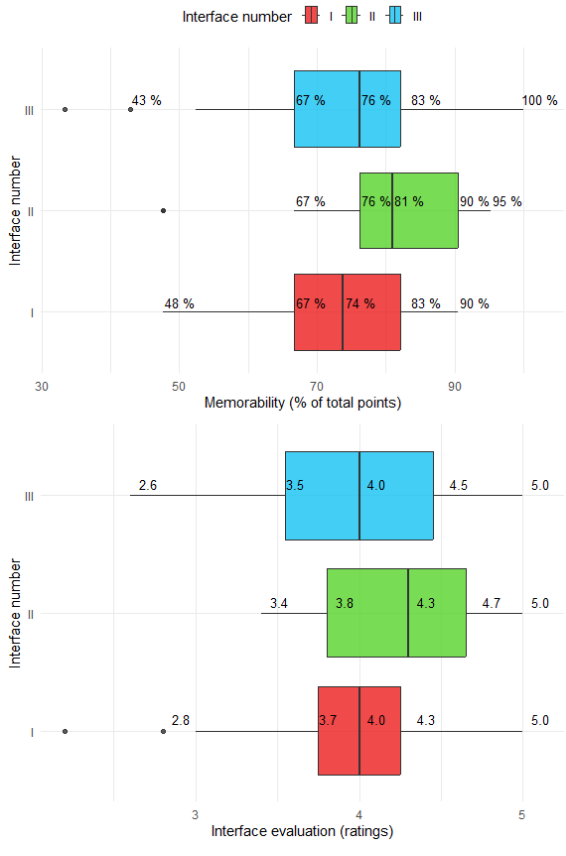

Fig. 3. The percentage of total points gained by the participants (top) and average participants ratings (bottom) for each web interface (I-III)

The top graph in Figure 3 represents the percentage of points scored by individual participants. The most frequent scores in the simple interface were between 67–83% with a median at 74%. The moderate interface performed best with the most frequent values between 76% and 90% with a median around 81%. In contrast, the users of the advanced interface had the most frequent results in the 67–83% range, which is similar to the simple interface, but with a higher median at 76%, which can indicate higher values. From the arrangement of the boxes, however, it can be seen that the users of interface II, i.e. the moderate one, scored more points above 83% of all than the users of the other interfaces.

The situation is similar for user ratings of the interfaces. In the bottom graph in Figure 3, it can be seen that the most popular range of values in the ratings for the simple interface was between 3.7 and 4.3, with a median score of 4.0. In the moderate interface, the ratings tended to be in the 3.8-4.7 range, with a median score of 4.3. In contrast, interface III received the most ratings between 3.5 and 4.5, with a median score of 4.0.

Both the highest memorability scores and the high interface ratings were related to the moderate interface. These results can be observed in Figure 4 in the form of green colored triangles located in the area marked with a red ellipse.

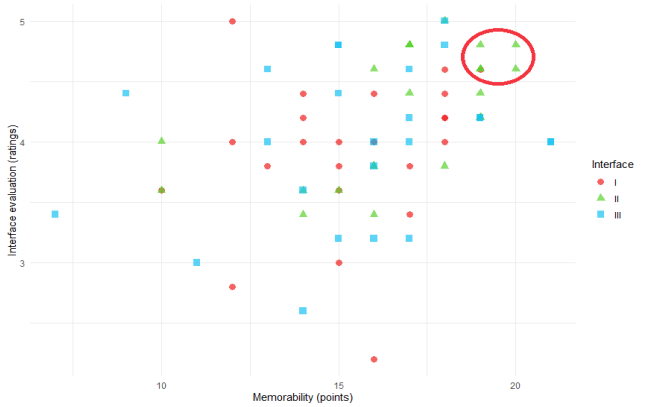

Fig. 4. Overview of memorability results and interface ratings for each website (I-III)

During the study, it was observed that there were large differences in the degree of computer literacy among the study participants, which due to the relatively small study group cannot be averaged, and as a result, the significance threshold for statistical analysis was set at 0.06. Due to the lack of a normal distribution for the variable "Memorability level" of the moderate interface, it was not possible to conduct an ANOVA (analysis of variance). Therefore, it was decided to perform the Kruskal-Wallis test, which is its non-parametric counterpart. The P-value for this test reached 0.05806, which, with the assumed significance threshold, allows to reject the null hypothesis that there are no significant differences between the groups. This means that the alternative hypothesis can be accepted and it is possible to conclude that there are significant differences between the three groups analyzed, although the result is close to the assumed significance threshold.

In order to check exactly which groups differ from each other, the Wilcoxon test for pairs of observations was conducted. The resulted p-values are shown in Table 2. At the assumed significance threshold, it can be concluded that memorability results while using the moderate interface differ from those in the simple interface ($p = 0.056$). In contrast, the level of memorability for the complex interface does not differ significantly compared to the other two interfaces. At the same time, the high p-value may indicate that the least significant differences occurred while comparing the results of the simple and the complex interface.

Table 2. The results of the p-value Wilcoxon test for pairs of observations for the level of memorability expressed by the number of points scored in a given interface

Interface	I	II
II	0.056	-
III	0.670	0.148

On the other hand, for the "Interface rating" variable for individual sites, the Kruskala-Wallis test resulted in a p-value of 0.1978. This means that there seems to be no basis for rejecting the null hypothesis for this test, and therefore it can be deduced that there are no significant differences between the ratings of the various interfaces given by the study participants.

In accordance with the hypothesis the obtained results indicate that the interfaces of moderate complexity are the most understandable for students and let them memorize the most information. The moderate interface did not prove to be the best in terms of memorability only when the number of incorrect answers is taken into consideration. This may be due to the fact that the information in question was seen and identified on the site but was not memorized by the participant. The moderate interface received the highest ratings in the questionnaire on the subjective opinions and feelings of study participants.

In the case of the complex interface, most participants answered "I don't know and there was no such information on the site", which suggests that some information on the site was missed. This is especially the case with information hidden under various interactive elements, which were not properly and precisely described. Similar observations were presented in an article by A. Osmulska et al. [13], which stated that although graphical buttons speed up operations in the interface, they can also make usage difficult for people with little experience, visiting the site for the first time or only using it occasionally. The worst ratings were given by users operating the simple interface. Its text-based, unattractive form did not evoke interest in its content among schoolchildren; instead it was perceived as boring, monotonous and tedious and hence the low level of content memorization by students and their low ratings of this interface marked in the questionnaire.

At the end of this section, it is important to mention some limitations of the conducted research. The interfaces were tested by relatively small groups of participants consisting of an average of 24 students. For statistical purposes this would have to be increased. Another issue that was not taken into account was the varying level of computer skills among the students. Future research should consider creating and adding two intermediate sites between a complex and a medium complex site and between a medium complex and a simple site.

4. Conclusions

The results of the statistical analysis confirmed the hypothesis that the complexity level of the website's layout influences the amount of material learned and memorized. In addition, the results of the tests conducted on the interface with the medium complexity differed the most from the results of the other two website interfaces prepared for the study.

The collected results demonstrate that the best performing interface in the study was the one with moderate complexity which was prepared in accordance with universal design principles. It is worth pointing out there were no major differences in users' subjective ratings of the interfaces, although both the median and mean of these ratings were highest for the interface of moderate complexity.

In conclusion, the moderate interface performed considerably better than the other two interfaces. However, due to the similar probability values of the test statistic (p-value) to the adopted significance threshold during the statistical analysis conducted, it is worth undertaking further research with a larger group of participants, in order to ensure that the level of computer skills of the participants is equal and sufficient.

When designing services, especially those of an educational nature, it is important to bear in mind their main objective, which is the effective transfer of knowledge. At the same time, it should be remembered that the form in which the content is presented is of great importance. The research done has shown that it should be moderately complex, and in order to achieve this, good practices should be taken into consideration, which were used by the authors during the construction of one of the analysed sites. Decorative and graphically attractive elements, if they appear on the page, should not distract the user from the content. Furthermore, it is good if all the material is displayed on the page and reaching the content does not require any additional interaction. It is also a good idea to divide the text displayed on the screen into smaller sections and arrange them according to hierarchy of importance using dividing lines and their logical positioning. When graphics are used, they should be relevant to the information displayed. Graphics should be of an appropriate size so as not to dominate or unnecessarily distract from the content. The use of text links is not recommended; it is better to replace them with buttons with captions. On the other hand, it may be beneficial to use highlighted subpage titles which show where the user is currently on the site and how far away he or she is from the end of the lesson. Sensible moderation is also recommended when it comes to the colour scheme of the site. To increase readability and create interest, it is sufficient to use 3 colours so that they contrast with each other. It is also necessary to equip the site with basic accessibility tools to change the contrast and to change the font size of the text displayed.

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