Usability of Educational Websites for Tablet Computers

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ABSTRACT
Learning outcomes depend significantly upon usability of educational websites. This paper places an emphasis on educational materials used on tablet computers as these devices are widely used in education today. Usability of educational materials is examined from three perspectives: education, gesture interaction and website. A number of studies consider those perspectives separately, such as usability heuristics for websites or gesture interaction on touch screens. Other research focuses on the impact of physical mobile device characteristics on usability. Educational sources underline the importance of learner’s motivation. However, those methodologies are not fully compatible; they emphasize different aspects. This paper aims at creating a consistent list of heuristics developed for educational materials for tablets. The pilot inspection on educational exposition of the Science Museum in London serves as the first validation stage of the developed set. The inspection confirmed the adequacy of developed set and unfolded omitted aspects.

Author Keywords
Usability; inspection; heuristics; education; mobile; touch screen; HCI

ACM Classification Keywords
H.5.2. User interfaces; Evaluation/Methodology.

INTRODUCTION
The growing usage of mobile devices and particularly tablet computers (further tablets) in education encourages designers to consider the usability of educational materials. Learning materials should be accessible from various devices and therefore are usually developed as websites.

Tablets have smaller screen and limited input capabilities than personal computers. The lower internet speed and lack of cursor makes browsing less comfortable comparing to desktop computers [25]. The browsing becomes more and more popular with mobile devices [27]. Therefore websites generally and educational particularly are adjusted for touch screen users’ needs [6]. Usability is a key component of commercially successful websites, because interactivity has a positive impact upon user satisfaction [17].

Primary example of universal usability principles for evaluation are Nielsen’s heuristics [21]. Domain-specific heuristics unfold the aspects important for particular domains. Web usability has been studied from various perspectives: learnability, consistency, safety and satisfaction [22], reliability and navigation [7], interactivity [17], layout [24], user return rate in commercial websites [2]. Existing usability inspection methods are not fully compatible, they highlight various aspects. Frequent usability problems of educational websites are inconvenient search, confusing navigation and redundancy of educational content [15].

There is no consistent method focused on educational website for mobile devices in general and tablets in particular. Educational material design requires to make decisions on amount of information, site structure, navigation and design as well as various ways of input, such as finger gestures [19]. Moreover, usage habits of young learners have to be taken into account when developing such a website. Users’ age is important for gestures interaction because children and adults intuitively choose different gestures [11].

This paper aims at developing the consistent list of heuristics that support usability inspection of educational websites for tablets. Figure 1 illustrates how the heuristics has been developed. The next section deals with the research on usability principles for educational websites. Then, the existing educational, mobile device with touch screens and website usability heuristics are analyzed, compared, and systemized. Further, the validity of the developed set was checked by inspecting the high quality educational objects in Science Museum in London. Finally, the refined set of usability heuristics is presented and conclusions are drawn.

USABILITY OF EDUCATIONAL WEBSITES
The usability of educational sites for tablets combines the educational, mobile device and website aspects. This section deals with related studies.
Existing usability heuristics:
- Nielsen’s heuristics
- Touch screen heuristics
- Educational websites heuristics
- Content management system heuristics

Development guidelines for educational websites

Gests interaction with mobile device

Aggregated heuristics

Summarized usability aspects

Validation by evaluating educational website

Final list of heuristics

Figure 1. The development of educational heuristics for tablets

Educational websites
There is no precise definition of educational website. It can be a site of educational institution although such a site does not support any learning [15,23]. It can also indicate the instructors’ sites with the instructional materials [9]. The educational website can refer to an electronic platform that stores resources for facilitating educational purposes and supporting active learning [4,12,20]. In this paper, the educational website is any site serving the learning purposes.

Educational sites support instruction, communication and supplementation. Instruction contains syllabus, homework assignments, class calendar, lecture materials, etc. Communication provides channel for user feedback and interactivity via web-boards, forums, chat rooms, etc. Supplementation provides additional information, external links that users may need [9].

Cook and Dupras [4] identified the educational principles that guide teaching practice:
- the active contributions to the learning process,
- learning by solving real life problems,
- taking into account learner’s current knowledge,
- support for practice accompanied by self-assessment and constructive feedback from teachers and peers,
- opportunity to reflect the practice.

Usability of educational websites
In educational websites, usability impacts the learner’s experience while learning, conducting individual and group assignments, communicating with teachers and peers. Although educational websites are usually devoted to specific domains and specific users groups, there are attempts to summarize educational specifics in order to develop usability guidelines. One example of such attempts is the usability guidelines for online educational tools [12] that aim at improving the usability of navigational systems and interactive simulations. According to them, navigation can be improved in the following ways:
- visible navigation bars on consistent position and appearance,
- clear hierarchical order with links to supplementary content, available return one step back and to homepage,
- visible search function, preferable in upper-right corner of a screen;
- consistent visual icons or cues to help user locate specialized content such as multimedia content,
- minimize distraction by limiting text, reducing unnecessary graphics and animations,
- clearly identified hyperlinks with consistent formatting for all pages,
- available feedback with website administrators,
- appropriate visual cues or icons for downloadable content.

NG [20] carried out an exploration of the teacher’s opinions on the critical design factors of high-quality educational website and divided factors into three categories: multimedia, user and education. Multimedia comprise font and typography, texture, color, graphics, audio and videos. User category includes further three elements which are related to the general web aspects, such
as usability, accessibility and navigation. From educational perspective, learning is usually supported by multimedia elements, therefore the Multimedia Learning Principles suggested by Meyer [18] are chosen as one of the considerations. The second of education oriented aspects involves appropriate integration of subject contents with underlying pedagogical considerations in Technological Pedagogical Content Knowledge-Web, proposed by Lee and Tsai [16].

Principles of usable interactive simulations that promote active learning and regard unique needs of students and teachers [4]:

- list instructions in bullet points, making content easier to digest,
- present learning objectives before the simulation,
- instructional videos should contain audio instructions of how to interact with simulation,
- clearly distinguish interactive and non-interactive page elements,
- provide appropriate navigation.

The study on how teachers and students use the internet and what makes a great educational web site resulted in the following findings [14]:

- good look motivates users to explore the site further,
- a well-developed search engine by level and subject,
- concise content with hyperlinks to detailed information,
- a glossary of terms assists students in understanding of content,
- available copy-right free images,
- text-only versions for computers with limited technical capabilities.


Summarizing the presented studies, the most frequently mentioned usability aspects are navigation, clear hierarchical order, sophisticated search, concise texts and clear visual cues for interactive, specific and downloadable content. These guidelines can be regarded as required for a good educational system.

Each study provides also unique recommendations that are not replicated in other studies, such as a glossary of terms, copy-right free images for didactical purposes, etc. These recommendations could be summarized as optional.

**OVERVIEW OF USABILITY HEURISTICS**

Nielsen established five usability attributes [22]: efficiency, learnability, memorability, errors and satisfaction. However, the inspection results depend heavily on experience of an evaluator, because the attributes are abstract. Various evaluators can receive non-replicable outcomes that decrease the reliability of inspection.

Ergonomic and HCI standard ISO/IEC 9241-11 defines effectiveness, efficiency and satisfaction as usability attributes that should be evaluated regarding to users, their goals and context in which interaction occurs [29]. Standard provides also evaluation criteria and measures. Nevertheless, standard criteria and measures do not fit the needs of evaluators. Therefore, the usability heuristics was developed to support usability inspections. Usability inspection is frequently used as a cost-effective evaluation method that is useful in various phases of product design. The heuristics are based on attribute models and support product development and evaluations.

Nielsen’ heuristics are a prime example of universal heuristics that reflect the general usability principles. However, applications have also domain-specific aspects that are not covered by universal heuristics. Many domain-specific heuristics are built refining universal usability models and heuristics. In this section we analyze, collate and systematize universal and domain-specific sets in order to identify shared aspects. The assumption is that common elements of universal, educational, web and mobile usability are universal and do not depend upon domains. Therefore, they should belong to the target set.

**Universal usability heuristics**

A set of heuristics for specified domains can improve the product quality by preventing developers from the known usability problems [1].

Nielsen’s heuristics for interaction design are presented in Table 1. Domain-specific sets will be compared with this set in order to identify common principles.

<table>
<thead>
<tr>
<th>Nielsen’s heuristics</th>
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<tr>
<td><strong>N1</strong> Visibility of system status: the system should always keep users informed about what is going on, through appropriate feedback within reasonable time.</td>
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<tr>
<td><strong>N2</strong> Match between system and real world: The system should speak the users’ language, with words, phrases and concepts familiar to the user, rather than system-oriented terms.</td>
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<tr>
<td><strong>N3</strong> User control and freedom: users often choose system functions by mistake and will need a clearly marked “emergency exit” to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.</td>
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</table>
The popularity of mobile devices among students encouraged adapting content of e-learning sites to handheld devices. Mobile technology provides the learner with a flexible, readily accessible learning resource that can be personalized for an individual use. The advantages of integrating mobile devices into educational initiatives outweigh the device limitations [5]. This paper is focused mainly on tablets, however, existing usability principles are considered for whole class of handheld devices with touch screens, such as smart phone, tablets and handheld computers.

The mobile device challenges include small screen size, lack of ubiquitous access, cost, technical support, the risk of distraction and the danger of sudden obsolescence [5]. From the educational perspective, a small size can be regarded as a benefit, too. The content must be split into small packages thus simplifying training.

The universal usability principles are actual for mobile usability, however, for mobile usage the following limitations are identified [26]:

- **mobile context** includes location, nearby people, objects as well as environmental elements that distract users’ attention,
- **connectivity** impacts the usage as slow and unreliable wireless network connections that affects data downloading time and quality of streaming media,
- **small screen size** can make direct presentation of web sites aesthetically unpleasant, un-navigable and at the worst case, illegible,
- **limited processing capability and power** forces developers to create the limited functionality versions comparing to full desktop systems,
- **limited data entry methods** requires a certain level of proficiency and may reduce input speed.

Zhang and Adipat [26] have also included the lower screen resolution to the list of challenges. However, the newest mobile devices have already as high resolution as desktop computers. Therefore, this aspect is excluded.

Universal usability models do not regard the mobile device limitations. The mobile usability models, such as PACMAD (People At the Centre of Mobile Application Development), aim at addressing the shortcomings of universal models when applied to mobile interaction [10]. In PACMAD, effectiveness, efficiency and satisfaction attributes from the ISO/IEC standard are combined with the five Nielsen’s usability attributes. The attribute of cognitive workload is added. Furthermore, the definitions of Nielsen attributes are adapted to mobile usage context. The redesigned mobile usability attributes are defined as follows [10]:

<table>
<thead>
<tr>
<th></th>
<th>Nielsen’s heuristics</th>
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<tbody>
<tr>
<td>N4</td>
<td><strong>Consistency and standard:</strong> users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.</td>
</tr>
<tr>
<td>N5</td>
<td><strong>Error prevention:</strong> even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.</td>
</tr>
<tr>
<td>N6</td>
<td><strong>Recognition rather than recall:</strong> Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.</td>
</tr>
<tr>
<td>N7</td>
<td><strong>Flexibility and efficiency of use:</strong> Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.</td>
</tr>
<tr>
<td>N8</td>
<td><strong>Aesthetic and minimalist design:</strong> Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.</td>
</tr>
<tr>
<td>N9</td>
<td><strong>Help users recognize, diagnose, and recover from errors:</strong> Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.</td>
</tr>
<tr>
<td>N10</td>
<td><strong>Help and documentation:</strong> Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.</td>
</tr>
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</table>

Table 1. Universal user interface design heuristics [21]

**Mobile usability models**

Glen Farrally [8] defines the mobile device as a handheld computer that has ability to connect to the internet, support user input and interaction, offers multiple functionalities, is lightweight and less than 10in. Mobile devices include smart phones, tablets, netbooks, personal digital assistants, and GPS navigation devices [8]. They enhance applications by taking into account user location, available network resources and device sensors.
• **effectiveness** as an ability to complete the task in a specified context supports variable context, too,
• **efficiency** as an ability to complete task with desired speed and accuracy also regards the mobile users needs, because users tend to use mobile applications for short tasks,
• **satisfaction** as a perceived level of comfort of usage is adequate for mobile usage as well,
• **learnability** as the easiness with which user gains proficiency with an application,
• **memorability** is significant because according to survey responses almost 50% of mobile applications is used only once a month,
• **errors** in PACMAD are considered by taking into account their nature as well as frequency,
• **cognitive load** refers to the amount of cognitive processing that is required by the user to use the applications; this main contribution of PACMAD regards the fact that users’ attention can be distracted by changing environment and by making other activities, such as walking.

PACMAD model shows that mobile usability is influenced by factors valid for non-mobile as well as specific mobile interaction. While developing the heuristic evaluation for mobile interactions, the non-mobile interaction heuristics should be considered. The literature overview also reveals the lack of the mobile usability model for educational websites.

The interaction with mobile devices is supported mainly by touch screen. Hinrichs and Carpendale [11] investigated visitors gestures interaction with exhibit at the Vancouver Aquarium. Visitors intuitively used seven categories of gestures: drag/move, enlarge/shrink, rotate, tap, sweep, flick and hold. This study relates tasks with intuitive gestures and is a source for touch screen heuristics.

Instroza et al. [13] redefined and updated Nielsen’s heuristics and developed 12 heuristics for touch screen mobile devices (Table 2). In this set three heuristics are redefined: the error prevention, effectiveness of use and performance heuristics. The further two heuristics were added: minimization of the user’s memory and physical interaction and ergonomics.

### Educational heuristics

Educational heuristics (Table 3) are considered from the five perspectives [1]: user, motivational factors, content information and process orientation, learning process, and design and media usability.

<table>
<thead>
<tr>
<th>Perspectives</th>
<th>Educational heuristics</th>
</tr>
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<tbody>
<tr>
<td>User</td>
<td>E1. Supports modifications and shows the progress of evaluation.</td>
</tr>
<tr>
<td></td>
<td>E2. Supports user tasks and avoids difficult concepts.</td>
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<tr>
<td></td>
<td>E3. Feedback and support services</td>
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<table>
<thead>
<tr>
<th>Touch screen heuristics</th>
<th>Touch screen heuristics</th>
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<tbody>
<tr>
<td>T3</td>
<td><strong>User control and freedom</strong> should allow users to undo and redo their actions and provide clear exits preferably through physical buttons.</td>
</tr>
<tr>
<td>T4</td>
<td><strong>Consistency and standards (N4)</strong> heuristics by following established conventions enable users to do things in a natural and consistent way.</td>
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<tr>
<td>T5</td>
<td><strong>Error prevention</strong> in mobile devices is aimed at presenting available functionality, warning users about critical actions and providing access to additional information.</td>
</tr>
<tr>
<td>T6</td>
<td><strong>Minimization the user’s memory load</strong> recommends making visible available objects, actions and options to prevent users to memorize information from one part of dialog to another.</td>
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<tr>
<td>T7</td>
<td><strong>Customization and shortcuts</strong> is aimed at providing basic and advanced configuration and allowing shortcuts to frequent actions.</td>
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<tr>
<td>T8</td>
<td><strong>Efficiency of use and performance</strong> heuristics emphasize the displaying required information, smooth animations and transitions as well as minimization of the required steps.</td>
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<tr>
<td>T9</td>
<td><strong>Aesthetic and minimalist design</strong> suggests avoiding to display unwanted information in a defined context of use.</td>
</tr>
<tr>
<td>T10</td>
<td><strong>Help users to recognize and recover from errors</strong> heuristics recommends to present messages in a familiar language to the user, indicating the issue and suggesting a constructive solution.</td>
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<tr>
<td>T11</td>
<td><strong>Help and documentation</strong> should be easy to find and user task-centered.</td>
</tr>
<tr>
<td>T12</td>
<td><strong>Physical interaction and ergonomics</strong> suggests providing buttons for main functionalities, located in recognizable positions which should fit the natural posture of user’s hands.</td>
</tr>
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</table>

**Table 2. Touch screen heuristics [13]**
file editing and

MS runs within browser.

Table 3. Educational usability attributes with related heuristics [1]

Heuristics for content management systems

Educational website is a specific instance of web applications in which an interaction with users is restricted to browser capabilities. Content is delivered via internet, so system response time can increase unexpectedly.

Learning process comprises reading and performing assignments. This involves input and management of content in various formats, user profile editing and configuration. These activities are similar to the activities that users perform in content management systems (CMS). The investigation of internet systems users’ habits, text input and content management resulted in redefinition of eight Nielsen heuristics (Table 4) and identification of the five CMS specific heuristics (Table 5)[3].

Table 4. CMS heuristics adapted from universal Nielsen’s heuristics [3]

Five CMS specific heuristics were added to the CMS heuristics set (Table 5). Two Nielsen’s heuristics were omitted. The first, user control and freedom, is limited by platform capabilities because CMS runs within browser. This already has been covered by CMS11. The second, issues regarded emergency exits, undo and redo are incorporated into a heuristics of error prevention (CMS7) because error prevention and error recovery are related [3].

Specific CMS heuristics

CMS9 Conformance to other applications stresses the consistency with desktop and web

CMS8 Provide help and instruction (N10) in the form of context-sensitive and online help, even better is to integrate instructions into the application by using descriptive labels and tooltips whenever appropriate.

CMS7 Error prevention and recovery merges help users recognize, diagnose and recover from errors (N9) with part of N3 user control and freedom where special form of undo is needed. User should be protected from drastic consequences. Upon invalid data entry feedback and suggestion should be provided. Actions leading to error should be unavailable.

CMS6 Aesthetics and minimalist design (N8) accommodate limited use of windows, avoid overuse of features and complicated dialogs, splitting information-excessive screens.

CMS5 Flexibility and efficiency of use (N7) relate the shortcuts that should be industry-standard, direct manipulation features and response time because web applications load via network, which can cause long load and response times.

CMS4 Recognition rather than recall (N6) is slightly adjusted by adding suggestion to use default values and the idea that hyperlinks and controls should be easily distinguishable.

CMS3 Consistency (N4) heuristics is adjusted to cover internal consistency. External consistency is excluded to a separate heuristics (CMS9).

CMS2 Match between System and real world (N2) comprises speaking the users’ language and added items: support user’s data flows and organization of menu items.

CMS1 Visibility of system status (N1) involves feedback on fulfillment of actions, content of feedback messages, real-time status indicators and progress throughout the task.

<table>
<thead>
<tr>
<th>Perspectives</th>
<th>Educational heuristics</th>
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<tbody>
<tr>
<td>Motivational factors</td>
<td>E4. Easy to remember</td>
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<td></td>
<td>E5. Support learner curiosity</td>
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<tr>
<td></td>
<td>E6. Learning content design and attractive screen design</td>
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<tr>
<td></td>
<td>E7. Motivation to learn</td>
</tr>
<tr>
<td>Content information and process orientation</td>
<td>E8. Relevant, correct and adequate information</td>
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<td></td>
<td>E9. Reliability and validity</td>
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<td></td>
<td>E10. Privacy and security</td>
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<td>Learning process</td>
<td>E11. Assessment</td>
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<td>E12. Interactivity</td>
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<td>E13. Evocation of mental images of learner</td>
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<td>E14. Resources</td>
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<td>E15. Learning management</td>
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<td>E16. Learnability</td>
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<tr>
<td>Design and media usability</td>
<td>E17. Multimedia representations</td>
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<td></td>
<td>E18. Accessibility and compatibility of hardware devices</td>
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<td></td>
<td>E19. Functionality</td>
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<td></td>
<td>E20. Navigation and visual clarity</td>
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</tbody>
</table>

Table 3. Educational usability attributes with related heuristics [1]
applications that user is used to work with, industry-standard controls and task flows. Plug-ins help overcome browser’s shortcomings.

CMS10 Follow application conventions as part of N3 (follow platform conventions) suggests single rather than double click, easy recognizable controls and hyperlinks.

CMS11 Browser controls and navigation suggests considering that back button and menus takes up a prominent space on the screen and can cause data loss. Browser controls should be easily distinguishable from the web application control.

CMS12 Allow easy data entry that minimizes the chance of errors points up various types of input, easy entry of restricted data, direct manipulation, always visible entered data, etc.

Table 5. CMS specific heuristics [3]

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<tbody>
<tr>
<td>N7. Flexibility and efficiency of use</td>
<td>T7. Customization and shortcuts</td>
<td>E2. Supports user tasks and avoids difficult concepts</td>
<td>CMS5. Flexibility and efficiency of use</td>
</tr>
</tbody>
</table>

Table 6. Heuristics with a similar purpose

The remaining heuristics are discussed separately whether they have unique aspects and should be added to the final list or not. Two touch screen heuristics have specific properties: CMS heuristics reflect the usability aspects of desktop internet system. The further analysis will identify which of them have an impact on mobile system usability.

SYNTHESIS OF HEURISTICS FOR MOBILE DEVICES

Specific educational heuristics are developed for e-learning systems that run on desktop computers. Existing mobile usability models also highlight the importance of cognitive workload. Usage on mobile devices requires considering how gestures interaction and touch screen features impacts interaction. In sum, the final set of heuristics should combine educational, mobile device and touch screen by selecting, aggregating, redefining and adding aspects from existing sets that fit usability models.

The comparison of the definitions and scope of the universal, touch screen, educational and CMS heuristics allows identifying similar and complementary elements (Table 6). Touch screen and CMS heuristics were based on Nielsen’s heuristics, therefore they have a lot of similar elements. Educational heuristics have less common elements with other sets, because they reflect only educational aspects. Nevertheless, certain educational heuristics can be associated with pure usability.
• T8. Efficiency of use and performance heuristics aspects are already covered by N7, N8 and CMS5. So, they are not unique and will not be included as a separate item.
• T12. Physical interaction and ergonomics heuristics relates to the mobile device size and ergonomics. This heuristics is not covered and will be added to the final set.

The appropriateness of including educational heuristics to the final is discussed below:

• E1. Supports modifications and progress of evaluation – important and has been not covered yet, will be added.
• E5. Support learner curiosity – will not be added, because it is partially covered by E7, as curiosity and motivation are similar factors; therefore curiosity aspects will be included to E7.
• E7. Motivation to learn – will be added, because learners’ motivation is maintained by encouraging curiosity, providing assessments, awarding, etc.
• E8. Relevant, correct and adequate information – will be added, reading the educational material is important learning activity and information have to be correct and reliable.
• E9. Reliability and validity – will not be added, because this heuristics related to the content and process, that is already covered by E8.
• E10. Privacy and security – will be added, because it is not covered by any of mentioned heuristics.
• E11. Assessment – will be added as significant educational aspect.
• E12. Interactivity – will be added, critical factor for attractive education process.
• E13. Evocation of mental images of learner – will not be added, because partially covered by E7 and E17.
• E14. Resources – will not be added, as partially covered by E8.
• E15. Learning management – will be added as inherent part of educational process.
• E16. Learnability – will be added, information and tasks should be easily comprehensible.
• E17. Multimedia representations – will be added, critical for the effective learning [20].
• E18. Accessibility and compatibility of hardware devices – will be added, it is a requirement for nowadays systems.

The list of educational heuristics is very detailed and quite large. Similar aspects can be grouped refining their definitions.

CMS and educational websites run on browsers, therefore specific CMS heuristics can be relevant for the final set:

• CMS9. Conformance to other applications – inappropriate, as educational sites depend heavily upon the subject and every application can have unique features.
• CMS10. Follow web application conventions – inappropriate, because promotes interface standardization that can be incompatible with unique educational elements.
• CMS11. Browser controls and navigation – appropriate as sites uses browser functionality.
• CMS12. Allow easy data entry that minimizes the chance of errors – appropriate because performing assignments involves the input of data.

In this section, the universal, touch screen, educational and CMS heuristics were compared and selected the appropriate for the educational domain.

INITIAL VALIDATION WITH MUSEUM EXHIBITS
Analysis of the usability models and heuristics from related domains identified candidate heuristics to the final set. The first validation was conducted with recognized high quality educational materials. The exposition of Science Museum of London has won the honorable mention award MUSE 2011 in recognition for the highest standards of excellence in the use of media and technology for interpretive interactive installations [28]. The aim is to apply the working set to the recognized high quality educational technology solution. All attributes of the developed set should be valid for that product. The prime solution validates the developed set of heuristics and may help to discover the missed attributes.

Exposition educational materials are presented on tabletops, tablets and personal computers. For the purpose of study, the attention is focused on the touch screen solutions. Although tabletops are not mobile devices, they have educational and usability features that can give valuable insights validating the touch screen heuristics. Tabletops are used for two purposes: to resnet educational materials and to maintain learning process. Users interact with the material with gestures like in mobile devices.

Museum spaces are devoted to different subjects. Devices have different interfaces, content presentation solutions, various gestures interaction, object size and colors. This divergence maintains visitor’s curiosity and motivation to continue with learning.

The evaluation was conducted by the developer of heuristics. The validation was performed in two iterations. During the first iteration, the evaluator has used the exhibit as a learner by searching the answer for the questions related to the presented topic. Then, the heuristics were applied to the each interaction step.

The evaluation gave the interesting insights into various ways to present information. Memory load is minimized providing consistent navigation. Primary and secondary navigation as well as images stay on the same place on a
screen. Navigation on large vertical screens is duplicated on the upper and bottom parts of a screen.

Interesting interactive solution is implemented providing information structure as term cloud where instances can be resized in order to get know more about that term. A small effort is needed to understand the whole structure.

When exhibit is not used for a certain time, object automatically returns to the main screen. Objects are accessible for disabled users: large navigation buttons, high contrast text and images as well as available subtitles for audio information. Despite different interaction and information presentation styles objects are easily understandable. Thus, visitors’ curiosity is maintained and motivates them to continue learning activities.

The exhibition confirmed the identified heuristics. However, it also revealed aspects that were not covered by developed set:

- stable navigation layout and locally reloaded information minimizes user’s memory load;
- interactive and animated site structure encourages curiosity and strengthens educational component;
- return to the initial page on the screen in public place is important for the next learner;
- subtitles for multimedia content make materials accessible for people with disabilities.

THE FINAL HEURISTICS
Usability heuristics of mobile educational websites are organized in three groups: educational, mobile and web.

Educational attributes comprise interactivity, information presentation and focus on maintenance of users’ attention (Table 7).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sub-attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1. Content and information</td>
<td>E1.1. All materials can be reached from navigation&lt;br&gt; E1.2. Educational material is exact, correct and reliable&lt;br&gt; E1.3. Information structure is meaningful and clearly presented&lt;br&gt; E1.4. Content is presented in various formats including multimedia.&lt;br&gt; E1.5. Multimedia content is accessible for people with disabilities.</td>
</tr>
<tr>
<td>E2. Motivation</td>
<td>E2.1 Learner’s curiosity is maintained by combining appropriate tasks and materials.&lt;br&gt; E2.2. User interface support the learning process</td>
</tr>
<tr>
<td>E3.</td>
<td>E3.1. Learner accesses its outcomes.</td>
</tr>
<tr>
<td>E4. Learnability</td>
<td>E4.1. System and learning processes have to be easy comprehensible.&lt;br&gt; E4.2. Learning process should be controlled by a learner.</td>
</tr>
<tr>
<td>E5. Security and privacy</td>
<td>E5.1. User’s private information is not accessible to the public by default&lt;br&gt; E5.2. User’s assessments are private by default.&lt;br&gt; E5.3. User’s communication with teachers is private by default</td>
</tr>
</tbody>
</table>

Table 7. Aggregated educational attributes

Mobile devices and touch screen group includes gestures interaction and adaptation to variable screen sizes (Table 8).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sub-attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1. Ergonomics</td>
<td>M1.1. System adapts to the physical characteristics of mobile device&lt;br&gt; M1.2. Systems reacts in real time to the changes in device orientation&lt;br&gt; M1.3. Interface widgets are comfortable to select using finger&lt;br&gt; M1.4. The important actions can be accessed by one touch.</td>
</tr>
<tr>
<td>M2. Gestures interaction</td>
<td>M2.1 Ability to control with gestures&lt;br&gt; M2.2. System recognizes one or more gestures interaction techniques&lt;br&gt; M2.3 System responds to gestures interaction in an acceptable time&lt;br&gt; M2.4 Recognition of compound gestures</td>
</tr>
<tr>
<td>M3. Context</td>
<td>M3.1. System is comfortable to use in various contexts&lt;br&gt; M3.2. System can be used in background</td>
</tr>
</tbody>
</table>

Table 8. Aggregated usability attributes influenced by mobile device physical characteristics and gestures interaction

Website and CMS attributes encompass general internet system design guidelines (Table 9).
When some usability aspect is repeated in all sets, it indicates that such an attribute is common to all interfaces, for example learnability. In the first phase these attributes were selected and assigned to the final set. Then, the appropriateness of domain-specific heuristics was analyzed according to educational and mobile usability models.

Analysis also revealed the conflicting heuristics. For example, the conformance with other applications heuristic (CMS9) contradicts to support learner's curiosity (E5) heuristics and the fact that each educational system can have unique features. Educational aspects has a higher priority in this case, therefore, the CMS9 heuristics was not added to the final set.

The initial validation in Science Museum of London confirmed the appropriateness of decisions made. Primary usability attributes were confirmed by inspecting exhibits. The pilot inspection showed that exhibits contained the examined attributes. It also revealed the omitted attributes, such as automatics return to main screen. The pilot inspection was conducted on various touch screen devices. Developed set was appropriate for tabletops, too. In the future, the developed heuristics will be applied inspecting learning websites on tablets in order the check their effectiveness in detecting usability problems. The results with heuristics evaluation will be compared with the results of user tests and observations.

REFERENCES


### Table 9. Usability attributes of websites

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sub-attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1. Navigation</td>
<td>W1.1. System navigation is intuitive and memorable</td>
</tr>
<tr>
<td></td>
<td>W1.2. Avoid deep hierarchical structures</td>
</tr>
<tr>
<td></td>
<td>W1.3. Site map is available</td>
</tr>
<tr>
<td></td>
<td>W1.4. Link to help is available</td>
</tr>
<tr>
<td>W2. Accessibility</td>
<td>W2.1 Internet browser and connection is enough to use the system.</td>
</tr>
<tr>
<td></td>
<td>W2.2. System loads in acceptable time.</td>
</tr>
<tr>
<td>W3. Information presentation and user interface</td>
<td>W3.1. System provides comfortable presentation, search, sending and receiving of data.</td>
</tr>
<tr>
<td></td>
<td>W3.2. Attractive and pleasing design.</td>
</tr>
<tr>
<td></td>
<td>W3.3. Important information is displayed.</td>
</tr>
<tr>
<td></td>
<td>W3.4. Animation and graphical elements do not distract user’s attention and do not disturb effective use.</td>
</tr>
<tr>
<td></td>
<td>W3.5. Information is presented consistently.</td>
</tr>
<tr>
<td>W4. Consistency</td>
<td>W4.1. User is able to determine the effect of future actions.</td>
</tr>
<tr>
<td></td>
<td>W4.2. User is able to assess the effect of past actions.</td>
</tr>
<tr>
<td></td>
<td>W4.3. User is able to apply experience gained using similar systems.</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Usability of educational websites used on mobile devices with touch screen combine attributes from educational, mobile device and web system domains. While developing desired heuristics, usability guidelines and heuristics from related domains have been investigated. During the analysis the following domains with established usability heuristics were selected: universal user interface design heuristics and specific educational, mobile and web system design.

Analysis showed that domain-specific heuristics are frequently developed by adopting and redefining the universal set of Nielsen’s heuristics. Therefore, the domain-specific sets involve universal heuristics with original definitions and some definitions are redefined. Moreover, each set is augmented with domain-specific heuristics that have no analogs in other sets. The common aspects were synthesized by collecting, comparing and aggregating similar heuristics.


