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Design Lessons on Access Features in PAPER

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Abstract. Using Nielsen's Heuristic Evaluation, this paper reports a user study with six usability-trained subjects to evaluate PAPER's access features in assisting users to retrieve information efficiently, part of an on-going design partnership with stakeholders and designers/developers. PAPER (Personalised Adaptive Pathways for Exam Resources) is an improved version evolving from an earlier implementation of GeogDL built upon G-Portal, a geospatial digital library infrastructure. After two initial evaluations with student and teacher design partners, PAPER has evolved into a system containing a new bundle of personalized, interactive services with four modules: mock exam; personal coach (practice and review); trend analysis and performance review. This paper highlights lessons learnt in the design of PAPER using Nielsen's heuristics, and discusses implications for the design of access features in digital libraries in general.

1   Introduction

Subject-based digital libraries (DLs) are beginning to emerge on the Web, and promise opportunities we never had with traditional libraries or even the Web. Recent work developing educational applications of DLs across all disciplines range from primary schools through graduate schools. However, there are many design and usability issues that remain unresolved. One of which is still the lack of more user studies done on interactive systems to improve navigation and help, a concern voiced in a keynote address by Ben Shneiderman at the 8th ERCIM Workshop on "Universal Access for All" at Vienna (Austria) in June 2004 [5].

As part of an on-going design partnership with stakeholders and designers/developers, in this paper, we report a third user study employing six usability-trained subjects as design partners to evaluate PAPER's access features, particularly on instructions or descriptions to assist better user navigation and understanding of PAPER. PAPER is a DL of geography examination resources designed with four main personalized, interactive services: (1) a mock exam; (2) personal coach (practice and review); (3) trend analysis and (4) performance review.

The paper concludes with lessons learnt in the design and development of PAPER, and discusses implications for the design of access features in DLs in general.

2   Design History and Philosophy of GeogDL and PAPER

PAPER, which stands for **P**ersonalised **A**daptive **P**athways for **E**xam **R**esources, was first conceptualized as GeogDL, a geospatial DL on geography examination resources, an application built upon G-Portal [3]. G-Portal aims to explore identification, classification and organization of geospatial and georeferenced content on the Web, and the provision of digital services such as searching and visualization. One of the main objectives of G-Portal is allowing authorized users to contribute resources to a common environment for knowledge sharing.

Since then, GeogDL has undergone several refinements, resulting from participatory design partnerships with prospective stakeholders and designers/developers. Prior to the study reported in this paper, two previous studies with student and teacher design partners were conducted and reported in [7, 2].

In the first study [7], student design partners gave feedback from the perspectives of prospective users on possible scenarios of use in GeogDL (predecessor of PAPER), and identified usability problems with positive and negative consequences employing Carroll's Claims Analysis, and grouped usability problems using Nielsen's heuristics. Based on their feedback, GeogDL was modified. In the second study [2], teacher design partners were employed, resulting in new, additional services or modules. GeogDL was renamed as PAPER.

In section 2.1, we briefly revisit our previous work on GeogDL to provide a background for the body of this paper and the issues explored within it. Section 2.2 describes PAPER, improved version of GeogDL. Section 2.3 reviews and compares related work.

2.1   GeogDL – Early Version

In GeogDL, past-year examination questions (with their solutions) are created as separate G-Portal projects. Each project consists of Web resources, at least one of which contains the solution to the question. Other resources contain information to related topics and are used as supplementary material for further exploration. Resources may be further organized into layers depending on the needs of the teacher. For example, the solution to an equatorial region question could appear as a resource in a layer while a separate layer might contain supplementary vegetation resources found in equatorial climates.

In the initial version of GeogDL, examination questions are first accessed through the classification interface that organizes questions by year. Upon selection of a question, the associated project, its resources, and the corresponding map are loaded. Resources are divided into three categories containing question, solution and supplementary resources, each of which is accessible separately via the classification interface.

To view the question, the user selects it using the classification interface, causing GeogDL to display metadata associated with it on the Resource Information Window. This includes information such as the year in which the question appears, type of question, keywords and URL of the question. The user then selects the URL and the question appears in a separate Web browser window. Viewing the solution and supplementary resources follows a similar process. The user first loads the desired category of resources on the classification interface and selects a resource from it. The URL of the resource is selected on the Resource Information Window and G-Portal will then display it in a separate Web browser window. More information may be found in [7].
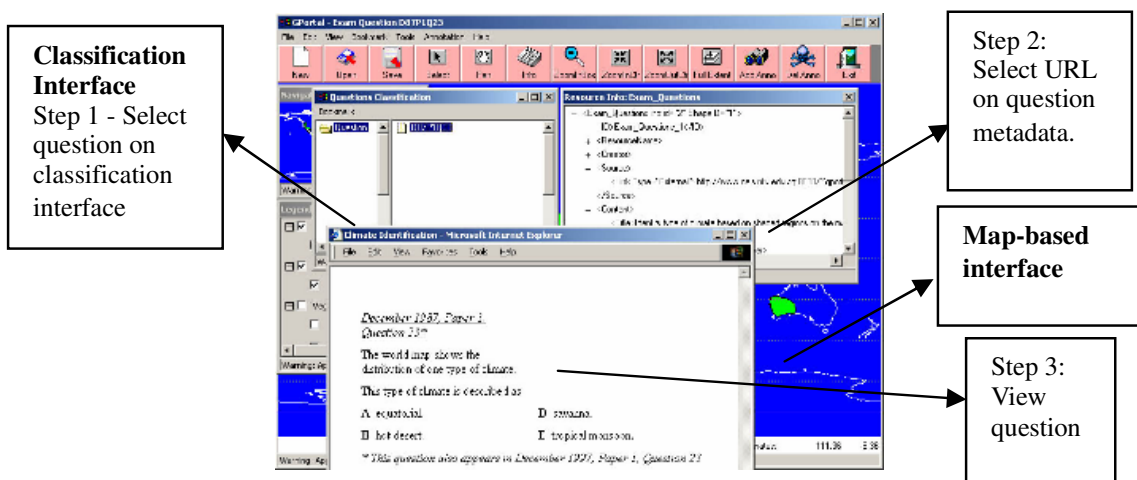

Fig. 1. Viewing an Examination Question

2.2   PAPER – Revised Version of GeogDL

Below are brief descriptions of the four modules implemented in PAPER, a revised version of GeogDL, based on the first two user studies:

1. *Mock Exam.* Provides a timed and scored test that reflects the structure and content of the actual geography examination. Presently, multiple-choice questions are available. Upon reading a question, users select an answer and proceed to the next question. Users may also revisit previous questions to modify their answers. PAPER monitors the time taken for each question to give an indication on how difficult a particular question is to a student. Upon completion of the mock exam, PAPER grades it and displays a performance report. The report contains a summary of the results and includes the total score and total time taken. Users may also review the solutions and explore supplementary resources from the report interface.

2. *Personal Coach (Practice and Review).* Provides recommendations of examination questions to attempt based on performance in previous mock exam sessions (see Figure 2). The personal coach may be invoked from the mock exam

report. The interface consists of two major sections with the panel on the left providing a list of recommended questions organized into topics as described in the geography syllabus, and the panel on the right presenting a question selected by the user and also allowing users to attempt it. Questions are recommended based on a user's past performance in the mock exams. Specifically, each question in a mock exam is associated with one or more topics in the geography syllabus. The personal coach calculates a competency level for each topic based on a user's performance for that topic in previous mock exam sessions. This is a weighted score involving the most recent mock exam and a cumulative score from previous sessions. Using this approach, the personal coach adapts to the student as he or she interacts with PAPER. Difficulty levels range from 1 (easiest) to 5 (most difficult) and are stored in each question's metadata. These are once again assigned by experienced geography teachers to ensure validity.
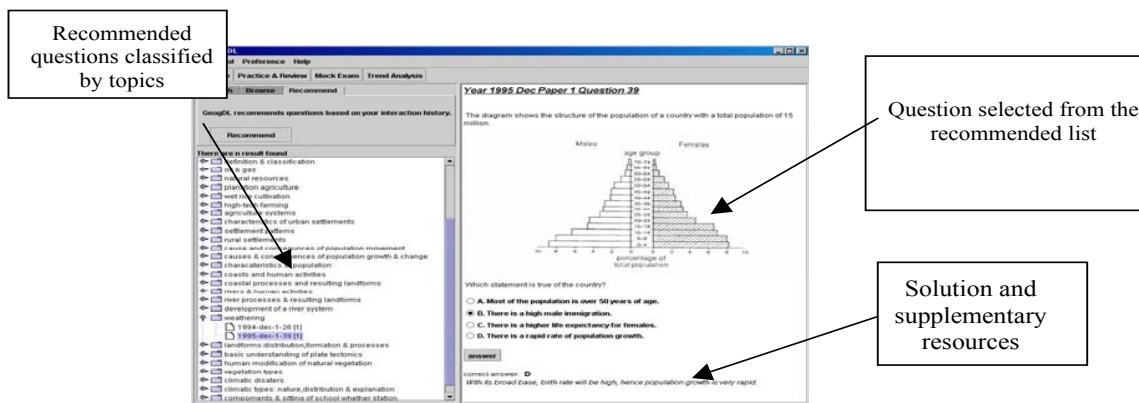

Fig. 2. The Personal Coach : Practice and Review

3. *Trend Analysis*. The idea is to give information on when and what questions are being set over the years (see Figure 3). This would help students identify trends in the types of questions asked and the topics covered. The tool provides statistics on topic areas that appear within a user-specified range of years. These are generated using metadata associated with each examination question. Once again, questions within each topic are classified as "very easy" to "very hard". Selection of a particular bar in either chart will cause PAPER to retrieve and list the associated questions. Upon selection of a particular question, PAPER will display that question together with its answer and supplementary content.

4. *Performance Review*. It provides diagnostic tools to help users gauge how well they fare in their attempts at questions in the mock exam (see Figure 4). It allows students and teachers to view individual or aggregate performance in examination questions. From a student's point of view, the performance review module allows the student to see how well he/she has done in answering questions in the mock exams. Teachers, on the other hand, can either view each student's performance in

mock exams as well as aggregate performance across all students in the class. Performance indicators are categorized by topics so that a student, for example, is able to determine which topics he/she are weak in and therefore pay amount attention to them during revision. Likewise, teachers are able to use this information to tailor their lessons according to the learning needs of the class [2].
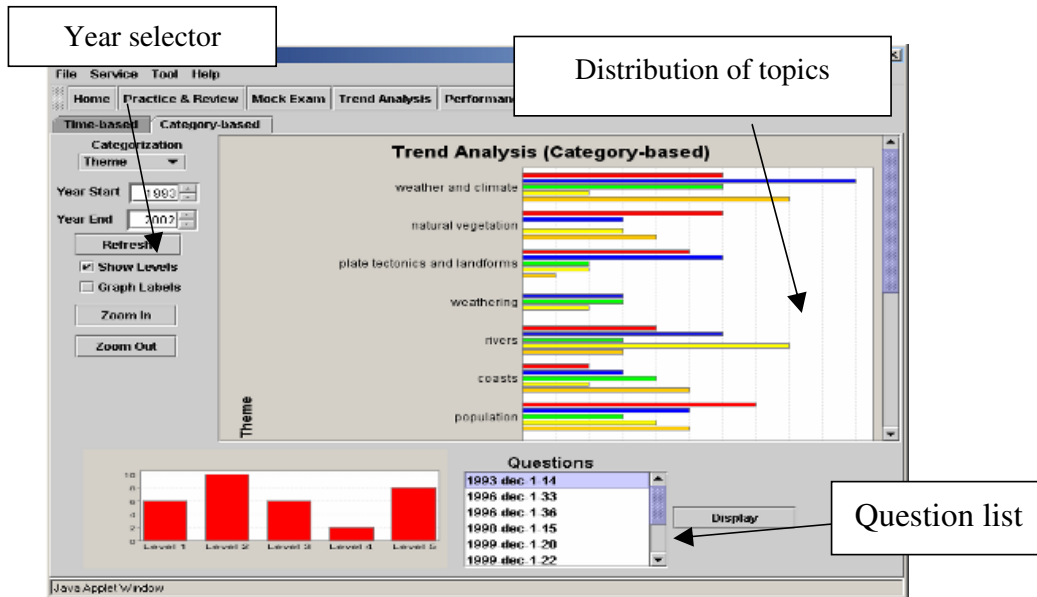

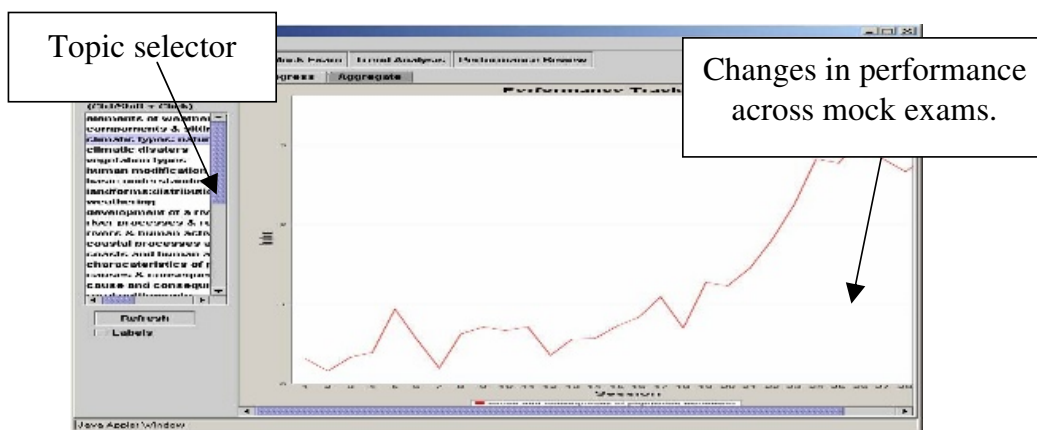**Fig. 3**. Trends Analysis for All Topics Over Time

Fig. 4. Performance Review by Mock Exam Session

2.3   Comparison with Other Educational Digital Libraries

While PAPER shares the same education philosophy of active learning as existing education-oriented geography DLs, its design and implementation approach differs due to the importance of examinations in the Singapore education system. For

example, the Alexandria Digital Earth Prototype System [6] provides students with "learning spaces", personalized collections of geospatial resources relevant to one or more concepts or hypotheses. Through the process of exploring, manipulating and interacting with the resources in these learning spaces, students' scientific reasoning skills in geography may be cultivated. These skills can then be applied to solve real-word problems as well as examination questions. In contrast, PAPER adopts a "bottom-up" approach in which students are first assisted with examination preparation. As students explore examination questions and solutions, PAPER provides related higher-level concepts for them to investigate, allowing them to draw associations between various geographical issues and developing their reasoning skills. Since requirements for the geography examination are broad, solutions and their associated supplementary resources are developed in cooperation with experienced geography teachers who know how much depth and breadth to provide for each question.

In addition, while the mock exam module shares similarities with existing online tools such as QUIZIT [8] and PILOT [1] in that all provide a Web-based environment for testing and grading, our approach differs in that the mock exam is integrated with PAPER's other modules thus offering various interrelated avenues for revision. For example, because the mock exam operates in conjunction with the Trend Analysis and Performance Review modules, students are not only able to ascertain their areas of weaknesses through their scores but also receive recommendations of important topic areas and hence, examination questions, that should be explored further.

3 Modified Heuristic Evaluation

3.1 Experimental Protocol

Since this study is part of an on-going design partnership with stakeholders and designers/developers, it is important that we obtain "quick" and frequent feedback on PAPER. Hence, in the user studies carried out so far, we made use of small numbers of subjects. In this study, six usability-trained subjects were recruited to evaluate PAPER using Nielsen's Heuristic Evaluation. Compared to other forms of usability evaluation techniques, Heuristic Evaluation is simple to conduct and common usability problems could be detected quickly [4]. These six subjects were graduate students at a local university trained in Heuristic Evaluation. They were frequent Web and DL users, and had been taught how to carry out Nielsen's Heuristic Evaluation.

The subjects were first given a quick tour of PAPER (see http://155.69.149.173:10001/geogdl/index.htm), and then another ten minutes to browse PAPER before they were asked to attempt four different tasks, with one task described for each of the four modules :

- Task 1 *:* Subjects were to use the "*Practice and Review*" module to practise and review exam questions from 2000-2001 on "rivers".
- Task 2 *:* Subjects were to take a mock exam using the "*Mock Exam*" module to retrieve papers from "Paper Year 2002 December".

- Task 3 *:* This involves getting the subjects to review "exam question trends" on "weather and climate" from 1999 – 2003, using the "*Trend Analysis*" module.
- Task 4 *:* Subjects reviewed performance for Tasks 1 and 2, as well as overall performance from other subjects using the "*Performance Review*" module. They were also asked to explore other features provided in the module on : (i) number of attempts; (ii) proficiency of subjects; (iii) progress of subjects; and (iv) aggregate scores.

In accomplishing these tasks, the subjects were also asked to interrogate PAPER using Nielsen's well-established heuristics focusing specifically on access features

Table 1. Nielsen's Ten Heuristics

H1 : *Visibility of system status.* The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
H2 : *Match between system and the real world.* The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
H3 : *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.
H4 : *Consistency and standards.* Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
H5 : *Error prevention.* Even better than good error messages is a careful design which prevents a problem from occurring in the first place.
H6 : *Recognition rather than recall.* Make 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.
H7 : *Flexibility and efficiency of use.* 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.
H8 : *Aesthetic and minimalist design.* 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.
H9 : *Help users recognise, diagnose, and recover from errors.* Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
H10 : *Help and documentation.* 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.

such as search and browse facilities. To ensure that the subjects had the same understanding of Nielsen's heuristics, they were also given a handout with the following descriptions on the ten heuristics (see Table 1).

In giving feedback on the different modules, the subjects were asked to complete four sets of evaluation forms, one for each module, to identify violations against the respective heuristics, and suggest possible recommendations to address these problems. All the subjects completed evaluations of the four modules in approximately two hours.

4   Findings

Although there were only a small number of subjects, using Nielsen's Heuristic Evaluation, we were able to obtain insightful feedback on PAPER. The heuristics

Table 2. Violations against Heuristic #1 and Suggestions for Improvement of the Four Modules

Modules	Violation against Heuristic H1 (Visibility of system status)	Suggestion(s) for Improvement
Personal Coach (Practice and Review)	▪ The current location is not easy to know. ▪ Not sure what happened to system when entered query. No error message was given.	▪ Make the tab page more informative; users may feel confused where they are. ▪ Provide some error messages after entering command.
Mock Exam	▪ No question number given. ▪ I don't know when the exam is over. Don't know how many questions in total, how much is left, how much to be finished. ▪ Not sure what review means.	▪ Question number should be given, so that students can move back to questions they are not sure of. ▪ Should provide clear message and instructions. ▪ Need to specify that "review" means review previous performance.
Trend Analysis	▪ No indication on what's going on. ▪ No indication of progress. ▪ User keeps clicking same option unanswered if processing is taking place	▪ Make the tab page more informative. ▪ System should show a message box indicating the process of running when I click on the "refresh chat". ▪ System takes time to process request. Hence, a display like "please wait…" would tell us system still working.
Performance Review	▪ If I choose one question bar, such as "rural settlements", there is no response. ▪ No feedback from the system when I click on refresh for a user who has not taken a test before. ▪ Not clear what the different charts mean	▪ Tell user their choices. Grey out options not available. ▪ Provide feedback. ▪ More informative labelling of charts.

helped the subjects to interrogate the four modules in PAPER, focusing on identifying "obvious" usability problems that came about because of violation against the ten heuristics.

In general, the subjects found PAPER useful in helping students prepare for geography examinations, and PAPER was sufficiently easy to navigate, once they got used to the interface. However, they highlighted that more could be done to assist navigation, and hence provide better user experience.

Due to space constraints, we will not be presenting all the tables highlighting usability problems of the four modules. As an illustration, we selected Table 2, which reports findings of the study with respect to violations against heuristic H1 "visibility of system status" (see Column 2), with suggestions for improvement (see Column 3) by the six subjects. The feedback given by the subjects showed that the modules in PAPER should comply with H1 to "always keep users informed about what is going on, through appropriate feedback within reasonable time". For example, in the Personal Coach module (see Table 2, Row 2, Column 2), subjects did not know where they were, and wanted messages to inform them of what PAPER was doing with their inputs. The subjects suggested making the tab page more informative, and provide messages informing them of errors made or status of PAPER (see Table 2, Row 2, Column 3).

Similar tables such as Table 1 were compiled for all the ten heuristics and four modules. The heuristics were useful in helping subjects to focus on common usability problems highlighted by Nielsen's heuristics, initial efforts made in this project to ensure a good, usable PAPER before implementation and deployment in schools.

5   Discussions on Usability Problems and Recommendations

In this section, owing to space constraints, we will only identify some areas of design recommendations in the four modules based on violations against Nielsen's ten heuristics (see Table 1) detected by students described in tables similar to Table 2, to illustrate that useful recommendations by students serve as on-going design lessons for us in addressing and "fixing" design flaws in PAPER.

5.1   Personal Coach : Practice and Review

Design Violations Against

- *Heuristic H1*. Subjects were confused with regard to where they were. PAPER did not provide enough messages or cues.
- *Heuristic H2*. The subjects did not like the grey background colour, and thought PAPER should be more attractive. The "search" button in the advanced search seems to be in the "wrong place" as the subjects needed to move the mouse down to select the parameters then up again to submit the search. Search's submit box is not next to query field, e.g. "because I expected search results to be displayed on right window but it is in left window, at the bottom", etc.

- *Heuristic H3*. Subjects indicated that they did not know how to switch between the simple and advanced searches.
- *Heuristic H4*. Subjects could not understand what "show annotation" meant. They thought the interface was more like a traditional database system, but it did not comply with established web design conventions.
- *Heuristic H5*. No keywords stemming provided, and some results were not relevant.
- *Heuristic H6*. Not able to distinguish between search and simple search. Annotation feature does not match with prior experience.
- *Heuristic H7*. "Simple search" and "advanced search" were not easy to find. Did not know they should click the text. Feature did not allow submission of search by using "enter" on keyboard.
- *Heuristic H8*. No violation. Generally, subjects were happy with the minimalist design.
- *Heuristic H9*. No good help given. "When entered with invalid characters, no message except sorry! No exam question…"
- *Heuristic H10*. No documentation provided for subjects if they were unsure how to proceed.

Some Recommendations

Recommendations include making the tab page more informative to give context of where they are (see H1). Some error messages should be given, for example, if server is down (see H1). "Search button" should be placed next to query search box, following normal conventions (see H2). Make simple and advanced searches obvious (see H6). Instead of "show annotation", it might be changed to "discussion board of questions" (see H6). The subjects also indicated that better improve information retrieval performance through stemming (see H7). There should also be multiple ways to submit search query (see H7).

5.2 Mock Exam

Design Violations Against

- *Heuristic H1*. Question numbers should be given, so that students can move back to questions they are not sure of. "I don't know when the exam is over. Don't know how many questions totally, how much left, how much finished." The subjects were not sure what review means.
- *Heuristic H2*. "When I get zero scores. It is "00" I think "0" is better. The subjects were confused with this interface, not a conventional one
- *Heuristic H3*. Need to first specify answer, next question appears. The question should not already have a predefined checkbox at the answer. Don't replicate an exam setting. Users should be allowed to stop exam, a cancel option should be given. Linear form of navigation from first question to last and vice versa restricts flexibility. Test papers could be loaded by double-clicking on the exam paper list displayed. No "back button" to return to select a new exam.

- *Heuristic H4*. Loading exam and starting exam seemed like the same function. But their functions are supposed to be different. Not consistent with "practice & review" module.
- *Heuristic H5*. User must click on "load paper" before all the papers show up. Seems like an extra step. Not sure what "Pre" button means, and no explanation given when clicked. It had a default answer from the second question onwards, so users might make mistakes if they did not know what to choose.
- *Heuristic H6*. Numbering of questions should be provided.
- *Heuristic H7*. PAPER did not prompt to "save" work done in other modules.
- *Heuristic H8*. Subjects were satisfied with the simple design.
- *Heuristic H9*. No indication on how to proceed when errors occurred.
- *Heuristic H10*. Proper paper instructions should be given on the structure of PAPER. No "help" feature is available on-line.

<u>Some Recommendations</u>

Should provide clear message and explain what "review" means (see H1). The next question icon should be available all the time (see H2). Checkbox should not be ticked before the user selects the answer (see H2). Give timing as well as cancel options (see H2). Perhaps, a feature should be added to allow users to mark questions they are not sure of, so they could navigate back to the question when they have extra time (see H3). Allow exam papers to be loaded by double clicking the list (see H3). Give a workflow of how this function works, or offer the same search interface similar to "practice & review", or directly display two mock papers, so there is no need to click "load" (see H7). Make help more prominent at present (see H10). System should explain the difficulty levels of the questions (see H10).

5.3 Trend Analysis

<u>Design Violations Against</u>

- *Heuristic H1*. "No indication on what's going on." System should show a message box indicating the process of running when subjects clicked on the "refresh chat".
- *Heuristic H2*. "Trend analysis" option is not intuitive. Normally, the convention is from left to right. But displayed questions on PAPER are from right to left.
- *Heuristic H3*. User may feel confused because lots of options are available. Not clear if users can have multiple choices from list. Display functions cannot be displayed by double-clicking.
- *Heuristic H4*. Category type field is grey. Users may think it is invalid. Time based & categories based are different interfaces. Year in "practice & review", for example, is a dropdown list but it is not in this module.
- *Heuristic H5*. Not sure what "levels" mean.
- *Heuristic H6*. "Refresh chart" icon is not very intuitive. For category-based, there is no indication on the meaning of colours. The choices and design are not very interactive.

- *Heuristic H7*. Not clear about what's difference between domain, theme and topic.
- *Heuristic H8*. The design is complex. The user should not have to scroll horizontally to read the category name under category list as well.
- *Heuristic H9*. The response time is long, and subjects not certain whether it encountered error or working. Not clear what this module can achieve. Should provide intuitive display of error messages, when users do something wrong.
- *Heuristic H10*. No help available.

Some Recommendations

Make the tab page more informative so users may not feel confused where they are (see H1). PAPER takes time to process request. Perhaps, a display like "please wait…" would tell users whether PAPER is still working (see H2). Should provide help and make the options more informative (see H3). More informative labelling of features should be available. Provide on-line help to assist user (see H10).

5.4 Performance Review

Design Violations Against

- *Heuristic H1*. The interface and fonts were not clear. No feedback from the system when subjects clicked on refresh. Not clear what the different charts mean.
- *Heuristic H2*. Yes. The message box use "Error" as title. Confused by the interface. The use of "Ctrl+click" to select user is not conventional.
- *Heuristic H3*. Clicking on the blue bar did not show list of question attempted already. The various themes should be displayed as rule-headings under :

<div align="center">main domain-> theme->topic</div>

- *Heuristic H4*. No violation.
- *Heuristic H5*. Not sure what "save as" do. Attempts, proficiency, and aggregate have no data at times.
- *Heuristic H6*. Subjects did not know they had to click bar to retrieve question lists.
- *Heuristic H7*. No violation.
- *Heuristic H8*. Had to scroll both horizontally and vertically to read topics. The meaning of each review should be stated
- *Heuristic H9*. In the "attempts< when user did not choose a question bar, firstly and click "show questions", the error message just tells users should choose one question. No explanation given.
- *Heuristic H10*. Simple instructions should be given so that users can find questions of interest. Subjects did not see the purpose and benefit of each sub category.

Some Recommendations

More informative labelling for charts should be provided (see H1). Allow display list of questions by clicking on the blue bar (see H3). Provide documentation and help so that users will know what each function does (see H10).

6   Conclusions and On-Going Work

Using Nielsen's Heuristic Evaluation, this paper reported a third user study with usability-trained subjects on PAPER, following the first two studies with stakeholders such as students and teachers, to improve the access features, in particular the search and browse facilities. With six subjects, usability problems as a result of violations against Nielsen's heuristics were highlighted, and recommendations were made to address the problems.

Design ideas for PAPER could go on. However, in seeking improvements, it is sometimes tempting to propose the implementation of new features which, in the end, may or may not enhance the system. Whether it be an aesthetic make-over or a re-design of the underlying information structure, there will be a need to find out whether the changes suggested do, in fact, have the desired outcome prior to implementation, and this is where future work needs to be performed. In spite of this, the evaluation findings using Nielsen's heuristics suggest a few broad recommendations for PAPER.

In the three studies on PAPER, we carried out participatory design with a small group of stakeholders, designers/developers and usability-trained subjects to help us obtain "quick" feedback through testing and retesting initial designs. On-going work with PAPER involves deploying it in an actual school environment with "real" user students and teachers working in their "natural" settings.

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