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A Framework for Software Usability & User Experience Measurement in Mobile Industry

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Abstract—The mobile industry faces challenges in designing software usability and user experience (UX) measurement instruments. The major difficulties arise due to: 1) diversity of definitions and terminology used for usability and UX aspects and attributes, which lead to inconsistencies, and 2) lack of a taxonomy for these attributes with links to well-defined measures in the literature. In this paper, we present a framework to support mobile industry to overcome these challenges. We first unified the terminology and definitions for usability and UX attributes in the literature. Then, we created taxonomy of attributes and sub-attributes. By using the well-known Goal Question Metric (GQM) approach, we identified a comprehensive set of questions and measures for each attribute that could be used as a basis for developing measurement instruments. The framework was evaluated through a case study conducted in a usability research, development and consultancy company for mobile industry in Sweden.

Keywords—software usability; user experience; Goal Question Metric; evaluation; measurement; case study; mobile industry

I. INTRODUCTION

During the last decade, mobile phones and applications have become one of the most popular mass-market products. The mobile industry has to deal with challenges of increasing functionality requirements of the users as well as their demand for high quality. In order to survive in the highly competitive market, mobile development companies not only should satisfy the requirements of users but also provide more: a satisfying experience.

Kirakowski et al. [1] identified three interdependent aspects to be considered when evaluating technology: i) the product, ii) interaction between the user and the product (usability), and iii) experience of using the product (user experience). This paper deals with usability and user experience (UX) aspects.

Usability takes an objective view of quality; the hallmark of usability testing methods primarily rests on observation or measurement when participants interact with a product.

On the other hand, UX highlights non-utilitarian aspects of such interactions, shifting the focus to user affect and sensation. Since UX is subjective, it may not matter how good a product is objectively; its quality must also be “experienced” subjectively to have impact. And, several aspects can influence how people perceive quality during the interaction with the product.

There are a number of measures, instruments and tools developed for measuring usability and UX. However, the definitions for usability and UX vary significantly in software engineering (SE) community [2][3]. In addition, UX is an intriguing notion, which has been widely disseminated and is increasingly accepted in the Human-Computer Interaction (HCI) community as well. The independent efforts put forth by these two separate communities have further increased the diversity in the definitions and inconsistencies in terminology, and hence inconsistencies in understanding and measurement (see Section II and Appendix). Therefore, different organizations use different measures and instruments for evaluating their products, which does not allow comparability.

Furthermore, even though a few standards (such as [4], [5]) have been developed to enable standardization, they are not being widely used when developing measurement instruments. One identified reason is the lack of experts in these areas [6]. In addition, there is a wide gap between academic studies and industrial practice [7], which does not support development of measurement and evaluation instruments.

In order to address some of these challenges, we developed a framework [8] to support mobile industry when designing usability and UX measurement instruments and, thereby reliably compare their products. We tested the framework in a mobile application development company, where a measurement instrument that meets the needs of the company was developed using the framework.

This paper is organized as follows: In Section II, background work on usability, UX and evaluation methods is presented. Section III presents the developed framework, and Section IV, the case study. Finally, the conclusions are given in Section V.

II. BACKGROUND

Traditional usability definition strongly focuses on users’ tasks and their accomplishment; that is, more on the pragmatic side of the user-product relationship. On the other hand, UX represents a holistic view of the pragmatic aspects and hedonic aspects of product possession and use such as beauty, challenge, stimulation, or self-expression [9].

Usability considers barriers, problems, frustration, stress and other negative aspects, and their removal. On the other hand, UX often stresses the importance of positive outcomes of

technology use or possession; be it positive emotions such as joy, pride, and excitement or simply “value” [10].

As UX is associated with a broad range of fuzzy concepts related to emotion, affection, experience, hedonic and aesthetic, this creates difficulty in getting a universal definition for UX. Some examples of so-called elemental attributes of UX proposed by Cockton [11] are fun, pleasure, pride, joy, surprise, and intimacy. And these are just a subset of a growing list of human values.

Roto & Kaasinen [12] propose that UX is a term that describes user’s feelings towards a specific product, system, or object during and after interacting with it. Various aspects influence the feelings, such as user’s expectations, the conditions in which the interaction takes place, and the system’s ability to serve user’s current needs. According to Jetter & Gerken [13], UX incorporates not only the traditional qualities like reliability, functionality, or usability but also novel and hard-to-grasp concepts from visual or industrial design, psychology or marketing research, e.g. attractiveness, stimulation, fun, “coolness”, “sexiness” or the successful delivery of a brand proposition.

There are a number of researchers who investigated UX components [9][14][15][16][17]. They found out that there is a wide agreement that user’s earlier experiences and expectations as well as the context of use affect UX.

Hassenzahl [18] proposed a complex model, which defined key elements of UX and their functional relations. The author distinguished the difference between pragmatic and hedonic attributes in his model. Later, Hassenzahl & Tractinsky [9] defined three high level components, which are able to cover all aspects mentioned above. In [12][19], these three components are taken as a starting point and a set of attributes related to each component are identified. The first component is the *System*, which involves product, object, service, infrastructure and people, the complexity, purpose, usability, functionality as the characteristics of the designed system. The second component is the *Context*, which includes physical context, social context, temporal context and task context. The last component is the *User*, which considers user’s needs, the available mental and physical resources, emotional state, earlier experience and expectations.

There are various usability and UX evaluation methods in the literature, which were categorized by [20] as: a) user-based evaluation methods [21] such as user-administered questionnaires, observing users and empirical usability testing; b) inspection-based evaluation methods [22] such as heuristic evaluation, guideline-based methods, cognitive walkthrough and heuristic walkthrough; and c) model-based evaluation methods [23] such as task network model.

A number of studies in the literature show that usability is usually measured subjectively, and often not in a consistent way [24][25][26][27]. Evaluation of usability in this manner results in inconsistent results about the usability [28], or else incomparability of the test results of products.

III. A FRAMEWORK SUPPORT FOR USABILITY AND UX MEASUREMENT

In this section, we present the details of the developed framework, which has two main components: 1) A taxonomy for usability and UX attributes, and 2) A generic questions and measures set for developing measurement instruments.

A. A Taxonomy For Usability and UX Attributes

In order to develop the framework, we first defined a taxonomy for usability and UX attributes. Performing a comprehensive literature review, we explored the definitions and terminology for usability and UX attributes. We used the snowball approach when performing the literature review. We started by reviewing the standards discussed in [29] as the base for our further exploration. Then, by analyzing the results, we came up with a list of attributes with unified definitions and terminology. In the framework, we chose to use the definitions of the standards recognized by the community (see Appendix - Table 3 & Table 4 for the definitions in the literature).

Finally, we defined a taxonomy of attributes and associated sub-attributes by identifying the nature of the relationship among them (see Table 1). In total, we identified 9 main attributes and 27 associated sub-attributes. For example, the sub-attributes; Time behavior, Resource utilization, Operability, Minimal action, Feedback, Minimal memory load and Navigability are dimensions of Efficiency attribute. From the perspective of sub-attributes, for example, Attractiveness is related to two main attributes: Satisfaction and Generalizability. On the other hand, Understandability has no relation to any sub-attributes identified.

B. A Generic Questions And Measures Set For Developing Measurement Instruments

The framework was developed with the aim to support companies for developing their usability and UX evaluation instruments. Therefore, as the second step, we defined a generic set of questions and measures, which mobile companies can use in developing their usability and UX evaluation methods.

To this end, we used the well-known Goal Question Metric (GQM) paradigm [30][31]. GQM is a top-down approach used in identifying the required measures in a company based on the organizational or business goals. For the purposes of this study, however, we used the GQM approach for another purpose than how it is used traditionally.

As the framework was to be generic to allow designing measurement instruments for any mobile development company, we first defined generic top-level goals for the 9 usability and UX main attributes of mobile applications. For example, one top-level goal was “to assess usability and UX for a specific software product from the user’s point of view in the context of mobile applications”.

TABLE 1. TAXONOMY FOR USABILITY AND UX ATTRIBUTES

		ATTRIBUTES (with # of Questions identified)								
		Efficiency (77)	Effectiveness (48)	Satisfaction (98)	Productivity (5)	Learnability (52)	Safety (16)	Accessibility (22)	Generalizability (32)	Understandability (18)
SUB-ATTRIBUTES	Time behavior	•			•					
	Resource utilization	•			•					
	Users' assessment		•							
	Experts' assessment		•							
	Operability	•		•				•		
	Minimal action	•		•		•		•		
	Feedback	•	•						•	
	Minimal memory load	•		•		•		•	•	
	Flexibility		•	•				•	•	
	Quality of outcome		•							
	Navigability	•	•			•		•	•	
	Preference			•						
	Users' attitudes/perceptions			•						
	Memorability		•			•				
	Likeability			•						
	Fault tolerance						•			
	Security						•			
	Privacy						•			
	Accuracy		•				•			
	User Guidance			•		•		•	•	
	Consistency		•			•		•	•	
	Completeness		•							
	Attractiveness			•					•	
	Self-descriptiveness					•		•	•	
	Simplicity					•		•	•	
	Controllability							•	•	
	Readability							•	•	

Then, we identified sub-goals for each main attribute/sub-attribute pair in the taxonomy. For example, one sub-goal was defined for Efficiency-Time Behavior and another for Learnability-Minimal action. In total, we defined 63 sub-goals.

Later, we defined a set of questions that can be used by mobile companies as part of measurement instruments as these correspond to information needs of the stakeholders.

We also included in the framework a couple of questions companies have already been using. For the main 9 main attribute/27 sub-attribute pairs, we defined in total 368 questions (Efficiency: 77, Effectiveness: 48, Satisfaction: 98, Productivity: 5, Learnability: 52, Safety: 16, Accessibility: 22, Generalizability: 32, Understandability: 18) as shown in Table 1.

Finally, we associated the measures found in the literature review to the questions. To answer each question, we added both objective and subjective measures that we

identified in the literature. We present a few examples in Table 2.

TABLE 2. EXAMPLE QUESTIONS AND MEASURES FOR USABILITY AND UX EVALUATION

<p>1. a. Attribute: Efficiency</p> <p>1.a.1 Sub-Attribute: Time behavior</p> <p>Q1: How long does it take before the system response to a specified operation? (ISO 9126-2)</p> <p>Measure: <i>Response time</i> $T = (\text{time of gaining the result}) - (\text{time of command entry finished})$</p> <p>Q2: What is the average wait time the user experiences after issuing a request until the request is completed within a specified system load in terms of concurrent tasks and system utilization? (ISO 9126-2)</p> <p>Measure: <i>Mean time to response</i></p> <p>$X = T_{\text{mean}} / TX_{\text{mean}}$</p> <p>$T_{\text{mean}} = \sum(T_i) / N$, (for $i=1$ to N)</p> <p>TX_{mean} = required mean response time</p> <p>T_i = response time for i-th evaluation (shot)</p> <p>N = number of evaluations (sampled shots)</p> <p>...</p> <p>1.a Attribute: Efficiency</p> <p>1.a.2 Sub-Attribute: Resource utilization</p> <p>Q1: Is the I/O device utilization too high, causing inefficiencies? (ISO 9126-2)</p> <p>Measure: <i>I/O devices utilization</i> $X = A / B$</p> <p>A = time of I/O devices occupied,</p> <p>B = specified time which is designed to occupy I/O devices</p> <p>Q2: What is the average number of I/O related error messages and failures over a specified length of time and specified utilization? (ISO 9126-2)</p> <p>Measure: <i>Mean I/O fulfillment ratio</i> $X = A_{\text{mean}} / R_{\text{mean}}$</p> <p>$A_{\text{mean}} = \sum(A_i) / N$</p> <p>$R_{\text{mean}}$ = required mean number of I/O messages</p> <p>A_i = number of I/O error messages for i-th evaluation</p> <p>N = number of evaluations</p> <p>Q3: What is the impact of I/O device utilization on the user wait times? (ISO 9126-2)</p> <p>Measure: <i>User waiting time of I/O devices utilization</i> T = Time spent to wait for finish of I/O devices operation</p> <p>...</p> <p>3. Attribute: Effectiveness</p> <p>3.3 Sub-Attribute: Accuracy</p> <p>Q1: How completely have the accuracy requirements been implemented?</p> <p>Measure: <i>Computational accuracy</i> (ISO 9126-3)</p> <p>$X = A/B$</p> <p>A = Number of functions in which specific accuracy requirements had been implemented, as confirmed in evaluation.</p> <p>B = Number of functions for which specific accuracy requirements need to be implemented.</p> <p>Q2: How often do the end users encounter results with inadequate precision?</p> <p>Measure: <i>Precision</i> (Nyberg et al., 2001)</p> <p>$X = A/T$</p> <p>A = Number of results encountered by the users with level of precision different from required</p> <p>T = Operation time</p> <p>...</p>
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IV. CASE STUDY

In order to evaluate the framework, we conducted a case study in a small telecom company. Our research question for this case study was as follows: “Does the framework provide improvement by supporting the design of usability and UX evaluation instruments?”

We designed this case study as a single-case study [32] as the case company and the selected application are representative and typical in software mobile industry.

The case company was Adduce AB, a Swedish research, development and consultancy company that was established in early 2009. Adduce AB mainly provides four services: Adduce Research, Adduce Studios, Adduce Consulting and Adduce Courses. The research part focuses on developing the Adduce toolbox, which would provide clients to drive, prove and maintain high-level of usability in their products. Adduce Studio mainly works on producing fun and innovative mobile applications and games. And finally, the company also offers expert consultancy in the area of

usability, UX, product management and software development.

A. Case Study Conduct

The case company decided to use one of the recent applications; BodyJournal application installed on iPod 8GB product (model number: A1288), as the case application. The main purpose of developing this application was to help people to keep fit and healthy by controlling daily calories gaining and burning amount.

For this case study, as the usability evaluation method, we used User-based evaluation method [21] - a combination of Questionnaire approach and Observing Users approach [33]. For the UX, we used a combination of Questionnaire approach and Narration approach [34][35].

To develop the measurement instruments, we tailored the framework for the needs of the company and the case application in an iterative by also involving the CEO of the company, who himself is a usability measurement expert. He has ten years of professional work experience on usability research. In the past, he worked as usability researcher, test leader, interaction design manager, and product strategy manager.

The experts decided to evaluate a number of use cases. At the end, two usability evaluation questionnaires were developed for each (one with 67 statements using a likert-scale from 1 to 5 for the end-user to fill in while each use case is conducted and the other with 27 questions selected from the framework for the test leader to make measurements while observing the user during the tests).

These two forms evaluate 8 of the usability sub-attributes; that is, Effectiveness, Efficiency, Productivity, Learnability, Accessibility, Generalizability, Understandability and Safety. The ninth usability sub-attribute, Satisfaction was evaluated through an overall satisfaction and UX evaluation form. In total, 19 statements were selected from the framework and customized for the BodyJournal application, which ended up with 10 statements in the form.

Later, we used these instruments during the expert evaluation session. Two participants from the case company were involved at this phase. One of the participants had five years of work experience as usability researcher and test leader, and the second has eight years of experience of method cooperation with industry [36] focusing usability. Both had experience of developing a usability test framework that became a de facto standard in industry with more than 350 employees [37].

The case study was performed in the company offices. One of the participants played the role of the user while the other as the test leader. During the case study, the test leader worked together with the user and the user was encouraged to think aloud to help the test leader to better understand how users were thinking and the motivations behind their behavior.

The test leader observed the user during the tests and made measurements according to the designed questions (e.g recorded the time taken to conduct an individual task; noted errors, and number of attempts to correct errors, observed the user's hesitation from a natural flow of user interaction, recorded time taken to look for help and etc.).

When performing each use case, the user was requested to complete the usability evaluation questionnaire concerning the application in relation to the specific use case just performed. This process was repeated for each use case and in between each use case, the test leader communicated his observations with the user and verified whether his impressions were correct or not. When all 7 use cases were completed, the user was asked to fill in an overall Satisfaction and UX evaluation form, which expresses the user's overall opinion of the application based on the experience.

The data collected during the sessions were summarized using a spreadsheet and presented as graphs to show the overall satisfaction.

B. Case Study Results

The participants of the expert evaluation session stated that the evaluation results of the end-users together with the expert tests provided good indicators regarding the strengths and weaknesses of the current version of the BodyJournal application.

For example, from the end-user evaluations (see Figure 1), it was identified that the Accessibility and Generalizability aspects (such as support for multi-language, interface customization and zooming functions) were not considered for the current design of the application.

FIGURE 1 BODYJOURNAL APPLICATION USABILITY & UX TEST RESULTS (END-USERS PERSPECTIVE)

Furthermore, even though the Learnability and Understandability aspects appeared to be good based on the end-user evaluations, the test results of the experts regarding two of the use cases showed that the grouping and ordering of the menu options were not intuitive for the users, and

some were confusing. Therefore, the experts decided to re-design the task flow for these use cases. The test results also indicated that it was necessary to check the calculation accuracy of adding activity function. The details of the test results can be found in [8].

One important result from the usability evaluation to improve the measurement and evaluation instruments was the need to further categorize the use cases according to their relationship to the specific aspects of usability and domain, and that the questions can benefit from being split according to the chosen use cases. This work needs to be done iteratively by applying industry.

On the other hand, the case study has some validity threats that require to be discussed. The case application was evaluated in one company for a single case product. Therefore, it is hard to generalize the results for other companies and cases. But, we believe that the study is strong in when it comes to conclusion validity, i.e. the degree to which conclusions we reach about relationships in our data are reasonable among professionals in the domain of usability and UX.

V. CONCLUSIONS

This paper presented a framework for supporting development of usability and UX measurement instruments.

The framework provides a unified terminology and taxonomy for usability and UX attributes sub-attributes. Furthermore, incorporating a generic set of questions and related measures, the framework serves as a guideline for mobile companies on how to trace and interpret the collected data on the usability and UX of their products. The collected data based on visible goals can eventually lead to better decisions to improve the usability and the UX of the mobile industry products.

Furthermore, during our discussions with the participants of the case study, we identified the significance of addressing context of use regarding usability measurement that requires further investigation. Also, in most cases, usability and UX measurements are still put in the late stage of software product development and there is a need to find a way to shift it to the early stage of development life cycle. A promising future work identified is the extension of the framework to help in identifying the relationship between usability and UX attributes and their relevant measures that could be used at different phases in the life cycle. This information might be used to develop evaluation methods early in the life cycle so that the final product usability and UX will be improved.

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APPENDIX

TABLE 3. USABILITY AND UX ATTRIBUTES DESCRIPTION

Attributes	Sources
Efficiency	[3][5][38][39][40][41][42][43]
“The capability of the software product to provide appropriate performance, relative to the amount of resources used, under stated conditions.” [3].	
Effectiveness	[4][40][41][42][43][44][45]
“The capability of the software product to enable users to achieve specified tasks with accuracy and completeness in a specified context of use.” [44].	
Satisfaction	[4][38][39][41][42][43][44][46]
“Satisfaction measures assess the user’s attitudes towards the use of the product in a specified context of use.” [44].	
Productivity	[40][43][44]
“The capability of the software product to enable users to expend appropriate amounts of resources (i.e. time to complete tasks, user efforts, materials or financial cost of usage) in relation to the effectiveness achieved in a specified context of use.” [44].	
Learn-ability	[3][38][40][41][42][43][45][46][47][48]
“The capability of the software product to enable the user to learn its application.” [3]	
Safety	[44]
“Safety metrics assess the level of risk of harm to people, business, software, property or the environment in a specified context of use. It includes the health and safety of the both the user and those affected by use, as well as unintended physical or economic consequences.” [44].	
Accessibility	[49]
The capability of a software product to be used by persons with some type of disability (e.g., visual, hearing).	
Generalizability	
This attribute concerns whether a software product accommodates different kinds of users with different cultural backgrounds, gender, age and etc.	
Understandability	[3][38]
Whether users can understand how to select a software product that is suitable for their intended use and how it can be used for particular tasks.	

TABLE 4. USABILITY AND UX SUB-ATTRIBUTES DESCRIPTION

Sub-Attributes	Description
Time behavior	[3][39]
“The capability of the software product to provide appropriate response and processing times and throughput rates when performing its function, under stated conditions.” [1]	
Resource utilization	[3][39]
“Capability to consume appropriate amounts and types of resources when the software performs its function under stated conditions.” [3]	
Attractiveness	[3]
Capability of the software product to be attractive to the user (e.g., through use of color or graphic design)	
Operability	[3][45]
“The capability of the software product to enable the user to operate and control it.”	
Likeability	[3][51]
“User’s perceptions, feelings, and opinions of the product” [50]	
Flexibility	[47][48][52]
“With flexibility allowing adaptation to some specified percentage variation in tasks and or environments beyond those first specified.” [52]	
Minimal action	[39][40][48]
“Capability of the software product to help users achieve their tasks in a minimum number of steps.” [48]	
Minimal memory load	[48]
Whether a user is required to keep minimal amount of information in mind in order to achieve a specified task. To ensure minimal working memory load will increase human performance. Minimal long-term memory load requirement will help users learn interface more easily. The less that users need to learn, the faster users can learn it.	
Memorability	[38]

The concept of memorability, within the usability context, is that a user can leave a software product and, when he or she returns to it, remember how to do things in it.	
Accuracy	[3]
“The capability of software product to provide right or agreed results or effects.” [3]	
User Guidance	[48]
Whether the user interface provides context-sensitive help and meaningful feedback when errors occur. In general, a computer system with a good user guidance scheme will improve the learnability of the system as well as decrease the mental workload of the users since no extra effort will be needed for the users to perform designated tasks.	
Consistency	[48]
“Degree of uniformity among elements of user interface and whether they offer meaningful metaphors to users.” In human computer interaction, consistency is recognized to be able to improve user performance and user satisfaction.	
Self-descriptiveness	[53]
“The capability of the software product to convey its purpose and give clear user assistance in its operation.” Self-descriptiveness provides simplicity by reducing users' memory load. Users can retain their capacity for their tasks instead of bothering with the system. They can work more efficiently.	
Feedback	[3]
“Responsiveness of the software product to user inputs or events in a meaningful way.” [3]	
Completeness	[55]
Whether a user can complete a specified task.	
Fault tolerance	[3]
“The capability of the software product to maintain a specified level of performance in cases of software faults or of infringement of its specified interface.” [3]	
Readability	[3]
Ease with which visual content (e.g., text dialogs) can be understood.	
Controllability	[41][42][43][53]
Whether users feel that they are in control of the software product.	
Navigability	[3]
Whether users can move around in the application in an efficient way.	
Simplicity	[54]
“Whether extraneous elements are eliminated from the user interface without significant information loss.”	
Privacy	[3]
“Whether users' personal information is appropriately protected.”	
Security	[3]
“The capability of the software product to protect information and data so that unauthorized persons or systems cannot read or modify them and authorized persons or systems are not denied access.”	
Quality of outcome	[55]
Measures of the quality of the outcome of the interaction	
Experts' assessment	[55]
Experts' assessment of outcomes of the interaction	
Users' assessment	[55]
Users' assessment of the outcome of interaction	
Preference	[56][57]
“Measures satisfaction as the interface users prefers using.” [55]	
Users' attitudes and perceptions	[55]
“Users' attitudes towards and perceptions of phenomena other than the interface” [55]	