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APPROACH TO COMPREHENSIVE WEBSITE TESTING: COMBINING USABILITY AND FUNCTIONAL TEST METHODS

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Abstract. *Testing website interface is a rather complicated process due to the large variety of existing testing methods. The article discusses an approach for testing the interfaces of educational and e-commerce websites in working conditions, which includes a combination of usability and functional testing methods. Based on the analysis of test results, possible types of websites projects and their constraints, we propose a test approach that provides an effective usability evaluation and verification of interface interaction with the server-side component of educational or e-commerce website. We expect the proposed approach can be used to identify a larger number of errors on a website in use and to form recommendations for its improvement when testing resources are limited.*

Keywords: *WEBSITE, USABILITY, FUNCTIONAL TESING, HEURISTICS, EXPERT, SURVEY, QUALITY.*

Introduction

It is important for the user to complete their task through the website (such as purchasing a product online, viewing electronic publications, etc.). The statistics show that in 2024, some of the most visited types of websites worldwide were e-commerce and educational websites [1].

Errors found on existing websites can create a negative impression on users, and a report by Microsoft shows that 56% of consumers stopped engaging with a brand due to a poor customer service, which includes digital interactions on the website too [2]. According to statistics, 67% of visitors report that unpleasant experiences are the reason for leaving a website. Furthermore, nearly 94% of users initial impressions of a website depend on the perception of its design [3]. In order to develop a high-quality website that meets the main user requirements, it is essential to conduct thorough testing to ensure user satisfaction and prevent errors in key interactions [4, 5].

Usability testing is the process of evaluating and ensuring the ease of use of a website for users of a digital interface. On the other hand, functional testing verifies that the product performs its main functions correctly. However, conducting only

usability testing on modern dynamic web pages does not guarantee the correct work of operations such as event handling, server requests, work of timers or complex animated components that display data based on user actions performed. Moreover, functional testing does not allow assessment of what users like or dislike about the product, nor does it offer a quantitative measure of such preferences [6]. Overall, this paper describes the proposed test approach for educational and e-commerce websites in use, which was designed to find more errors and, consequently, to ensure a positive user experience as well as to increase user loyalty and encourage long-term use of the website.

The purpose and objectives of the research

The purpose of this research is to improve the website interface testing process using the developed approach, which consists of combination of usability and functional testing methods.

To achieve this goal, the following tasks need to be solved:

– analysis of educational and e-commerce websites for testing;
– search for test participants;
– tests implementation and execution;
– analysis of errors found;
– developing options for using a test approach, depending on the possible type of the website's project.

Main part

Selection of websites for testing

The following websites were selected for testing:

– website #1 – *NURE*, https://nure.ua/;
– website #2 – *Dim Ria*, https://dom.ria.com/;
– website #3 – *Drink Arizona*, https://drinkarizona.com/pages/coffee-quiz/;
– website #4 – *MakeMyTrip*, https://www.makemytrip.com/how2go/.

The websites belong to the categories of the most visited websites in the world such as educational and e-commerce.

Before conducting testing it is essential to identify the most important user tasks because the goal of the testing is to effectively evaluate the website's interface. In accordance with the principle of priorities, the most typical user actions (tasks) related to the main functions of each website are analyzed.

Intuitive navigation on website is important for modern users [7-10], as well as ability to find and select quickly the necessary information [11, 12], for instance by using filters [13]. Also, statistical data show that today it is important for the active target audience of customers to use a discount in the form of a promo code on an e-commerce website [14]. An interactive quiz is capturing the audience's interest as it provides users with product purchase recommendations [16].

The key features and target audience of the selected websites were examined.

1. *NURE* website is an educational website of the Kharkiv National University of Radio Electronics. The main functions of this website are informational and navigational as users search for the necessary information. The main audience of this website includes students (18-24 years old) and faculty members of the institution, as well as applicants (under 18 years old) and their parents (35-54 years old).

2. *Dim Ria* website is an e-commerce website for real estate rental and sales. Some of the key functions of the Dim Ria website are search and the use of filters. User enters search parameters such as city and property type, and can also apply filters to refine the results (e.g., by neighborhoods or amenities). The main audience of this website includes families looking for apartments or houses for long-term rent (35-54 years old) and students (18-24 years old) or professionals seeking temporary housing for personal needs (20-34 years old).

3. *Drink Arizona* website with a *coffee quiz page* is a website for beverage sales with an interactive quiz that recommends a drink for a user. The target audience for this website includes young people (18-30 years old) interested in new beverages and cocktails, as well as adult beverage enthusiasts (35-54 years old). Some of the main functions of the quiz are navigational and informational. In most cases, the quiz is taken to receive beverage recommendations.

4. *MakeMyTrip* website with a *How2Go page* is an e-commerce website for searching and booking travel tickets for various types of transportation and routes within India. The target audience for this website includes travelers, families (35-54 years old) and students (18-24 years old) planning a vacation. Some of the main functions of *MakeMyTrip* website are searching for tickets, as well as using discount promo codes. Users can filter results by price, transportation type and other options. Most often, users enter the departure point, destination, and travel dates. The website displays available options with prices, travel times, and other parameters.

Analysis of usability testing methods

Usability testing is the process of evaluating and ensuring the ease of use, accessibility and overall user experience of a digital interface. It is important to identify and address issues that may affect user's satisfaction and engagement [17, 18]. The most common methods for evaluating the quality of a user interface, which are suitable for applying to a website in use, were examined [6, 19-21].

Heuristic evaluation.

The goal of heuristic evaluation is to identify potential design problems in a user interface. Its main feature is the quick analysis of the interface in order to detect problems with its ease of use.

Using the results of analysis of website's key functions, we create a set of heuristics based on Nielsen's 10 heuristics [22]. The obtained set of heuristics will be common for testing various website's functions from a usability perspective.

The selection of common heuristics for websites is performed using the method of expert evaluation and assessment of consistency of expert opinions. The most important criterias with a high degree of importance will be chosen as heuristics for testing.

The number of experts for heuristic evaluation can be limited to 5-7 people, who will be able to identify about 80% of the issues [23]. Experts should have basic knowledge of usability, design of interfaces and user experience.

After selecting the heuristics, a set of test questions (survey) is created. The test questions should cover the heuristics and take into account key functions of the websites. In order to facilitate the work of the experts, a description of the task is provided before the test questions. The description of a task is in the form of a sequence of steps required to verify the heuristic. The development of test questions can be based on the experts' experience with the given website and similar ones. The resulting set of questions is then minimized and the most important ones are selected.

Additionally, the following quantitative usability metrics are considered:

– task completion time (on average);
– number of errors found while using a function;
– number of successfully completed tasks during testing.

Test questions and descriptions of key tasks for each selected heuristic are combined into a group of test scenarios. These questions are then added to the survey using the Google Forms service for collection and analysis of experts' responses. When the survey is created, the heuristic evaluation is conducted by all experts. Experts should not see each other’s evaluations until their own evaluation is complete.

When creating questions for heuristic evaluation, closed-type questions were used with the following features:

– rating scale for evaluation, such as the Likert scale, which indicates the degree of agreement of the respondent with the statement on a scale from 1 to 5 (where 1 - is the lowest score and 5 - is the highest score). Additionally, highest and lowest scores were matched with a linguistic rating (e.g., from ‘Difficult’ to ‘Easy’ and others);

– multiple choice questions («What would you like to improve on the website?»);

– single choice questions («Have you encountered any errors while using the website?»).

Open-ended questions were related to the experts' opinions on what specifically could be improved on the website.

Before starting the usability testing participants provide information on which device they will perform testing (smartphone, laptop, computer, tablet).

After completing the test tasks and providing answers to the questions, the results of the survey are analyzed and a report is created with the identified issues. As a result of this stage, conclusions will be drawn about the level of potential usability problems on the websites. These will take into account factors such as number of identified errors, average task completion time and user satisfaction with the website design.

All identified issues are documented and assigned a severity level. The following severity level scale can be used to assess severity of usability issue:

– 5 points – very critical issue that completely blocks the use of the website;

– 4 points – high severity, issue significantly interferes with task completion, should be fixed as soon as possible;

– 3 points – medium severity, issue negatively impacts user experience, but does not affect task completion;

– 2 points – low severity, issue negatively affects the perception of interface, but does not require immediate fixing;

– 1 point – very low severity, issue related to very minor discomfort (e.g., a text error).

Experts in heuristic evaluation may also provide recommendations for improving the usability of the websites.

Usability task based testing.

The aim of usability task based testing is evaluating the ease of use of a product or system in the context of performing specific tasks by respondents. The main objectives of usability task testing include:

– assessing product's ease of use, determining how easily users can perform tasks;

– identifying issues that prevent users from completing actions;

– optimizing the interface, specifically gathering data that will allow to improve design and functionality of the interface.

In order to perform usability task based testing, it is important to involve real users and then a survey or questionnaire should be conducted among them. To determine the minimum number of respondents, the representativeness of the sample needs to be calculated. To assess the required scope of the representative sample n, the formula is applied:

$$n = \frac{s^2 Z_\infty^2 N}{\Delta^2 N + s^2 Z_\infty^2} = \frac{pq Z_\infty^2 N}{\Delta^2 N + pq Z_\infty^2},$$

where N – size of general population;

Δ – sampling error or the discrepancy between the characteristics of the sample and the population. The sampling error is set by the researcher and it is generally not recommended to accept a sampling error greater than 0.05 or 5%;

Z – coefficient that depends on the confidence level chosen by the researcher. For usability testing, a 95% confidence level is used in most cases, as the main goal of the testing is to identify key issues and hypotheses for improving the interface. For a 95% confidence level, the corresponding Z coefficient value is 1.96;

p – proportion of respondents with the studied characteristic. If the percentage of respondents with the selected characteristic is unknown in advance, the most likely proportion p = 0.5 or 50% is usually assumed, as it gives the maximum possible error and, accordingly, the largest required sample size for a given confidence level;

$q = (1 - p)$ – represents the proportion of respondents who do not have the studied characteristic.

In order to obtain more objective survey results, it is recommended to follow certain requirements for testing participants. These should be representatives of typical age groups for popular websites. It is recommended that half of the respondents have experience using similar websites, and ideally, there should be a number of respondents without such experience. Three-quarters of the respondents should be within the target audience age range, and approximately one-quarter should be outside of this range. Respondents should conduct testing on various types of devices (smartphone, laptop, etc.) to cover the scenario of using the website on screens of different sizes.

In usability task based testing the main user tasks (functions) of the websites are defined. When the tasks are defined, a set of questions is created for these tasks. The main goal of the question is to find out if a specific function on the website is easy to use. The resulting set of questions is then minimized, and the most important ones are selected. Additionally, evaluation scales for answering the questions are chosen, similar to the scales mentioned above for heuristic evaluation. Quantitative metrics are also taken into account and they are similar to those used in heuristic evaluation. Created questions are added to the survey and sent to the respondents.

Next, usability task testing is carried out with required number of participants. Finally, obtained results are collected and analyzed, and then a report is prepared with the identified issues. The issues are assigned a severity level (see severity level scale for heuristic evaluation mentioned above).

The main challenges in performing usability task based testing are finding participants for the test and conducting the test, which can take a lot of time. Usability task based testing is limited to certain scenarios and does not cover all possible paths of interface usage. Therefore, priorities in testing need to be determined from the very beginning. If a large number of responses are received, time must be spent for analyzing the respondents' answers and properly interpreting the context of the identified issues.

Analysis of AI heatmaps.

Heat map is a visual tool that uses a color palette to show which areas of a website receive the most attention from visitors and where their main activity is concentrated [24].

Heat maps use the following scale: warm tones indicate areas that users show the most interest in, while cool colors represent areas with the least attention. By analyzing the highlighted colored areas of heat maps, assumptions can be made on how to improve navigation and element placement to make them more user-friendly. The data from heat maps can be used to justify changes in design to the project management team. When analyzing heat maps for each website, screenshots of web pages that contain key website functions are prepared. These screenshots are then sent for processing to AI heat map generation service. Obtained heat map is analyzed and then conclusions are drawn about predicted user engagement for the elements of key website

functions. Lastly, recommendations for improving website elements from a usability perspective can be developed.

It is important to note that real IT projects may have specific internal rules regarding the use of third-party services and tools. Before using heat map AI generation services, it is essential to check the service's privacy policy regarding image processing and, if possible, obtain confirmation from the project manager to use such service.

Analysis of functional testing methods

Functional testing is aimed to verify that website or web application works according to the specified requirements [4]. It's important to pay attention to correct response of the interface to user actions, proper displaying of interface elements and interaction of interface with the server side. Functional testing includes black-box testing, which is done without reference to an application internal structure.

In order to identify critical errors in the web application as early as possible, risk analysis of the product is used [4, 25] and necessary test techniques are chosen to focus test efforts on most critical product areas. Test scenarios are prioritized by importance of execution, which can ensure quality within a limited time frame.

State transition testing.

In order to perform state transition testing, key states of a website are identified. They should represent critical stages of product usage. In context of websites, main pages or elements, which are important for user, can be selected as states. It is impossible to test all pages, so the testing priority principle must be applied to select the most important ones.

From this point, the main and most important transitions between states or actions that cause changes in states need to be determined. For instance, click on a link can cause transition to another web page. Then a transition matrix is created, showing the transitions between states. This will help visualize possible navigation paths on the site.

Based on the obtained state transition matrix, test scenarios are created in tabular form or as statements, and testing is conducted. It's important to verify that the transition between states occurs without errors, the necessary information is displayed on the target page, and key elements work correctly. If the actual test behavior matches the expected one, the test case status is marked as 'PASS', otherwise, it is marked as 'FAIL'. When test results are obtained, they are analyzed and errors found are documented and reported. The errors are assigned a severity level.

Positive and negative testing.

Positive and negative testing of a website starts with analysis of the most typical user actions and key functions that matches them on websites. Test scenarios are created, which include both positive and negative scenarios of website's functions usage. It is recommended to test cases where errors may occur during the use of website's functions. Based on the test results, a report is prepared with the errors found. Each error is assigned a severity level.

Scenario testing.

Before conducting scenario testing, test scenarios are created that cover real user tasks. It is better to choose the most commonly used scenarios for the key functions on the target websites or similar ones. After selecting the scenarios, the tester (QA) begins executing them. Finally, retrieved test results are analyzed and errors found are assigned a severity level.

Test closure activities

After completing the testing, it is necessary to analyze the obtained results [26]. It is important to consider that the same issue on a website may be found by several test methods at the same time.

This may show a correlation between errors in correct work of website functions and their usability. Therefore, if an issue is repeated across different types of test methods, it clearly points to a defect that requires an attention of the entire project development team and which has a high likelihood to have a negative effect on product quality, making it important for fixing.

Obtained analysis results are handed over to the website development team and the project manager.

Research results

Application of the developed approach to testing

All selected tested websites belong to the categories of the most visited websites in the world, such as education and e-commerce. It is assumed that the primary users of all the websites have above-average experience in using computers or smartphones and use the internet quite often.

1. Implementation of heuristic evaluation.

In order to identify potential usability issues in design of website interface through heuristic evaluation, a set of heuristics was composed. Selected heuristics were common for evaluating functions, such as navigation, applying filters and promo codes across different websites. The expert evaluation method was used to develop this set of heuristics. Based on the key functions and complexity level of websites, six experts were involved in the testing, including fourth and sixth year students of specialty G20 Publishing and Printing.

Assessment of the importance of Nielsen's 10 heuristics was conducted using a scale from 1 to 10 (where 10 means the property is fully present, and 1 means the property is absent).

The relative weight (w) was calculated for each heuristic in order to assess its importance. The weight of a heuristic w was calculated as the ratio of the total sum of ratings for each heuristic to the sum of all total ratings using the following formula:

$$w_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}},$$

where x_{ij} – represents total sum of ratings for each heuristic.

The ratings provided by the experts were checked for consistency using the calculated value of the coefficient of variation for each heuristic, according to the following formula:

$$V = \frac{\sigma}{\bar{X}_e} \cdot 100\%,$$

where σ – represents a standard deviation;

$\bar{X}_e$ – represents a mean value according to all the experts.

$$\sigma = \sqrt{\frac{\sum_{j=1}^{n} \left(X_j - \bar{X}_e \right)^2}{n}},$$

where X_j – represents the rating given by the j-th expert;

$\bar{X}_e$ – represents a mean value of the rating according to all the experts;

n – represents a number of all experts.

The obtained values of the coefficient of variation for each heuristic are $V \leq 0.2$, which shows consistency in the experts' opinions.

Based on the results of the expert method, 6 heuristics were selected for usability testing, which are common for evaluating key functions on 4 websites:

– visibility of system status (w = 0.11);
– user control and freedom (w = 0.12);
– recognition rather than recall (w = 0.10);
– flexibility and efficiency of use (w = 0.10);
– error handling and recovery (w = 0.11);
– aesthetic and minimalist design (w = 0.09), this heuristic will be used to evaluate the overall design of the website [27, 28].

The defined key functions of the websites were used in order to formulate questions for heuristic evaluation. Key functions were covered with at least one of selected heuristics.

Questions were using a scale from 1 to 5 and there were such types of questions in survey as multiple-choice, open-ended and close-ended questions.

A Google Form was created for participants to provide their responses during heuristic evaluation. The form contains components such as a description of the main tasks and questions for each of selected heuristics.

Example of form's section with some questions for Dim Ria website is shown in Figure 1.

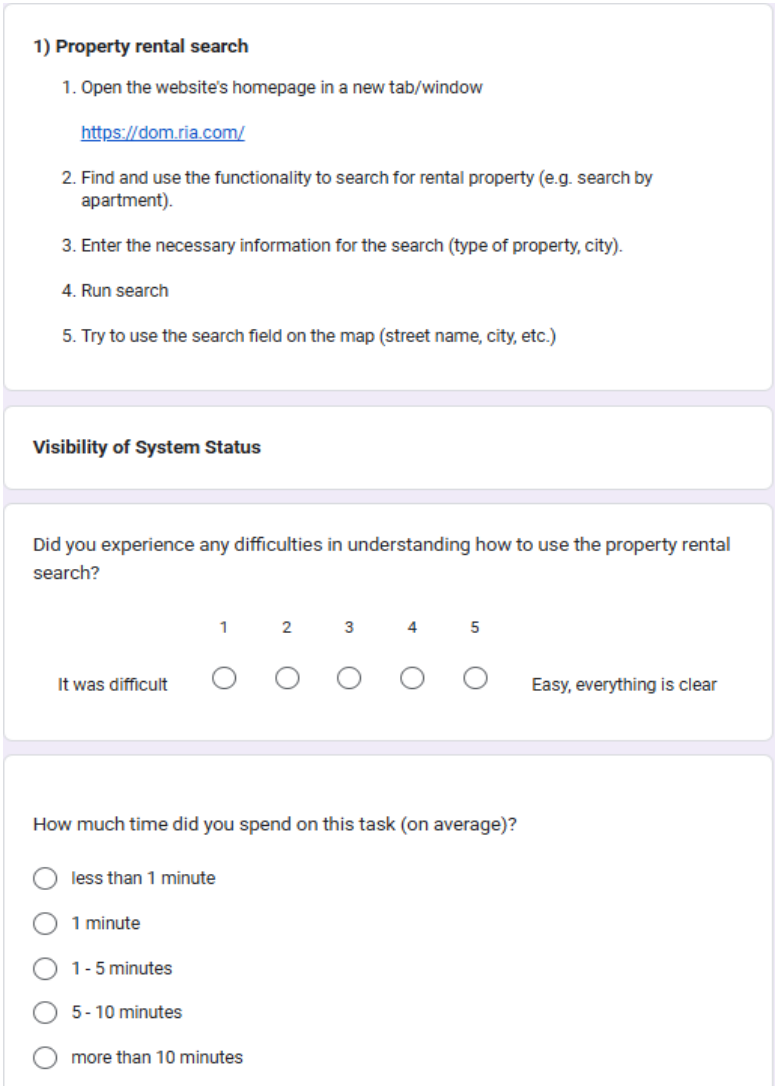

Figure 1 – Example of form's section with some questions for Dim Ria website

Since the group of questions includes optional and open-ended questions, in order to ensure the correct calculation of experts' opinion consistency, it was appropriate not to consider such responses due to the difficulty of converting them into numerical form. Responses such as 'Yes' or 'No' were converted into numerical values, where 'Yes' option was assigned the highest rank (score 5) and 'No' option was assigned a slightly lower rank (score 3).

If the website contained several key functions, the overall group of questions was divided into several separate groups to calculate the consistency of experts' opinions for each function.

When usability of the website functions was evaluated by experts, the quantitative survey results were obtained. In a similar manner, usability was evaluated for the other websites functions using heuristics.

The obtained experts' ratings were normalized for more accurate data usage, ensuring that the sum of ratings in each column equals one, with each rating in the column being divided by its sum. The results with the normalized data for the heuristic evaluation of the website's navigation function on Dim Ria website are shown in Table 1.

Table 1 – Normalized experts' ratings for the heuristic evaluation of the navigation function on Dim Ria website

Function	Heuristic	Question	Experts					
			1	2	3	4	5	6
Navigation	Visibility of system status	Did you experience any difficulties in understanding how to use the property rental search?	0.12	0.11	0.09	0.11	0.09	0.14
	User control and freedom	How easy was it for you to clear the data from the search bar?	0.08	0.11	0.11	0.11	0.11	0.14
	Recognition rather than recall	How would you rate the amount of information on the map? Is there anything excessive or unnecessary?	0.12	0.09	0.11	0.11	0.11	0.11
		How would you rate the emphasis on important search elements (input fields, buttons) on the page?	0.08	0.09	0.11	0.11	0.11	0.11
	Flexibility and efficiency of use	How would you rate the ease of changing search data? (e.g., street, city, subway)	0.08	0.11	0.11	0.05	0.11	0.08
	Error handling and recovery	Have you encountered any errors while navigating and searching the website?	0.12	0.07	0.07	0.14	0.07	0.08
	Aesthetic and minimalist design	Do you think the website was overloaded with visual elements?	0.08	0.11	0.11	0.08	0.09	0.08
		How would you rate the color palette of the website?	0.08	0.11	0.11	0.08	0.11	0.08
		How would you rate the overall design of the website?	0.08	0.11	0.11	0.08	0.09	0.11
		Is there anything in the design or information that you think could be made simpler and more user-friendly?	0.19	0.07	0.07	0.14	0.11	0.08
Sum			1	1	1	1	1	1

The next step in assessing the consistency of experts' evaluations of the navigation function usability on Dim Ria website was to calculate the coefficient of variation, which is determined by the following formula:

$$V = \frac{\sum \sigma}{\sum \overline{x}},$$

$$V = \frac{0.193}{1} = 0.193.$$

If the coefficient of variation is $V \le 0.2$, the experts' opinions are considered consistent. The calculated value of the coefficient of variation indicates that the experts' opinions are consistent.

The Kendall's coefficient of concordance was calculated for navigation function of Dim Ria website:

$$W = \frac{12 \cdot S}{m^2 \cdot \left(n^3 - n\right)},$$

where m – number of experts;

n – number of criteria;

S – standard deviation of all rating scores:

$$S = (d_i - \bar{d})^2,$$

where d_i – the sum of the ranks of the i-*th* indicator across all experts:

$$d_i = \sum r_{ij},$$

where r_{ij} – the sum of the ranks of the i-*th* indicator, determined by the j-*th* expert;

$\bar{d}$ – the average value of the criteria, which is determined by the formula:

$$\bar{d} = \frac{n(n+1)}{2},$$

$$m = 6,\ n = 10,$$

$$d_i = 6,\ \bar{d} = \frac{10 \cdot (10+1)}{2} = 55,$$

$$S = (6 - 55)^2 = 2401,$$

$$W = \frac{12 \cdot 2401}{6^2 \cdot (10^3 - 10)} = 0.808.$$

Obtained concordance coefficient value of 0.808 for the navigation function on Dim Ria website shows that the experts' opinions are consistent.

In the same way, the coefficients of variation and concordance were calculated for the key functions of all websites. The obtained results are consistent, showing that the experts' opinions align in terms of evaluating the usability of the main functions of the websites based on the heuristics.

The data obtained from the heuristic evaluation of all 4 websites show that 50% of experts conducted the testing on laptops, about 33% on smartphones, and nearly 17% on desktop computers.

1. Overall, for *NURE* website the survey results show that the interface and navigation on it were well rated by the experts, while critical issues were related to search bar element and presence of broken links for some courses and other pages. Testing results for *NURE* website show that 66.7% of experts did not encounter any errors when navigating and searching on the website, while only 33.3% experts noticed errors with these functions. The errors found form a group related to the website's navigation.

The average satisfaction level of the website's design was 3.7 out of 5 possible points. Half of the experts also felt that the website was overloaded with visual elements and the design could be improved. The experts were satisfied with a way how easily users could navigate between sections, as well as with the focused emphasis on important webpage elements.

2. Survey results for *Dim Ria* website show that the experts were satisfied with the navigation on the website and the ease of changing filters. 1 major defect and several minor issues were found during testing. Issues found were related to search by street address on the map and the presence of very large number of filters.

It is worth noting only 16.7% of experts encountered issues on the site. According to the experts, in general, the design of Dim Ria website is good, with an average satisfaction score of 3.8 out of 5 possible points.

3. Survey results for *Drink Arizona* website show that respondents were satisfied with the navigation in the quiz. 1 major defect and 1 minor defect were found during testing, both related to the navigation within the quiz.

It is worth noting only 16.7% of experts encountered issues while using the quiz. Almost all experts rated the quiz design as good, with an average satisfaction score of 4.8 out of 5 possible points.

4. Survey results for *MakeMyTrip* website show that respondents were satisfied with functions such as search by route, filters usage, and applying promo codes. 1 major defect and 1 minor defect were found during testing. Issues found were related to the website's design, specifically with the overloaded advertising banners and unclear margins in the search results.

The average satisfaction score for the website's design was 4 out of 5 possible points. Half of the experts rated the design as good, while the other half found it not very user-friendly, which may indicate the need to review the way how information is presented to user and its ease of perception.

2. Implementation of usability task based testing.

Usability task based testing was conducted to evaluate the ease of use of the websites by users. In order to obtain a representative sample, the minimum number of testing participants was calculated:

$$\mathrm{n} = \frac{\mathrm{pqZ}_{\infty}^{2}\mathrm{N}}{\Delta^{2}\mathrm{N} + \mathrm{pqZ}_{\infty}^{2}},$$

$$n = \frac{0.5 \cdot 0.5 \cdot 1.96^{2} \cdot 20000}{0.05^{2} \cdot 20000 + 0.5 \cdot 0.5 \cdot 1.96^{2}} = 284.03,$$

where N – size of general population. Considering the average visitors' statistics for the websites, N = 20 000;

Z – coefficient, which value is 1.96 for a 95% confidence level;

Δ – sampling error, which value is 0.05;

p – proportion of respondents with the studied characteristic, p = 0.5;

q – proportion of respondents who do not have the studied characteristic, $q = 0.5$.

Based on the calculation, the minimum number of survey participants should be 284 people. There were 312 respondents involved in the testing.

Three main respondent groups were involved in the usability testing of the websites. The first group consisted of students aged 18-19, the second group included users aged 20-34, and the third group included users aged 35-54. The distribution of respondents by group in percentages was 44.2% for first group, 42.3% for second group and 13.5% for third group.

Level of computer, smartphone and internet skills was generally above average in all groups. The third test group included a number of people who rarely use the internet but have experience using computers or smartphones. The first group and part of the second group consisted of third to sixth year students of specialty G20 Publishing and Printing, who have knowledge and experience in design and usability of digital interfaces, as well as online marketing. Additionally, almost all participants in the third group and part of the second group of respondents were IT professionals with more than 5 years of experience, such as software developers (backend, mobile) and QA engineers.

Usability testing was performed on the most popular types of screens, where 44.2% of respondents used smartphones during the testing, 38.5% used laptops, 15.4% used desktop computers and 1.9% used tablets.

Test scenario designer's experience in field of web applications testing, along with feedback from users working with similar websites, were used in order to select most important functions for users on the websites.

Using received data, usability tasks for survey were formed. An example of usability tasks for Dim Ria website is shown in Table 2.

Table 2 – Example of usability tasks for navigation and applying filters functions on Dim Ria website

Function	Question	Answer option
Navigation and search for information on a site	How easy was it for you to search for property rentals?	From 1 to 5, where 1 - is Difficult and 5 - is Easy
	Was it easy for you to use the search by name of street or city?	From 1 to 5, where 1 - is Not Easy and 5 - is Easy
	Was it clear to you how to use the property search on the map?	From 1 to 5, where 1 - is Very Hard and 5 - is Easy
	How much time did you spend on this task (on average)?	<1minute, 1 minutes, 1-5 minutes, 5-10 minutes, >10 minutes
Applying filters	How easy was it for you to find and use the filters to select the desired property?	From 1 to 5, where 1 - is Difficult and 5 - is Easy
	How much time did you spend on this task (on average)?	<1minute, 1 minutes, 1-5 minutes, 5-10 minutes, >10 minutes
	How easy was it for you to cancel the selected filters?	From 1 to 5, where 1 - is Difficult and 5 - is Easy

Table 2 Continued

Function	Question	Answer option
Applying filters	Was it easy for you to understand how to return from the property details view to the map (and vice versa)?	From 1 to 5, where 1 – is Not Clear and 5 - is Clear
	How much time did you spend on this task (on average)?	<1minute, 1 minutes, 1-5 minutes, 5-10 minutes, >10 minutes
	Were all the filters easy to understand and did they provide clear information?	From 1 to 5, where 1 – is Not Clear and 5 - is Clear
	How sufficient was the information about the property on the website for you?	From 1 to 5, where 1 – is Not Enough and 5 - is Clear
	How easy was it for you to change the selected filters?	From 1 to 5, where 1 - is Very Difficult and 5 - is Easy
	Did you encounter any errors while using the filters?	Yes or No
	The number of errors or issues found (if none, please enter '0')	Field to fill, your answer
	Brief description of the error/issue found in a few words (if any)	Field to fill, your answer
	Were there any interface elements that you didn't like or found unclear?	Yes or No
	Please specify what exactly you didn't like or found unclear (if any)	Open-ended question
Overall user experience on a website	How much do you like using the navigation on the website?	From 1 to 5, where 1 - is Don't like it and 5 - is Really like it
	How much do you like using the filters on the website?	From 1 to 5, where 1 - is Don't like it and 5 - is Really like it
	How much do you like design of the website?	From 1 to 5, where 1 - is Don't like it and 5 - is Really like it
	How satisfied are you with using this website?	Poor (the interface prevents me from completing tasks); Fair (there are serious issues that prevent the use of website); Good (there are minor issues, but overall the interface is acceptable); Excellent (the interface is intuitive and easy to use)
	What would you like to improve on the website?	Multiple Choice: Navigation; Intuitiveness and ease of use of the filters; Too much animation; Design (overall or of certain elements); Some website's functions are overloaded with visual details; Website is displaying results slowly; The presented way of solving tasks is not interesting for the user.
	Please specify what exactly could be improved in your opinion?	Open-ended question

Usability tasks and questions for the rest of the tested websites were formed in a similar way.

A Google Form was created for participants to provide their responses during testing. The form contained a description of key tasks and questions with answer options for each website. When all the respondents completed the testing, the following results were obtained.

1. Survey results for *NURE* website show that average satisfaction level of using the website interface is good, with some minor issues. Specifically, the navigation function had a positive perception from users, averaging 3.8 out of 5 points. The average satisfaction level of using the search bar was 3.75 points, which shows some problems with usability.

4 major defects and several minor ones were found during testing. Issues found were related to the search bar errors, errors in navigation and inconvenient design of elements. It is worth noting only 15.4% of experts encountered issues on the site.

According to the answers, in general, the design of *NURE* website is good, with an average satisfaction level of 3.4 out of 5 points. Respondents noted that they would like to improve the website's design, make some functions less overloaded with details, and also work on the navigation.

2. Survey results for *Dim Ria* website show that satisfaction level of using the key functions of the website is good and the website's interface is user-friendly. The average satisfaction level of using the navigation and filter functions was 4.4 and 4.3 out of 5 points, accordingly.

4 minor defects were found during testing. Issues found were related to inconvenient search by street name, also some users noted that the touchpad gestures didn't work well on a map, and the website froze on some smartphones when closing the cookie banner. Only 7.7% of respondents encountered errors on the website.

The average satisfaction level of the design of *Dim Ria* website was 4.25 out of 5 points. Respondents mentioned that they would like to reduce the user's memory load when using filters, work on the filters' design and ability to make them more intuitive.

3. Results of survey in general show good level of satisfaction with a quiz on *Drink Arizona* website, specifically the satisfaction level of the navigation function was 4.5 out of 5 points.

2 major defects and 5 minor ones were found during testing. Issues found were related to the error when users were adding products to the cart after quiz completion, error with not opening page for popular drinks, unclear way of returning to previous steps in the quiz and canceling the selected answer.

The average satisfaction level of the design of *Drink Arizona* website was 3.94 out of 5 points. Respondents noted that they would like to improve the design of elements related to the quiz (progress bar, Back button, answer selection) and the navigation.

4. Survey results for *MakeMyTrip* website show an overall good level of satisfaction with the website. Specifically, the satisfaction level of the navigation features was 3.63 out of 5 points, the satisfaction with the filter function was 3.88 points, and the satisfaction with the promo code function was 3.94 points.

2 major defects and several minor ones were found during testing. Issues found were related to the inconvenient way of changing route destinations, issue with tickets page loading for certain types of transportation (flight, train), as well as the overall website design overloaded with details and animations. A small number of test participants encountered an error showing that the website was not available in their region.

The average level satisfaction with the design of *MakeMyTrip* website was 3.7 out of 5 points. Respondents mentioned that they would like to reduce the number of details on the page and focus attention on the main tasks, improve navigation and usability of the filters.

3. Implementation of testing with AI heatmaps.

In order to generate heatmaps, the online service MediaModifier Heat Map, which uses artificial intelligence, was used. This service creates a predictive heatmap, providing a quick overview of potential user engagement level for any image, photo, or design. Heatmaps were generated for all 4 websites. During the analysis of the websites' heatmaps, 2 defects with moderate severity (3 and 2 points) were found on websites Dim Ria and Drink Arizona, accordingly. No issues with incorrect user attention engagement were found on NURE and MakeMyTrip websites.

4. Implementation of functional testing.

Before start of functional testing, the key functions of the websites tested were reviewed and then verified using black-box test techniques.

1. Navigation is a key function on *NURE* website. Therefore, navigation testing can be performed across website's sections and pages using a state transition test technique. Firstly, the key states of the website or target pages were identified, such as: Home page, University section, Applicants section, Students section and other main pages. Secondly, the main transitions between pages (states) were defined, and a state transition matrix was created with a description of the expected behavior after website moved to the next state. Additionally, main use cases were tested for search bar element near Contacts section, including positive and negative testing.

2. Navigation and the applying filters are one of the key functions on *Dim Ria* website. State transition testing was performed for these functions. Functional testing of the search bar element on *Dim Ria* website was performed by checking the main use cases and performing both positive and negative testing for it. Scenario testing technique was applied for filters on *Dim Ria* because of the presence large filters' number for selecting a property type.

3. Navigation is one of the key functions on Drink Arizona website. As quiz process relates to changing the states of web pages, state transition technique was applied during testing. Based on the use of state transition testing techniques, test scenarios were created and testing was performed.

4. Navigation, applying filters and promo codes are examples of key functions on *MakeMyTrip* website. Based on the use of state transition testing techniques, test scenarios were created and testing was conducted. Functional testing of the search bar

element on *How2Go* page of *MakeMyTrip* website was performed by checking main use cases and performing positive and negative testing. Results filtering by route type (e.g., fastest, cheapest) and sorting by mode of transport was verified. Testing of promo codes was conducted by creating positive and negative scenarios of their use.

An example of designed test cases and received test results for functional testing of NURE website are shown in Tables 3, 4.

Table 3 – Tests results for applying state transition technique on NURE website

#	Current State	Action	Next State	Expected result	Actual result	Status
1	Home page	Click on 'University' section	University page	List of available information about the university is displayed	List of available information about the university is displayed	PASS
2	Home page	Click on 'Applicants' section	Applicants page	List of links for applicants is displayed	List of links for applicants is displayed	PASS
3	Home page	Click on 'Students' section	Students page	List of links for students is displayed	List of links for students is displayed	PASS
4	Home page	Click on 'Science' section	Science page	List of links about science at the university is displayed	List of links about science at the university is displayed	PASS
5	Home page	Click on 'Education' section	Education page	List of links about education is displayed	List of links about education is displayed	PASS
6	Home page	Click on 'Press-Center' section	Press-Center page	List of links related to Press-Center is shown	List of links related to Press-Center is shown	PASS
7	Home page	Click on 'Contacts' section	Contacts page	University Contact information is displayed	University Contact information is displayed	PASS
8	Students page	Go to 'Timetable of Classes' page	Timetable of Classes page	Timetable of Classes page is displayed	Timetable of Classes page is displayed	PASS
9	Applicants page	Go to Specialties -> F3 Computer Science	F3 Computer Science page	Page with the info about Computer Science specialties is displayed	Page with the info about Computer Science specialties is displayed	PASS
10	Applicants page	Go to Home page	Home page	Home page is displayed	Home page is displayed	PASS
11	Home page	Go to 'Distance Learning' in the menu on the right	DL NURE service page	DL NURE service page is displayed	DL NURE service page is not opening	FAIL
12	Home page	Go to Education – Faculties at the bottom of the site	Faculties page	Faculties page is displayed	Faculties page is displayed	PASS
13	Applicants page	Go to Admission Rules 2025. Click on 'NURE Admission Rules in 2025'	Admission Rules page	PDF file with admission rules is being loaded	PDF file with admission rules is being loaded	PASS

Table 4 – Test results for search bar element on NURE website

#	Scenario description	Expected result	Actual result	Status
1	Search that gives results	Search results match the query	Search results match the query	PASS
2	Search that does not give results	Empty search result	Results are returned for English	FAIL
3	Search by part of a word or phrase	Search results contain part of a word or phrase from the query	Search results contain part of a word or phrase from the query	PASS
4	Search using different case (uppercase/lowercase)	Search is not case-sensitive	Search is not case-sensitive	PASS
5	Search using special characters	Special characters are ignored, search results are returned for the query	Special characters are ignored, search results are returned for the query	PASS
6	Search without hovering over the search bar	Search results match the entered query	Search does not start	FAIL
7	Search without parameters (empty search string)	An empty result is returned	Some results are returned	FAIL

After executing all the test cases, an overall test report was created that included errors found, as shown in Table 5. Results that were found by multiple testing methods are in italics.

Table 5 – Overall test report

Website	Heuristic/Function	Error found	Error's Severity
Heuristic evaluation			
NURE	Flexibility and efficiency of use	*Opening the wrong courses pages, displaying a white page*	4
	Visibility of system status	Search is inconvenient (through the search bar)	4
	Aesthetic and minimalist design	Design issues; Improve the design and add a dark theme; Make the 'News' columns the same length (based on the longest item), work on the website's navigation	3
Dim Ria	Flexibility and efficiency of use	Search by street name is not convenient	3
	Flexibility and efficiency of use	*There are too many filters, try to group them into logical categories for easier understanding*	2
	Aesthetic and minimalist design	Design issues; Font size of the headings on the homepage is a bit large	2
Drink Arizona	Flexibility and efficiency of use	Inconvenient to change selected option	3
	Flexibility and efficiency of use	Not clear what is the progress of the quiz	2
MakeMyTrip	Visibility of system status	Big padding in the route search results gives the impression that not everything has been loaded	3
	Recognition rather than recall	Reduce the number of advertising banners to simplify and minimize the information for user	2

Table 5 Continued

Website	Heuristic/Function	Error found	Error's Severity
Usability task based testing			
NURE	Navigation	Not all submenu items are visible on small screens	4
	Search	The search button was hard to find	3
		The search returns irrelevant results, for example, it's difficult to find anything about the scholarship ranking using the keyword 'scholarship'	4
		The search does not start if the cursor is not placed on the search bar	4
	Design	There is no support for standard accessibility features (keyboard navigation, partial hover support, all focus states)	3
		Carousel on the homepage looks doubtful	2
		Not a very user-friendly design; Improve the information structure; Use a minimalist design	3
Dim Ria	Navigation	Search by street name returns irrelevant results when the name is typed manually	3
		Touchpad gestures work poorly on the map	3
		The website froze on the smartphone when closing the cookies banner	2
	Filters	*Inconvenient to cancel the filters due to their large number*	3
Drink Arizona	Navigation	Unclear how many questions are in the quiz	2
		Inconvenient to cancel selected option	3
		The Back button is very small in comparison with other elements in quiz	3
		Product has not been added to the cart	4
		The page with popular drinks is not opening	4
	Design	Too bright colors	2
		Results are overlapped by the Accessibility icon when trying to view popular products	2
MakeMyTrip	Navigation	The page with tickets for certain types of transportation (book flight, book train) does not load	4
		Inconvenient to change the route destination points	3
		Website is unavailable in some regions	2
		The route search freezes on the smartphone	3
	Filters	*Unclear error appears when applying a filter that returns no results*	3
	Design	The interface is overloaded with visual details	4

Table 5 Continued

Website	Heuristic/Function	Error found	Error's Severity
Analysis of AI heatmaps			
NURE	Navigation	-	-
Dim Ria	Navigation	The menu with markers on the right side of the map is not critical, but it draws a lot of user attention	3
Drink Arizona	Navigation	Quiz answer options in the form of a list of rectangles with text distract the user's attention from the main question	2
MakeMyTrip	Navigation, applying filters and promo codes	-	-
Functional testing			
NURE	Navigation	DL NURE page is not opening from Home page	4
		Searching for a non-existent key returns result for English	2
		Search does not start if the cursor is not hovered over the search bar	4
		Searching with an empty field returns some results	3
Dim Ria	Navigation	Searching for a non-existent key returns results for English	3
	Filters	Results are returned when applying the «Search by ID» filter and future dates in the «Submission Period» filter	2
Drink Arizona	Navigation	*The selected answer option is not visible when returning to the previous quiz step*	3
		The cart is empty when adding items via «Add to Cart»	4
		404 error when navigating to the page with popular drinks	4
		Discounted item is overlapped by the Accessibility icon when trying to view popular products	2
MakeMyTrip	Navigation	'Oops, something went wrong' error occurs transitioning from the train route to the train selection page	4
		Search for a non-existent route does not start, and there is no hint why	3
		'No Locations Found' error is displayed when clicking on the search field after receiving results	2
		When navigating to the ticket selection page, an additional page for ordering tickets opens, and it is impossible to return to How2Go page	4
	Filters	*'Oops, something went wrong' error appears when applying a filter that returns no results*	4
	Promo Codes	Promo code is automatically canceled when using an already applied promo code again through the coupon input field	3

16 critical and 36 minor issues were found during testing. The results showed that issues, such as errors with the search bar element on *NURE* website, inconvenient way of changing the selected answer in the quiz, the inability to add the selected product to the cart, and problems with the Accessibility banner when viewing quiz results on *Drink Arizona* website, as well as an unclear error when nothing is found during results filtering on MakeMyTrip website, indicate a correlation between issues in usability and functionality of the website. These errors also have a negative impact on the product quality and are recommended to be fixed as important.

In order to develop the test approach for websites interfaces, a comparative analysis of the results obtained for each test method was performed, as shown in Table 6.

Table 6 – Results of applying testing methods for 4 websites

Test method	Average number of issues found	Average duration of execution by 1 participant	Number of participants	Number of working days
Heuristic evaluation	3.5	20 minutes	6	1
Usability task based testing	6.25	25 minutes	312	10
Analysis of AI heatmaps	0.5	1 hour (45 minutes for selection of key interface objects, preparation of screenshots, and 15 minutes for results analysis)	1	1
Functional testing	4	8 hours	1	1

To obtain a high-quality approach to website testing in use, it is necessary to determine the complexity of the website and its development project, as well as the level of formality of the test approach that will be acceptable in the existing conditions. A survey was conducted among IT specialists involved in the development of software products for identifying typical situations on projects when testing of a website in use is required. Based on their experience, 7 possible project options were defined:

1. A website of low complexity, the development team is small (2-5 people). There are limited resources and time allocated for testing, the testing process is not formally defined. Changes are planned in the website's UI/UX part (e.g., mobile adaptation of the site, interface optimization). No changes are planned for the website's server-side.

2. A website of low complexity, the development team is small (2-5 people). There are limited resources and time allocated for testing, the testing process is not formally defined. Changes are planned in the server-side of the website (e.g., performance optimization, integration with external services). No changes are planned for website's UI/UX part.

3. A website of medium complexity, the development team is medium-sized (5-10 people). There are limited resources and time allocated for testing, the testing process is not formally defined. Changes are planned in website's UI/UX part and the server-side, including the website's API.

4. A website of medium complexity, the development team is medium-sized (5-10 people). There are sufficient resources and time allocated for testing, the testing

process is formally defined. Minor changes are planned in website's UI/UX part (e.g., simplifying key elements, such as filters) and in the server-side (e.g., implementation of cloud technologies or integration with payment systems).

5. A website of medium complexity, the development team is medium-sized (5-10 people). There are sufficient resources and time allocated for testing, the testing process is formally defined. Significant changes are planned in website's UI/UX part (e.g., simplifying navigation on the site, mobile adaptation, optimizing the shopping cart and promo codes). No changes are planned in the server-side of the website.

6. A website of high complexity (but with low traffic), there is a large development team (10-30 people). There are sufficient resources and time allocated for testing, the testing process is formally defined. Minor changes are planned in website's UI/UX part and the server-side will be modified (e.g., optimization of the server architecture).

7. A website of high complexity (with high traffic), there is a large development team (10-30 people). There are sufficient resources and time allocated for testing, the testing process is formally defined. Changes are planned in the UI/UX part, as well as improvements for the server-side.

According to the reviewed testing scenarios and website's project constraints, the test approach consists of the following stages showed below.

1. Analysis of project indicators:

– criticality and complexity of website;

– planned changes on the website, such as changes in design, interface or server side (if applicable);

– size of changes on website (if applicable);

– project constraints (scope, time, budget, resource, etc.);

– maturity of the development process of a website.

2. Identification of key user tasks on the website:

– use experience with similar products;

– use users feedback;

– use web analytics data whenever possible.

3. Searching for test participants:

– heuristic evaluation: from 3 to 8 experts with at least basic experience in design and usability;

– usability task based testing: real users, representatives of the main target audience groups. It should be from 5 to 20 people for simple small projects, and approximately 50-150 people and more for complex projects;

– analysis of AI heatmaps: 1 designer or QA with basic usability knowledge;

– functional testing: 1 QA engineer, preferably with experience in UI and API testing.

4. Determination of project's type and its corresponding test method:

– project #1. Heuristic evaluation and analysis of AI heatmaps;

– project #2. Heuristic evaluation and functional testing;

– project #3. Heuristic evaluation and functional testing;

– project #4. Heuristic evaluation, analysis of AI heatmaps and functional testing;

– project #5. Heuristic evaluation, analysis of AI heatmaps, usability task based testing and functional testing;

– project #6. Heuristic evaluation and functional testing;

– project #7. Heuristic evaluation, usability task based testing, analysis of AI heatmaps and functional testing.

5. Test Implementation:

– heuristic evaluation: define a set of key heuristics for a website using the expert method; create a set of questions that verify the key tasks of the website and cover the set of heuristics; add the questions to a survey;

– usability task based testing: create a set of questions that will assess the usability and ease of use of the key website features, based on accumulated experience working with the website or its analogs; add the questions to a survey;

– AI heatmap analysis: create a set of screenshots of pages covering the key functions and interface elements of the website;

– functional testing: create a set of tests in tabular form, using techniques as state transition test technique, positive and negative technique and scenario technique, considering the key functions of the website.

6. Test execution.

7. Documentation of testing results, assigning severity to errors found.

8. Performing analysis of errors found, test report preparation.

9. Deliver test results to the development team and project manager.

The provided test approach helps to improve the process of finding more errors on educational and e-commerce websites in working conditions, as well as contributes to finding more areas for improvement and growth on the website. The use of a combined test approach affects comprehensive understanding of website's usability and the correct work of its key features. This is shown by the number of errors found during testing.

Analysis of the results of applying test methods provided an understanding of a way how these methods can be effectively applied on projects with different complexity.

The developed test approach for educational and e-commerce websites allows to perform effective testing, taking into account the complexity of the website, its development project and resources allocated for testing. It is recommended to use a larger combination of usability and functional testing methods for highly complex websites, as well as when large changes are planned in website's design or way of interaction with end user. The complex test approach conducted on a website will significantly increase the likelihood of creating a high-quality web application.

Conclusions

In conclusion, modern websites provide convenient approaches to solve user's everyday tasks online, such as making purchases, browsing and searching for information, etc. End users mostly interact with the website's business logic and databases through web pages, which have many elements, resulting in a complex user interface. Users are often provided with several options for interaction with the website (e.g., navigation, using filters, promo codes, etc.), which leads to appearance of various testing paths. As a result, the role of testing increases as it can identify errors both in the critical functions of the website and in its usability.

The study found that a combined test approach, using both usability and functional testing methods, is necessary for complex evaluation of the user experience on educational and e-commerce websites.

Developed test approach will help UI/UX designers, software developers, and QA specialists find a greater number of errors on the website, which will significantly improve the quality of the website in use. The obtained values of the severity of the errors found will assist the product manager, software developer and UI/UX designer in focusing attention on the main issues of the website and prioritizing their order for fixing.

The analysis of the results of applying test methods illustrates the possibility of applying their various combinations, depending on the potential types of website's development and its complexity. It has been determined that the preliminary analysis of project indicators and the defining of key user tasks on the website play an important role in this approach.

The obtained data showed that the use of the proposed combined test approach on educational and e-commerce websites in working conditions allows to find the most critical issues and identify opportunities for further improvement of the website. The results of the research may be of interest to a wide range of specialists (program managers, UI/UX designers, QA engineers, software developers) who aim to deliver a web application that meets user needs and helps achieve its key business objectives.

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