Usability Heuristics Evaluation for Child E-learning Applications

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***Abstract*— Selecting usability evaluation methods (UEMs) to expose usability problems in e-learning programs is influenced by time, cost, ease of application, and efficiency. Heuristic evaluation has become a widely accepted method of usability evaluation in software development. This paper introduces Heuristic Evaluation for Child E-learning applications (HECE), a comprehensive set of heuristics for child e-learning along with a detailed explanation for the usability experts on how to apply them. These sets of heuristics are based on Nielsen's original ten heuristics developed for software. Nielsen heuristics are basically generic, and might not encompass usability attributes specific to children or e-learning. The new HECE set would overcome these shortcomings. The validity and effectiveness of these heuristics were evaluated against two developed e-learning programs designed by ReDSOFT for KG-2 and special need students. The results indicated that HECE identified qualitative similarities and differences with user testing, and that HECE is best suited for evaluating general and child usability. Combined with user testing, HECE offers a new track that can assist in guiding the child e-learning industry to design applications that are both educational and pleasurable for children.**

***Index Terms*—E-learning, Human Computer Interaction, Usability Evaluation**

I. INTRODUCTION

Nowadays e-learning applications is considered a fast growing field in the software design industry. According to traditional marketing wisdom, the usability of an application must be analyzed correctly to create successful products. In the e-learning industry the challenge is to design e-learning applications that are both educational and pleasant for the learners. Evaluating the usability of e-learning applications poses its own requirements; hence, its usability evaluation is different from that of general task-oriented systems and requires different criteria. This is a maturing area in which research has been conducted by, among others, [1, 2, 3, 4]. The evaluation of e-learning should address aspects of pedagogy and learning from educational domains, as well as usability factors such as the efficiency, effectiveness and satisfaction of interfaces.

Heuristic evaluation is a methodology for investigating the usability of software originally developed by Nielsen and Molich, and later refined by Nielsen [5, 6]. Promoted for its cost efficiency and ease of implementation, the HE method consists of one or more experienced evaluators (3-5 recommended) applying an established set of guidelines called heuristics as they review a given application. It is also called the 'inspection' method or 'discount method' of usability evaluation. HE is seen as an economical alternative to experimental usability tests involving actual users. HE has also been reported to be the most used usability evaluation method [6]. The traditional heuristics formulated by Nielsen are basically generic, and might not encompass usability attributes specific to children or e-learning. Therefore, there is a need to develop a corresponding set of heuristics that consider the specific needs of children as well as the requirements of e-learning applications. This paper aims to explore and propose a new set of heuristics to evaluate child e-learning applications.

II. RELATED WORK

Heuristics Evaluation (HE) is an informal method where expert evaluators analytically examine the usability-related aspects of a user interface [6]. HE is more subjective than traditional user testing evaluation since it is heavily dependent upon the evaluators' skills [7]. The main advantage of HE is its cost-effectiveness; it does not require sophisticated laboratory equipment to record users interactions, expensive field experiments, or hard-to-process results from widespread interviews [6, 8]. The evaluator alone can detect a wide range of usability problems and possible faults of a complex system in a limited amount of time [6, 7]. For these reasons, HE has achieved widespread use in recent years, especially in industrial environments [9].

When comparing heuristic evaluation and user testing with other methods, for example, cognitive walkthrough and software guidelines, Jeffries et al. [8] found that heuristic evaluation identifies larger number of usability problem than the others with lower cost. Usability testing, on the other hand, reveals more severe problems at high cost. Another study conducted by Desurvire et al. [10] confirmed that heuristic evaluation reveals more problems than usability testing at labs. However, the evaluation process needs to be conducted by evaluation expertise.

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Many heuristics have been developed to address some particular issues related to user interface designs. For example, Pinelle et al. [11] had developed a set of ten heuristics for video game design. The ten heuristics had some similarities with those developed by Nielsen [5, 6]; however, Pinelle's heuristics are more specific to issues raised from problems exists in computer games (e.g. customizability, skip non-playable content, etc.). the set of heuristics are based on reviews posted by professional editors on a gaming website. These editors, as mentioned by the Pinelle et al. are not usability experts and therefore, some usability problems might be missed. Still, these heuristics can reveal more problems than Nielsen's heuristics.

Another set of heuristics have been developed for playability by Desurvire et al. [10]. Their heuristics are concerned with game play, game story, game mechanism, and game usability. They had compared the problems revealed by their heuristics with those by user testing. Their results indicated that although user testing revealed problems that only can be found by experimenting with real users, playability heuristics revealed more problems and there was an overlap between the two sets of problems. An inserting predictive evaluation method for usability and fun is Structured Expert Evalaution Method (SEEM developed by Baauw et al[12]. SEEM's contain a checklist that consist of questions based on Norman's theory of action [13] and fun related concepts from Molone [14]. SEEM's result are very promising in predicting usability problems. Korhonen and Koivisto have developed a set of heuristics to address the playability issue for mobile games from three points of view, two related to game interfaces and one related to mobile framework [15].

However, a consolidated expert evaluation methodology for child e-learning applications has not yet been developed. Evaluating a program from the child's point of view requires additional heuristics and guidelines that consider child satisfaction and e-learning requirements. Several existing e-learning evaluation models and guidelines have been reviewed to identify specific features and components that can be applied to evaluate e-learning programs. On the other hand, some authors propose to use traditional usability techniques for evaluating e-learning systems [16, 17]. Squires and Preece [18] build on Nielsen's traditional usability heuristics and adapt them to generate a set of heuristics for 'learning with software'. Squires and Preece indicated that there is a clear need for further elaboration and empirical validation of their proposed list. Other researchers have evaluated e-learning applications by using usability evaluation methods that were developed to address the needs and challenges of users of interactive systems and were not specific for e-learning [19, 20]. On the other hand, Reeves et al. [21] provided a more elaborate tool for heuristic usability evaluation for e-learning programs. In this work, Nielsen's protocol was refined for the evaluation of e-learning programs by participants in a doctoral seminar. Their modifications primarily involved expanding Nielsen's original ten heuristics developed for software in general to fifteen heuristics designed to be more closely focused on e-learning applications. An evaluation framework called MiLE (Milano-Lugano Evaluation method) was developed for e-learning web applications by the University of Lugano. MiLE supports systematic and structured evaluation guidelines and practical suggestions for online application [20].

In conclusion, although many researchers and practitioners have proposed e-learning heuristics, most of them require further adaptation to the context of child e-learning environments. The evaluation of child e-learning applications deserves special attention, and designers need appropriate guidelines to design usable programs. Therefore, the aim of this paper is to refine and extend existing heuristics to consider child's requirements and abilities as well as the specific requirements of e-learning.

III. EXPANDED HEURISTICS EVALUATION

Applying the traditional heuristics formulated by Nielsen in the evaluations of child e-learning programs is quite not feasible. First, the existing heuristics does not deal with child requirements or e-learning aspects, which are two major aspects in child e-learning applications. Second, Nielsen heuristics are not described in detail so that they could have been directly adapted to the child e-learning development. Third, the reliability of the results is often entirely dependent on the individual know-how, expertise and skills of the evaluator. This problem was also pointed out by various researchers, who have defined more specific guidelines for particular system classes [20-21]. Therefore, we aimed to expand Nielsen's traditional ten heuristics to twenty-one heuristics with detailed explanations, to be more closely focused on child e-learning applications and overcome the above shortcomings.

First, we had to define what kind of aspects should be evaluated. The general usability of child e-learning programs is a very important aspect, as children do not want to struggle with an application, just because they are not interested in the user interface. It should also take into account the mental and physical ability of the child. Therefore, the user interface of the application should be very natural and intuitive to be used for example by 6 to 10 years old child. Since we are evaluating e-learning applications, another aspect is to evaluate the pedagogical effectiveness. Furthermore, the application has to support learners in learning the content material in such a way that they devote minimum effort to actual interaction with the program, and it must make learning more effective and exciting. As a result, we divided the set of heuristics into three categories:

- Nielsen Usability Heuristics (NUH), the traditional design heuristics concerned with general user interface design.
- Child Usability Heuristics (CUH), concerned with children's preferences and abilities.
- E-learning Usability Heuristics (EUH), concerned with learner-centered design.

New and existing guidelines or applicable checklists are adapted and consolidated in each category [6, 16-24], as shown in Tables I-III. In addition, we have added a detailed description of each heuristic to help the usability evaluators directly apply the heuristics in the development of the child e-learning applications.

IV. Verification of the Child E-learning Heuristics Evaluation

The aim of this research was to develop a set of verified heuristics for child e-learning applications. The first version of the Heuristic Evaluation Child E-learning applications (HECE) was based on adapting and organizing existing guidelines or applicable checklists into three categories. A detailed description of each heuristics has been added to help usability evaluator directly apply the heuristics while evaluating the e-leaning program. HECE was reviewed by usability experts and child e-learning designers from Kuwait University and ReDSOFT. In addition, the developed set of HECE was comparatively tested against traditional end-user testing. The results were examined to evaluate the validity of the developed set of heuristics, and to identify the strengths, weaknesses, and qualitative differences of the separate methodologies.

TABLE I

Nielsen Usability Heuristics with the explanations.

Nielsen Usability Heuristics (NUH)
NUH_1. Visibility of System Status **Explanation:** – The e-learning program keeps the child informed about what is happening through appropriate feedback within a reasonable time. – The child gets frequent, clear feedback that encourages him to carry on. – The child should always be able to identify his score/status and goal in the program. – The child understands all terminology used in the program. – The child knows where he is at all times, how he got there, and how to get back to the main page.
NUH_2. Match Between System and the Real World **Explanation:** – The e-learning program interface employs simple words, phrases and concepts familiar to the child. – The e-learning program makes information appear in a natural and logical order. – All learning objects and images should be recognizable and understandable to the child, and speak to their function. – The e-learning program holds to good principles of child information processing.
NUH_3. User Control and Freedom **Explanation:** – The e-learning program allows the child to recover from his input errors. It distinguishes between input errors and cognitive errors, allowing easy recovery from the former always, and from the latter when it is pedagogically appropriate. – Exit signs are visible. The child may leave an unwanted state without having to go through an extended dialogue. – Navigation objects and tools are kept in particular and clearly-defined positions. – The child should perceive a sense of control and impact on the e-learning application. He is allowed to move around in the program in an unambiguous manner, including the ability to go back to the home page or go back to previous visited sections. – The child can easily turn the application on and off, and can save his user profile in different states.
NUH_4. Consistency and Standards **Explanation:** – The child experiences the user interface as consistent (in control, color, typography, and dialog design). For example; all menu instructions, prompts, and error messages appear in the same place on each screen. However, the learning objects are varied. – Control keys are intuitive, convenient, consistent, and follow standard conventions. – The e-learning program is consistent in its use of different words, situations, or actions, and it follows the general software and platform standards.
NUH_5. Error Prevention **Explanation:** – The e-learning program is carefully designed to prevent common problems from occurring in the first place. – The e-learning program does not allow the child to make irreversible errors. – The e-learning program is designed to provide a second chance when unexpected input is received (e.g., You have selected "……" in response to the question. Did you mean "….."?)
NUH_6. Recognition Rather than Recall **Explanation:** – The e-learning program makes objects, actions, and options visible so that the child does not have to remember information from one part of the program to another. – Instructions for the use of the program are visible or easily retrievable, so that the child does not have to memorize unnecessary things. – Icons and other screen elements are intuitive and self-explanatory. – Navigation is consistent and logical.

Child Usability Heuristics (CUH)
NUH_7. Flexibility and Efficiency of Use **Explanation:** – The e-learning program is designed to speed up interactions for the expert child, but also to cater to the needs of the inexperienced child. – Learning objectives should be balanced with multiple ways to learn.
NUH_8. Aesthetic and Minimalist Design **Explanation** – The screen interface does not contain information that is irrelevant or rarely needed in the e-learning program.
NUH_9. Help Users Recognize, Diagnose, and Recover from Errors **Explanation:** – The e-learning program expresses error messages in simple language that does not include programmer code, precisely indicates the problem, and in a friendly way suggests a solution that a child can handle.
NUH_10. Help and Documentation **Explanation:** – The child should be given help while using the program so as not to get stuck or have to rely on a instructor help. – Help should be easy to search. Any help provided is focused on the child's task, and lists simple concrete steps to be carried out. – The e-learning program includes interesting tutorials or flashes that mimic lessons in the program. – The child does not need to use a manual to use the application. – The child has the option to receive additional guidance, instruction, or other forms of assistance as needed.

TABLE III

CHILD USABILITY HEURISTICS WITH THE EXPLANANTIONS..

Child Usability Heuristics (CUH)
CUH_2. Design Attractive Screen layout **Explanation:** – The screen layout is efficient and visually pleasing. – The font choice, colors and sizes are consistent with good child screen design. – The screen design appears simple, i.e., uncluttered, readable, and memorable.
CUH_3. Use Appropriate Hardware Devices. **Explanation:** – Input/output devices are used for their own purposes and are suitable for the specific age group of the child. – Potential e-learner children have all the necessary computer skills to use the application. There should be a consistency between the motor effort and skills required by the hardware and the developmental stage of the child.
– All input devices/buttons that have no functionality are disabled to prevent user input errors.
CUH_4. Challenge the Child. **Explanation:** – The child should have enough information to start to use the program when he turns it on. – The e-learning program's goals are clearly identifiable. – The e-learning program is easy to learn, but hard to master. The application is paced to apply pressure but not frustrate the child. The difficulty level varies so that the child has greater challenges as he develops mastery. – The child's fatigue is minimized by varying activities and difficulties during learning sessions. Challenges are positive learning experiences, rather than negative experiences ; resulting in the child wanting to learn more, rather than quitting. – The program is enjoyable to replay. – The program gives rewards that engage the child more deeply in the application by moving the child to a higher level. – The child gets involved quickly and easily with the lessons and/or progressive or adjustable difficulty levels.
CUH_5. Evoke Child Mental Imagery **Explanation:** – The e-learning program allows the child to use his imagination, which enhances his comprehension. – The e-learning program appeals to the imagination and encourages recognition to create a child's unique interpretations of the characters or contexts. – The child is interested in the e-learning program characters because (1) they are like the child; (2) they are interesting to him, (3) they are drawn from the child's own culture.
CUH_6. Support Child Curiosity **Explanation:** – The program supports the child's cognitive curiosity through surprises, paradoxes, humor, and dealing with topics that already interest the child. – Learning information is provided in layers or on different levels, in contrast to the linear approach more common to e-learning. However, a maximum of two layers or levels must not be exceeded according to Nielsen's 70 design guidelines for usability.

TABLE III
E-LEARNING USABILITY HEURISTICS WITH THE EXPLANATIONS.

E-learning Usability Heuristics (EUH)
EUH_1. Learning Content Design **Explanation:** – The vocabulary and terminology used are appropriate for the learners. – Abstract concepts (principles, formulas, rules, etc.) are illustrated with concrete, specific examples. – The organization of the content pieces and learning objects is suitable to achieve the primary goals of the e-learning program. – Similar learning objects are organized in a similar style. – The learning curve is shortened by following the trends set by the e-learning industry to meet the child's expectations.
EUH_2. Assessment **Explanation:** – The e-learning program includes self-assessments that advance child achievement. – The e-learning program provides sufficient feedback (audio, video) to the child to provide corrective directions. – The e-learning program provides the instructor with child evaluation and tracking reports.
EUH_3. Motivation to Learn **Explanation:** – The e-learning program incorporates novel characteristics. – The e-learning program stimulates further inquiry in different ways. – The e-learning program uses e-stories, games, simulations, role playing, activities, and case studies to gain the attention and maintain the motivation of learners. – The e-learning program is enjoyable and interesting. – The application provides the learner with frequent and varied learning activities that increase learning success. – The child's actions are rewarded by audio, video, text, or animations and the rewards are meaningful.
EUH_4. Interactivity **Explanation:** – The child becomes engaged with the e-learning program through activities that challenge the child. – The child should be able to respond to the program at his leisure. The program, on the other hand, needs to respond immediately to the child. . – The child has confidence that the e-learning program is interacting and operating the way it was designed to interact and operate.
EUH_5. Accessibility **Explanation:** – The e-learning program may be used on a variety of equipment and platforms such as laptops, PDA.

V. CASE STUDY

In order to validate the HECE set of heuristics, heuristics evaluation and usability testing were conducted and the results were analyzed and compared. Two e-learning applications designed by ReDSOFT were evaluated and examined for their usability; an e-leaning application for KG-2 and a deaf e-learning prototype; see Fig. 1 and Fig. 2. The e-learning application for KG-2 was designed for five to six years old child to learn simple reading, writing, math, and science skills. Eight activities were evaluated by both usability experts and usability testing with children. Further, a deaf e-learning prototype was designed for seven to nine years old children to learn new colors', numbers', animals' definitions, maps, and to read stories. All of the five activities were considered in the evaluation process by the usability experts and usability testing with deaf children.

Figure 1. User Interface sample of math lesson for KG-2

A. Heuristic Evaluation

Usability experts from Kuwait University, ReDSOFT and e-learning expertise from the Ministry of Education have participated in the evaluation of the two e-learning programs using the HECE set. The evaluators focused on how each heuristic was satisfied or violated, and then defined the child e-learning problems. For each predicated problem the evaluators had to explain the severity of the problem and suggest alternative solutions for resolving the issues if possible.

Figure 2. User Interface sample of deaf e-learning prototype

Heuristic Evaluation of the KG-2 Application

For the KG2- e-learning software, nine out of the ten Nielsen heuristics, five out of the six child usability heuristics, and three out of the five e-learning usability heuristics were useful in uncovering usability issues. This reveals that for child e-learning design, HECE is useful in all three categories. Eight activities in the e-learning application were evaluated. Further evaluation of the activities could potentially find additional usability issues, which would provide further evidence of the usefulness of the HECE set. Most of the usability issues were found in the Nielsen usability (29 issues) and the Child usability (24 issues) categories, whereas only seven issues were found in the E-learning category. This could be explained as follows: teaching educators from the Ministry of education and e-learning designer expertise participated in developing this software. However, no usability specialist participated in the development.

Heuristic Evaluation of Deaf E-learning Prototype

The number of issues found in each category is close to each other. Both of Nielsen's usability and child usability heuristics revealed twenty-two issues. The e-learning usability heuristics revealed sixteen issues. Most of Nielsen's usability issues were occurred because icons' representations were not suitable for deaf children, that violated NUH_2 for example match between system and real world was violated. Further, most of the e-learning usability issues were related to uncompleted parts of the applications. For example, there were no self-assessment at the end of each activity and there were no corrective feedback to direct the child to the correct action/behavior, which violated the EUH_2. In the "Quiz" activity, the child has no explicit directions, and, if he answers a question wrongly, he has no tool or directions to help him in correcting his actions. When it comes to child usability issue, CHU_2: design attractive screen layout was violated. Evaluators reported that the application's screen size was small; it should accommodate most of the window size. Further, the difficulty level for the activities cannot be adjusted, thus, when the child become experience with the application, he may get bored quickly.

B. User-Testing

User Testing of the KG-2 Application

After the heuristics evaluation was completed, usability testing was conducted with seventeen children (8 boys and 9 girls) from public and private schools to reveal software application problems. All participants were familiar with the use of computers. A one-hour session was organized in the child actual classroom environment. To set up a usability testing experiment; the guidelines described in [25] were followed. The children were given instructions to evaluate eight learning activities, asked to think aloud, and asked several questions while using the application and at the end of the usability testing. The child was then thanked and given a small gift. The evaluators videotaped the sessions, and took notes of the child's actions, comments, and their positive and negative experience. A positive experience was defined as anything that increased their pleasure, immersion, and the challenge of the activity. A negative experience was defined as any situation where the child was bored, frustrated, or wanted to quit the activity. The child was asked to think aloud, and his comments were used to verify any assumptions made by the evaluator. After the usability testing sessions were complete, design problems were identified and alternative design solutions were generated. Each issue was assigned a severity score based on its consequences and the child's ability to continue with the activity.

User-Testing of Deaf E-learning Prototype

Forty-two students (23 males, 19 females) from Kuwait (12 males, 8 females) and Jordan (11 males, 11 females) evaluated the deaf e-learning prototype. They ranged in age from seven to thirteen years old. Some student had partial loss of their hearing and others had a complete loss. Further, 68% of participants from Kuwait and Jordan are using computer at home or have previous computer experience.

Participants were registered to special education schools specialized for deaf students. In Kuwait, the average age of elementary school students is from seven-to-nine years old, whereas Jordan has higher average age, from seven-to-thirteen years old. Teachers also participated in the evaluation process and their comments were considered.

C. Comparing HECE Issues with User Testing Issues

The total number of issues identified from HECE was greater than the number of issues found from the user testing (see Fig. 3 and Fig. 4), but the nature of the user testing issues were more specific to the application and highlighted more severe problems. The user testing issues were very specific to the interface, such as the terminology, characters, and sounds that actually bothered the child. An example of an interface specific issue that is raised through HECE for deaf e-learning prototype, the "Quiz" section provided children with instant feedback, however, during the usability testing, some of those feedbacks were not understandable by deaf child.

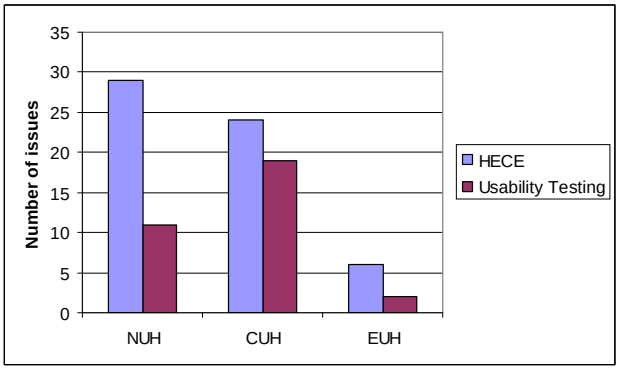

Figure 3. Comparison of Number of issues found using HECE and Usability Testing for E-learning applications (HECE) of the KG-2 Application

There was an overlapping between the issues found from the user testing and those found from the HECE in

the deaf e-learning prototype. For instance, 32.3% of issues found in user testing were also found in HECE. For example, EUH_3 was violated in both techniques. There was lack of encouragement after each lesson/activity except for the "Quiz" unit.

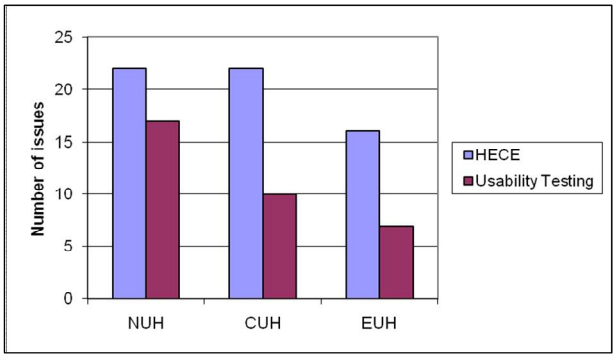

Figure 4. Comparison of Number of issues found using HECE and Usability Testing for deaf e-learning prototype

On the other hand, 83.3% of issues found using HECE was not found using usability testing. This can be explained as follow: deaf children at this specific age are difficult to communicate with. Their teachers' could mistranslate parts of their comments, or the child did not have the ability to deliver his opinion clearly regarding some issues. EUH_2 is an example of an issue that was found using HECE only. The e-learning program did not provide sufficient feedback (audio, video) to direct the child to the correct behavior/action. CUH_4 is another example of an issue found using HECE only. All the activities appeared in the same order and had no different levels. During the usability testing, none of children seems to be bothered from those issues; they did not report nor showed any type of frustration. This is because the child did not yet master the application since he used it only for half an hour.

D. The Advantage of User Testing

Overall, user testing uncovered many of the same issues found by HECE set, but also identified specific behaviors and problems that could only be found by observing the child interacting with the application. During user testing evaluators can identify limitations exists in current applications and suggestions for further improvements which cannot be found using inspection methods. The user testing findings highlighted issues specific to the e-learning: boring, comfy and attractive. These issues were not found through the use of the HECE set, whose benefit was in ensuring general e-learning usability principles.

VI. CONCLUSION

This paper presents the Heuristic Evaluation for Child E-learning applications (HECE) set to perform a cost-effective usability evaluation of child e-learning applications. HECE was found to be very helpful in evaluating child e-learning applications, and to be best suited to finding usability and e-learning problems early in the development process. E-learning applications may benefit from such a set of heuristics, because they provide precise feedback regarding child e-learning issues to the designers. However, user testing must still be conducted, as child behavior can be unpredictable and specific issues can only be revealed during such testing. Further refinements to the HECE set are likely to be made based upon the function of the heuristics to various child e-learning applications. Further work should also focus on expanding the validation of the HECE set so that usability evaluators can use it with confidence when evaluating the design of child e-learning application.

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