Working Globally via Wikis while Innovating and Acting Together: Case Wiki-Based Knowledge Sharing Portal

Helena Suvinen
Agora Center
University of Jyväskylä
Jyväskylä, Finland
Helena.suvinen@jyu.fi

Pertti Saariluoma
Computer Science and Information Systems
University of Jyväskylä
Jyväskylä, Finland
ps@jyu.fi

***Abstract*—Wiki-technology is one of the new Internet collaborative service platforms that allows, among other things, building innovation networks for industries and research groups. To make these wiki tools really effective it is essential to understand human interaction problems within information and communication technology (ICT) based on scientific psychological grounds, rather than resorting to folk psychological intuitions.**

The problem with wikis is that their inbuilt interaction problems may substantially interfere with the development of open innovation communities. This is why it is essential to investigate psychological factors evident in the interactions within open innovation systems. This study, realized with a wiki-based portal, aimed to help build innovation systems within a particular industrial area. Our results identified several problems and point to a variety of user psychology reasons behind these problems. These reasons were organized into a classification system of problems experienced by users in task execution.

Keywords—Innovation, networked co-creation, wiki, psychology, usability

I. INTRODUCTION

User psychology refers to the psychological analysis of users in interaction situations [27], [29], [30], [35]. Psychological concepts, methods, and theories can thus be used to analyze human–technology interaction. This type of approach is required to find scientifically grounded solutions to interaction and design challenges. Thus, psychological knowledge is more useful than folk psychology intuition.

The importance of psychological knowledge has been known for decades, and it has been applied in various forms to human–technology interaction. Human factors, cognitive ergonomics, and psychological usability research are examples of good approaches in which psychological knowledge has played an important role [34]. User psychology collects these scientific themes under a single approach. It is characterized by the pursuit of psychological explanations to various interaction phenomena, and, in the long run, a desire to replace folk psychological practices in interaction design [3], [32], [36]. User psychology originates, to a great extent, from cognitive modeling, which also has the goal of applying psychological theories for analyzing interaction problems [1], [3]. However, user psychology is not restricted to cognitive psychology only.

One reason for the pursuit to build on scientific psychology is the constant developments in technology, which makes some interaction problems increasingly complex. Ubiquitous, pervasive, and embedded computing, as well as novelties such as WEB 2.0 or agent technologies, are providing a more challenging field for designing interaction processes than did the traditional keyboard and screen interaction types [34]. The crucial difference is that, instead of immediate usability properties, today's designers must pay attention to more holistic interaction processes. One must be able to thoroughly grasp what people want to do, why they want to do that, can they do what they like, and how they feel about doing what they want to do. And, because these are psychological questions, it is important to investigate, in different types of environments, what kinds of psychological categories are important in explaining interaction problems. As a result, it is possible over time to implement psychological knowledge in design processes.

The European Union (EU) has launched a number of European Technology Platforms for interconnecting industrial and research communities. This kind of knowledge-oriented policy (KOP) underpins the construction of a cognitive web that allows various communities to communicate successfully among themselves and thus acquire and assimilate essential knowledge [9]. It also promotes "hybrid forums" [7] that bring together, in an innovative way, the insights emanating from markets, companies, and research communities. A network of agents interacting in a specific economic industrial area and working within a particular institutional research infrastructure [7] provides a rich web of channels, with the advantage of high source credibility. Experiences and ideas

can arise within the network [5]. An innovation system can be used to correlate and communicate knowledge [23] and to coordinate access to complementary knowledge. The Finish Fores Cluster Research portal, introduced at the Third International Conference on Internet and Web Applications and Services [41], is in focus of this study. Built on Mediawiki, the portal is a good platform for networked communication, co-creation, and global innovation. The development of WEB 2.0 opens up new possibilities for improved innovation management.

Wikis are groupware tools with collaborative capabilities. They work well in areas in which knowledge may be changing dynamically or where viewpoints differ about that knowledge and how to capture the informal knowledge that draws on the contributions [31] of a larger society for a specific domain. In organizations, the target area of wikis mainly consists of ad hoc problems in a distributed knowledge environment [44], [18]. Wikis can be used as a tool for continuous learning within and between organizations [18]. These tools can be private or public. The rapid growth of wikis, thanks mainly to voluntary contributors, shows that this environment as a service tool on the Internet merits serious attention [46], [47].

Wikis allow collaborative authoring in the context of a hypertext document set [33]. The main "wikinomics" principles are openness, peer-to-peer collaboration, sharing, and interacting globally [42]. This facilitates a real possibility for users to broaden their knowledge about a domain by openly sharing their own expertise and absorbing information from the large, global knowledge pools constructed via these wikis. Because the participants can possess totally different backgrounds regarding their educations and professional careers, this platform for combining of a variety of knowledge from several areas provides new opportunities for radical innovations to emerge.

Our article is presented as follows. In Section II, we describe our experiment: the materials, participants, procedure, and design. Section III contains the results of the research, with three qualitative examples of subjects executing the tasks, the number of errors the test subjects encountered, as well as the qualitative analysis of the errors the test subjects committed. The Discussion section delineates the user psychological problems behind these errors, the technical classification of the problems, and suggestions for developers. Finally, Section IV, Conclusions and Further Work, presents our proposals for remediation concerning the innovative Mediawiki-type knowledge-sharing portals. We end that section with our objectives for further work. Acknowledgments conclude the paper.

II. EXPERIMENT

We focused on Mediawiki as a portal developed for building *innovation systems*, particularly in industrial areas. There are several reasons why we chose this Mediawiki-based portal for our research. First, it has been the official tool since early 2008 for the Finnish Forest Cluster [11], which was established in September 2007 in line with the EU's European Technology Platforms [10], designed to encourage collaboration among industrial domains and public and non-public research communities toward joint innovation. This particular portal was developed according to the Strategic Research Agenda of the European Forest Sector within the European Technology Platform [39]. It became obvious that efficient tools such as portals are needed to enable researchers from traditional and emerging areas to contribute to national and Europe-wide research agendas.

By use of the portal, research groups can demonstrate their competencies, post research ideas, and plan projects. If needed, they can get help from portal facilitators familiar with the domain who champion research needs derived from the research agenda and the program related to it. These kinds of programs have been launched by Finland's Strategic Centre for Science, Technology and Innovation (TEKES). First of these programs, the Finish Forest Cluster (now, Forestcluster Oy), was established 2007 and our studies focused on its research portal.

The study dealt with the usability of a Mediawiki-based portal, with the aim to increase awareness about the technical usability of this kind of application [41].

A. Materials

The target in this study was a Mediawiki-based platform [49] written with the PHP scripting language for a Linux operating system. Mediawiki uses an Apache web server and a MySQL database. The idea behind this application was to gather the knowledge of various researchers and their teams, as well as other actors in this forest domain, into a single virtual location, allowing all participants to build up their knowledge, to share it with others, and employ it. The application was built for collaborative communication, co-creation, and open innovation in a networked environment.

The tests were recorded by way of an Easy Screen Recorder, which documents user behavior on the platform and the mouse clicks on the screen, as well as the speech of the test subject.

B. Participants

The experiment involved 14 researchers as test subjects. The test subjects comprised 7 women and 7 men, aged 18-48 years. All were very experienced computer users and information seekers: two of them had between 5 and 10 years of computer experience and the other 12 had used computers in their work for more than 10 years. Of this test group, 12 searched for work-related information daily, and the others a few times a week during work hours; all of them searched to some extent in their spare time. All of them also had used Wikipedia in the past, 13 of them when searching for information. One had built his own wikis and inserted information into them. Thus, the subjects demonstrated a deep understanding of the use of computers and Websites, mostly for work but also for personal interests. In addition, the subjects were motivated information seekers via the Web since they were postgraduates of various information science disciplines. These statistics are described in Table 1.

TABLE I. THE BACKGROUND INFORMATION ON EXPERIMENTAL SUBJECTS

N = 14	Experience/years	Sum
Use of computers	5-10 years	2
	>10 years	12
Use of WWW sites	6-7 days/wk	11
	3-5 days/wk	3
Information searching at job	Daily	12
	Few times/wk	2
Information searching on free time	Daily	5
	Few times/wk	8
	Few times/month	1
Use of Wikipedia		14
Use of Wikipedia for	Searching info	13
	Adding info	1

The test subjects were asked for their principal reasons for using Web sites. The foremost reason was for work-related information, followed by studying, and then for commercial use. Hobbies and entertainment were equal reasons. The least important reason for the subjects was use of public services.

C. Procedure and design

The research data were gathered in experiments where one test subject at a time navigated through the portal while thinking aloud about solving four different tasks. The navigation from an entry page to the target page could be executed via different routes but the most efficient way was known as the *optimal path* [12], [2]. This shortest path consisted of the Web pages the user had to visit, and there can be "several optimal paths for one information search [21]." The tasks studied and their optimal paths are presented here.

1) Find the main idea behind this Mediawiki-based portal.

Optimal path: Read from the Main Page.

2) Find the available research groups.

Optimal path: Main Page→ Click one of the eight Research Communities names→ Click some Research Group name→ Read the name of some researcher.

3) Find how to add wiki-type information into this Mediawiki-based portal.

Optimal path (When no information on that topic is available yet): Type some word in the Search box→ Press the GO button→ Click the Create This Page link→ Add information.

Optimal path (When information on that topic is already available): Type a word in the Search box→ Press the GO button→ Click Edit→ Add information.

4) Find how to format and organize wiki-type information in this Mediawiki-based portal.

Optimal path: Main Page→ Click the Quick Guide in the left bar→ Scroll to the end of the page and read the instructions→ and understand content.

The experiment was conducted in December 2006 at the University of Jyväskylä's User Psychology Laboratory. During the recording researchers observed the situation and the behavior of the test subjects. Following the tests, the data were analyzed and organized to investigate the usability of the Mediawiki-based interface and offer suggestions to its developers.

III. RESULTS

In this study the results were analyzed first on the basis of success (the number of subjects able to succeed executing the task) and then on the basis of using the optimal path (the number of subjects able to execute the tasks on the basis of the optimal path). The final analysis was based on the kinds of difficulties/problems the test subjects had during tasks executions.

A. Three qualitative examples

While it is not possible to present all our analyses in detail, for want of space, the examples below will give the reader a concrete view to the navigation processes and to the subsequent analyses. Our examples involve three subjects: one each performing Task 3 (inserting information to the portal) or Task 4 (editing text in the portal), and the final subject performing all four tasks. These examples are described here step by step in a text form and illustrated in figures as well. The Easy Screen Recorder captured the subject's navigation decisions in addressing the stated task. Their verbatim comments are stated in italic in quotation marks, and paraphrased comments are present in parentheses. Although they were asked to think aloud, there are silent phases in their task executions and this is represented with a dash (—) in verbatim quotes. Editorial comments are in brackets. The portal text at the time of the study was only English and thus subjects were Finnish non-native speakers of English; the direct quotes are translations by the researcher.

The first one shows how troublesome wikis can be for new users, regardless of whether they are experienced computer users or information seekers on the Web. In the second example, the test subject comes through easily, giving then her own contribution to the developers of this particular portal. In the last example the user is not familiar with wikis and, being an excellent computer user, performs quite well with this particular portal under study.

1) Subject 1, Task 3: Find how to add wiki-type information in this Mediawiki based portal.

Main page→ clicked the Smart Products link→ scrolled down→ clicked the Research Group link→ clicked the Back button→ clicked the Upload File button→ clicked the Browse button (wondered where the information would be saved)→ clicked the Cancel button→ scrolled down→ clicked the Community link→ clicked the first article under the letter C→ clicked the Back button→ clicked the first article under letter N→ clicked the Ideas for Future Research Projects link→ clicked the Ideas link (wondered whether it would be possible to edit here)→ clicked the Edit link at the top of the page→ clicked the Back button→ clicked the History button→ clicked the Back button→ clicked the

Move button at the top of the page→ clicked the Back button→ clicked the Unwatch tab→ clicked the Discussion button→ clicked the Back button→ clicked the Back button→ clicked the Upload file link→ clicked the Back button→ clicked the Back button→ clicked the Main Page link→ clicked the Back button→ clicked the Community Portal link→ scrolled down the Community Portal page→ clicked on the Selected Research Communities link→ scrolled the page→ clicked the Help link in the left bar→ clicked the Wikipedia Edit Page link [test subject got to the Wikipedia page and did not even notice that she had left the portal under study]→ clicked the Back button→ clicked the Back button→ clicked the Recent changes link on the left bar→ clicked the Community Portal link on the left bar→ scrolled down (admitted not knowing how to add information for this site)→ clicked the Special Pages link [while the researcher were advising her to use the Help page] → clicked the Back button [researcher advised her to select a word for the search box]→ typed *usability*→ clicked the Go button→ [was advised to move to the Create a page link on the opened page]→ (understood the procedure).

In Figure 1 the Optimal Path in Task 3 is illustrated in white circles. The large number of steps the Subject 1 took while trying to insert information to the Mediawiki–based portal are in black ovals.

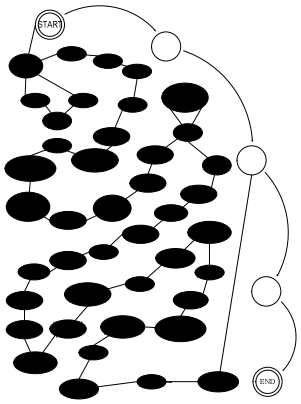

Figure 1. The results of the Subject 1executing Task 3.

This example was about inserting information. Only four test subjects were able to execute this task independently and none of them did so by following the optimal path. One subject vocalized her ideas regarding the application and about possible remediation of problems while she was searching for guidance in the portal in order to edit information. She managed to perform the task, using 4 minutes for five steps, but not along the optimal path.

2)Subject 5, Task 4: Find how to format and organize wiki-type information in this Mediawiki based portal.

"*Here is the HTML editor*," clicked Help→ scrolled down the page [when reached the right place] "*I assume that Wikipedia does the overall formatting, but I guess that is in the User's Guide.*"→ scrolled to the actual text about content formatting at the bottom of the Help page [thought she was in the User's Guide]→ clicked the Back button [in the interface and got back to the right Editing "Digimedia" page]→ filled in information on the page→ started formatting with the buttons at the top of the page, "*This has its own, special syntax for the formatting that differs in a very interesting way from everything else I am used to.*"→ clicked the Forward button in the interface, "*This is not HTML coding. This is some kind of totally individual marking language and text formatting. Obviously this is specified in the instructions, this syntax, which does not make it easier to insert content. So one would have to study a new content formatting language—. Add an asterisk. The more asterisks, the deeper the level—. In Word, the formatting is hidden from the writer. There is WYSIWYG—. In this we go back to the 1980s, when the formatting was done by coding separately with different symbols—with some code language. And this code is, for me, totally new. I have never seen anything like this—. This might come from some formatting language that I don't know—. One way to improve this would be to make it consistent with HTML code—so those who know HTML formatting, they would not have to learn a new code—. Does this come from the platform* [Mediawiki]*? —There is always the threshold of learning new* [tool]*—. All wikis should be the same—. These transitional periods for these kinds of new systems and environments are always cumbersome to the users and frustrating. They think that it is needless to learn a new coding language again—.*" [Task completed.]

In Figure 2, the Optimal Path in Task 4 is illustrated in white circles. Subject 5 took only three extra steps, pictured in black ovals, to find out how to format the added information.

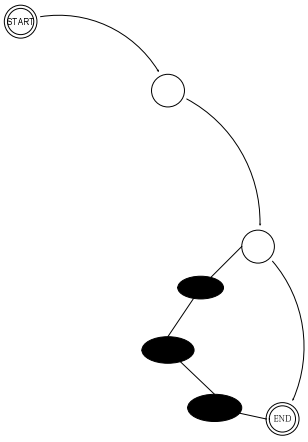

Figure 2. The results of the Subject 5 in executing Task 4.

Altogether 10 subjects managed to edit the information and three were able to do it following the optimal path. Only four subjects managed both the inserting and editing information to the portal and editing it (Tasks 3 and 4), but none executed these two most important tasks using the optimal paths.

3) Subject 13, Tasks 1- 4: Task 1, Find the main idea behind this Mediawiki-based portal.

Main Page→ clicked the Behind This link→ clicked the Main Page→ found the header What is New in Forest Cluster Portal [read]→ *"OK. It is on this page."*

In Figure 3, the Optimal Path in Task 1 is in white circles. It did not need any steps, just understanding that the information was on the Main Page. Still Subject 13 needed two additional steps (black ovals) for understanding this main idea.

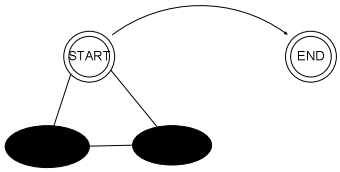

Figure 3. The results of the Subject 13 executing Task 1.

Task 2: Find the available research groups.

Main Page→ clicked the Community Portal link→ clicked the All Research Groups link→ clicked Template Research Groups→ clicked the Back button→ clicked the Groups: Scoma link→ *"OK. It is here."*

In Figure 4, the Optimal Path in Task 2 is illustrated in white circles. Subject 13 needed four additional steps (black ovals) to be able to read a researcher's name in one of the available research groups.

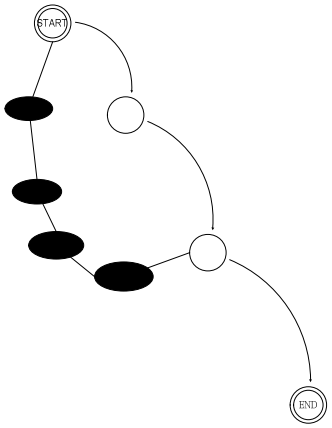

Figure 4. The results of the Subject 13 executing Task 2.

Task 3: Find how to add wiki-type information in this Mediawiki-based portal.

Main Page→ clicked the Others link→ clicked the Back to Main Page link→ clicked the Intelligent Resource link→ clicked the Main Page link→ clicked the Others link, *"I assume that my information would go to the Proposals or Ideas partition. No this does not so—."*→ clicked the Community Portal link→ clicked the Smart Fibre and Resources link→ clicked All Articles→ clicked the Proposals link→ clicked the Community Portal link→ clicked the All Categories link, *"It's a little bit confusing, flicking through these categories.— There are only 42—it's working quite badly…—. It is not sensible to show hundreds of available categories* [when only 42 results were available]*."*→ Clicked Main Page, *"I can create new categories, but how am I going to link them to other pages?"* [Researcher asks if the subject commonly uses the Help option.] *"I didn't expect that wikis would need help—; I thought it is easy to insert information in wikis!"*→ clicked Help→ clicked New Page Creating→ clicked Main Page→ typed *data mining* in the Search box→ pressed the Return key→ arrived at the Search Results page→ *"I found it—. It's same problem with the navigation as before. This shows there are up to 500 pages to see but there exists only five pages. This is confusing—. It is even possible to choose previous pages. It's a bad problem!"*→ opened a new working window→ typed "text mining"→ pressed the Return key→ opened the link to the Create This Page: Text Mining→ started editing the blank page Text Mining → *"OK. This is it."*

In Figure 5, the Optimal Path in Task 3 is in white circles. The additional steps the Subject 13 took while trying to insert information to the Mediawiki-based portal are shown in black ovals.

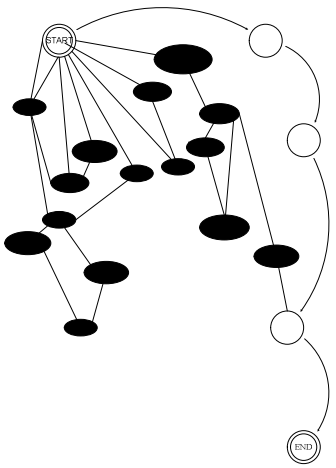

Figure 5. The results of the Subject 13 executing Task 3.

Task 4: Find how to format and organize wiki-type information in this Mediawiki-based portal.

"I suppose there are instructions for formatting in Help.→ pressed the Quick Guide link, *"Yes."* → scrolled to the end of the page→ *"OK,"* and wrote some sentences onto the Text Mining page. *"How do these icons work? — First we choose the text— ok— not all symbols are familiar to me—. Luckily, there are tool tips — makes it much clearer—. It would take some time to learn all these notations."* [The researcher asks if the subject thinks it is a good tool for formatting.] *"Enough for me—. Some would like to have WYSIWYG."* [Researcher asks if it would be easy to implement the WYSIWYG for this application.] *"Tools exist that generate HTML code—. Yes certainly—my opinion is that this wiki-formatting is generated so that you don't have to write HTML—. Yes this is a quite interesting way of formatting."*

Figure 6 shows only the optimal Path, which Subject 13 was able to follow correctly. He wrote some information on the page and formatted it instantly.

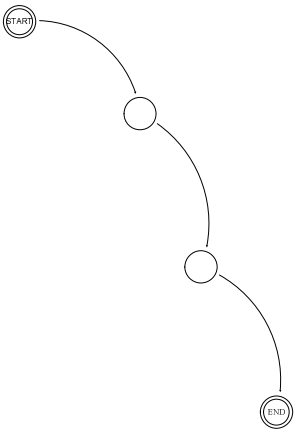

Figure 6. The results of the Subject 13 executing Task 4.

This particular test subject performed well with three tasks, even though he used the optimal path only in the fourth task. Only Task 3, adding information, was quite confusing for him. Even though the use of the wiki platform was quite transparent to him, he had to click around the portal while performing these four tasks, and once the researcher prompted him to use the Help. During the last task, while he was formatting the information he had typed in the portal, he gave some useful observations and ideas on how to evolve this kind of tool.

"Basically—clear layout— if someone has used Wikipedia before— maybe, if you should insert new information here—. Not very many would use Help—. There should be 'Welcome to insert information'—. Usually I can keep trying for a long time—.I don't give up easily—. Maybe it is more like— yes— in one way or another I insert something—. Maybe there does not exist a technology threshold—. You can always put in plain text— without any bolds or other formatting."

When they were inserting information, the users were confused between concepts such as article, page, and file, on the one hand, and wiki-type information, on the other. These differences are not obvious for new users to wikis. Younger people are quite likely to adapt into these working environments, judging by their habits of discussing and sharing their knowledge in the networked world, even in their spare time. This willingness to discuss and share knowledge is most likely going to change the way that work is conducted in organizations. Regarding older experts, capturing their vast knowledge in particular domains is not so simple. Equivocal concepts involved make their use of these cooperation tools more difficult for them.

B. Number of errors

The main quantitative results are presented in Figure 7. Columns 1-4 depict the tasks that the subjects were asked to do. All 14 of the subjects solved the first two tasks, 4 were able to add information (Task 3), and 10 were able to format that information (Task 4). The fifth column shows that only 4 subjects were able both to insert and to format information in the portal. Searching, inserting, and editing are critical functions with these knowledge tools. Properly designed, these functions prepare the way for collaboration, co-creation and innovating in networked societies.

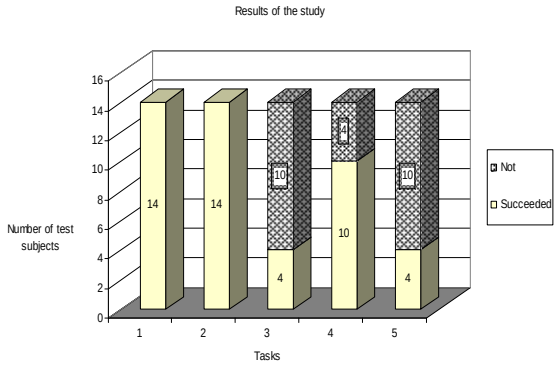

Figure 7. The results of the four tasks in the experiment with the Mediawiki based portal. Column 5 contains summary information showing the number of those who managed to do both tasks 3 and 4.

The optimal paths seemed more troublesome for the users. Six subjects managed this aspect in the first task, 4 in the second task, and 3 in the fourth task. In the third task, where the subjects were asked to insert information to the portal, no one followed the optimal path. These results are shown in Figure 8.

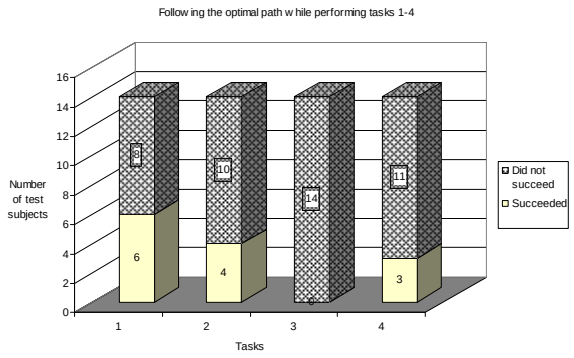

Figure 8. The results on how the subjects were able to perform the four tasks by way of the optimal paths.

The reasons for the problems that the users came across are explained in Subsection C. The number of users (NOC) who came across each problem is given and there is one example of each problem. The difficulties have been divided into several different categories.

C. Qualitative analysis of the errors committed by the test subjects

Quantitative distribution does not tell us much about the type of difficulties people had with this wiki. They merely show that certain types of task were difficult. It would be very important to also consider the quality of errors and their psychological interpretations. The latter indicates the kinds of psychological factors that can explain what is happening.

In order to get a better idea about the errors and be able to examine their psychological backgrounds it is essential first to discover the errors and then to find a scientific basis for understanding why these error generating points are difficult for people. This is why we present the qualitative analyses of all data classified into psychologically meaningful categories.

This type of categorization is a normal procedure in qualitative analyses [8]. However, using psychological categories presupposes interpretation of the observations in psychological terms. From a psychological point of view this process is in many respects methodologically close to clinical processes. In personality assessment, for example, psychologists categorize the symptoms and patients to connect the observed cases with psychological knowledge.

This is a rather detailed list but we think that it may be better from a developer's point of view than mere examples or numeric information would be. Nearly all errors we found in this study derived from the Mediawiki platform, but these same problems can be found in other ICT services too. Note that unlike earlier, verbatim texts are not italicized.

1) Difficulties in perceiving

We classify any failure as perceptually originated when the problems in navigating can be explained on the basis of some perceptual phenomenon that can be elaborated in perceptual terms.

Color of links: Subject 7 in Task 3 stated, "Is here some link? … It cannot even be seen that there is a link here. It is nearly of the same color [as the other text]." NOC 5.

Disconnecting the page by a picture: Subject 9 in Task 3 noted, "This picture disconnects the page [in the User's Guide]". NOC = 1.

Page resembling code: Subject 7 in Task 2 regarding the Recent Changes page, "Not a user friendly page. …Looks just like some code." NOC = 1.

Confusing namespaces area: Subject 2 in Task 3 noted, "Search in namespaces at the bottom deals with an area that is too wide." NOC = 2.

User's glance not directed to the right place: Subject 12 in Task 3 said, "This directs my glance to the middle of the page because there is the 'Munch' [the word she searched], not towards the top of it as it should. …I thought I should find it here nearby [word 'Munch'] and not on the top." NOC = 1.

Too much text: Subject 8 in Task 4 said, "Too much text to read.… Probably I would ask for advice from someone." NOC = 4.

No WYSIWYG: Subject 13 in Task 4 said, "For my needs, these editing icons are enough, but someone else might like to have WYSIWYG." NOC = 1.

2) Difficulties in understanding

Page layout leads to wrong navigation: Subject 3 in Task 2 saw that "Links to Wikipedia Help on top of the Help page guided users to Wikipedia." NOC = 1.

Hierarchy of the concepts not evident for users: Subject 5 in Task 2 had problems with the hierarchy of concepts. NOC = 1.

Confusing concepts: Subject 5 in Task 3 found, "The relation between Page, Article, Research Project, and Research Group is not obvious for the user." NOC = 15.

Confusing instructions: Subject 11 in Task 3 noted, "The Help is a little bit hard to understand because after [instructions of] creating a page, there is an instruction: 'However, this way isn't recommended.'" NOC = 1.

Confusing information on the page: Subject 9 in Task 3 went to the Recent Changes page and said, "No one is going to understand this page." NOC = 2.

Confusing messages, such as "There is no page titled [or article title and page text] *matches":* Subject 11 in Task 3 said, "The 'Usability' page already exists here.… This is confusing." The Search Results Page gave different matches for the page that the user was searching for, for the Page title, and for the content of the pages. NOC = 2.

Confusing content: Subject 1 in Task 2 said that the page content did not seem self-evident for her. NOC = 1.

The logic is not clear: For Subject 5 in Task 2, the logic of the portal was not that clear. NOC = 1.

Editing wrong page: Subject 3 in Task 4 edited the Help page. NOC = 7.

Hierarchy not evident for the user: Subject 9 in Task 4 noted, "It is easy to get lost in this interface." NOC = 5.

Information storing hierarchy not evident: Subject 7 in Task 3, queried, "How do I know, if I insert some

information here, whether it goes to Wikipedia or to this portal?" NOC = 2.

3) Transfer and memory

Difference between menus on the top and side: Subject 12 in Task 4 noted, "With these top and side menus, it is somehow difficult to see where to start." NOC = 1.

Difference between a portal and wiki: Subject 7 in Task 3 said, "I don't understand what the difference is.— Why is the wiki here?" NOC = 1.

Difference between Help, User's Guide, and Quick Guide: Subject 5 in Task 2 noted, "The difference between User's Guide, Help, and Quick Help is not evident for the users." NOC = 5.

Difference between Go, Search, and Return: Subject 3 in Task 3 stated the difference between the Go/Search buttons and the Return key was not very clear to him. NOC = 3.

Confusing information architecture: Subject 5 in Task 2 said, "The way the information architecture is constructed in wiki type portals is new and not yet well known." NOC = 2.

Confusing namespace listing: Subject 11 in Task 3 wondered, "Search in namespaces—. I could select— but what is the idea in this—. Default is Main—. This is a little confusing." NOC = 6

New formatting: Subject 5 in Task 4 found it difficult because "I would have to learn a new formatting style—. Not even HTML code." NOC = 1.

No breadcrumb trail: Subject 3 in Task 4 said, "There should be a breadcrumb trail so that the user would know where he located." NOC = 2

No site map: Subject 10 in Task 3 commented, "I didn't find the Main Page of the dictionary." NOC = 2.

Confusion about location. Out of the portal and in Wikipedia: Subject 7 in Task 4 stated, "I don't even know whether I am in this portal or in Wikipedia." NOC = 5.

4) Motivation

Motivational reasons: Subject 4 in Task 4 saw that the usage motivation is dependent on the necessity to use the portal. One might use it only if it was necessary for work, but it was too complicated to use with hobbies. NOC = 4.

Users do not use Help: Subject 9 in Task 3 acknowledged about the Help page, "No one reads this kind of information." NOC = 5.

5) Other functions

No inspection for formatting: Subject 9 in Task 4 wondered why "this does not inspect the formatting after one has inserted information." NOC = 3.

Linking stored information between pages: Subject 13 in Task 3 asked, "If I insert something, how do I link it to other pages?" NOC = 1.

IV. DISCUSSION

The experiment illustrates the substantial difficulties that the subjects can have with the two essential tasks in using these types of portal: inserting and formatting the information. These problems can be traced to the inherent problems in the Wiki platform. Qualitative investigation of stumbling blocks makes it clear that human psychological functioning is not sufficiently understood in the construction of wikis.

The data were gathered through the so-called thinking aloud method. When a test subject is quiet while working, the researcher is unsure whether the subject is reading the content or uncertain or confused about how to continue with the task. While observing the situation, the researcher is unable to perceive if there is a problem, any of the situations where he/she might be encountering a problem, or any of the reasons for the test subject's problems. When the subject thinks aloud, he/she provides the researcher a level of insight into what the subject is perceiving and reasons why he/she is completing the task in a particular way.

A. User psychological reasons behind the problems

Our aim is to categorize the usability problems raised by the subjects in psychological terms. This allows a direct connection between the problem points and the currently available psychological knowledge. Further, we can elaborate our conception of the human mind in interaction. One of our main goals is to develop psychologically grounded design principles. However, while modern engineering design is generally based on scientific knowledge, interaction design is mostly intuitive and based on folk psychology [36].

Some of the interaction problems were caused by perceptual difficulties. We found 15 such cases. One problem was caused by colors that were too similar and people could not easily discriminate between them. Properly used, color is a very good directive search cue, but if colors are too similar, the benefit is eliminated [43]. Situations comparable to this would be text too closely resembling code or simply too much text on a page. In both cases, discrimination of the target becomes problematic because the target and the background information confuse the user during a search [25], [40].

Another important problem is information invisibility, in which all the information necessary for controlling ongoing actions cannot be visually provided to the users. Essential information may be placed outside the screen. This of course can also be regarded as a memory problem, but because its correction is based on making missing information visible, we have classified it as a perceptual difficulty. We found three cases like this. Another demonstrative case of this effect is when important information is allocated outside the focus of the gaze. These problems often are due to overlong texts and incorrect page sizes. It may also be that WYSIWYG did not work adequately.

A third general concern about user psychological problems in wikis has to do with understanding. Understanding involves a human's ability to encode information into one's own mental representations. This means comprehending the meaning of information that is a word, a sentence, or an event.

In this experiment, subjects confronted many types of problems in understanding the interfaces. Some of the commands used in the portal were quite ambiguous and partly incomprehensible. Terms were not explained. Feedback was inadequate and thus prevented the subjects

from understanding the operational logic of the system. Navigation tools were inadequate or absent. The system did not indicate where the user was at any given time. The purposes of actions on some pages were not explicated or intuitive. Thus, expectations were difficult to comprehend.

Understanding is a complex process. One has to be able to take in and comprehend meaningful details and determine the right way of doing things. It is essential to be able to follow simultaneously many different types of information flows [24], [37]. In this study, the user had to be able to control at the same time navigations and program control flow while not forgetting the actual innovation text as well. Failure in processing any single component of this process may cause the entire process to fail.

Fourth, some of the problems were related to transfer, in which earlier learning negatively or positively affects learning new information [14]. For example, link colors were non-standard or inconsistent, causing problems for subjects who were used to different color codes. The same was true with the wiki's original features.

Two major types of situations can affect transfer. First, external user culture may influence the usability of a new system. People have usability habits and practices. If a new system or program differs fundamentally from the previous versions or familiar application, it will cause problems of negative transfer. Second, the system itself may be inconsistent and thus cause incorrect expectations in users.

One important rule has been found in research into transfer: The more overlapping the features of two interfaces, the greater the positive transfer between them [38]. Transfer is thus a very important phenomenon to consider when addressing user–technology interaction problems.

Fifth, we found concerns related to motivation. In human–device interaction, success is one of the main motivation factors for users. In e-learning, for example, people who are able to solve interaction problems often seem to become proud and self-confident, while people who fail might lose their motivation and often demonstrate a negative attitude towards e-learning [16], [17].

The final major set of problem we found were clearly technical bugs that hindered usability. These will be addressed separately because their resolution cannot be based on psychological information.

We focused on psychological analyses of the difficulties people face when interacting with technologies because such analyses can indicate to advanced interaction specialists how problems could be solved. We can speak of explanatory frameworks, among them cognitive, emotional, and socio-cultural, when we refer to the theory languages we can use in solving an interaction problem. We simply have to find the right explanatory framework in each case to be able to explain the problem. This means the right psychological basis for explaining why the interaction does not work optimally.

B. Technical classification of usability problems and suggestions to developers

While we need look the problems from a psychological point of view, it is important to pay attention to the technical side of interaction as well in order to get a clear idea of the types of corrections needed. We have listed the technical problems in a table in Appendix 1.

The area of *concept clarification* contained two kinds of problems in this portal. There were concepts that were not self-evident, so users either did not understand their meaning, or misinformed. A Tooltip help, which explains the word in a wiki page and does not merely replicate it, would make it easier to understand the concepts.

In the area of *content facilitation*, a distinction should be made between content, its generation, and its use. Titles should be clear and short and be made up of highly informative words. The first two paragraphs of a Web page must state the most important information.

There are several possibilities for *function facilitation* in wiki sites that can be employed well. First, there should be a page map with the location of the user visible, as well as a complete path from the home page down through all the levels of the information architecture. Second, the difference between the links on the left and at the top of a page (in this particular Mediawiki-based portal), as well as at the top of an article, should be made more clear to the users. In addition, the difference between the Go and Search buttons should also be made clearer, as well as how the Return key works in this portal. Finally, the use of namespaces at the bottom of the search results page should, likewise, be explained better.

Regarding *page elucidation*, we had several recommendations. First, pages with multiple content areas (header, its design element, and content) were confusing. To eliminate confusion, the line below the header that was used as a design element should be above the header and content area, rather than between the header and content. Moreover, pages such as this that were in the portal (groups of headers, content and edit functions) was not self-explanatory. In addition, users do not like scrolling very much, and for this reason, too much information on the Help pages induces errors when users search the rules in order to add information. Finally, employing effective visualization would make it easier to understand the functions available in this particular portal.

Well-executed *function automation* can prevent many errors. An Add button, which opens a template for writing new information, would facilitate the process. In addition, function automation should attend to the details of processing the added information. There should be access to help online, with an option to jump to the specific answer on the Help page. Hovering the cursor over a link should give a Tooltip text with more information about the link.

The study site contained so much text that only highly motivated users would read it all. Providing in the portal a demo on how to use the port would make it easier to get a mental picture of the site. It is obvious that *training and motivating users* are big challenges for the designers of this portal. Therefore, the working cultures of open societies that are adapting wikis for particular industrial and research domains should be built or adapted through carefully planned user training. This would facilitate the emergence of truly open societies creating new knowledge and innovating together on a particular domain.

V. CONCLUSION AND FUTURE WORK

Because the trend in emerging innovations is about firms operating in a coordinated manner in networks [22], the nature and necessity of collaboration within networked environments must be understood. In this context, large-scale collaborative development of tools, like wikis "and use of open source software merits a great deal of further attention and analysis" [48].

The role of human capital in innovation is important as well, both at the firm and the aggregate levels [28]. Wikis are tools that enable organizations to gather some of this capital for collective use, while the "open innovation paradigm assumes that there is bountiful supply of potential useful ideas outside the firm" [6]. This means "valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well" [6]. "Innovation co-operation requires active co-operation with other firms or public research institutions on innovation activities (and may include purchases of knowledge and technology)" [28].

Wikis can be bridges to sources of information, knowledge, technologies, practices, and human and financial resources. They can be used a link that "connects the innovating firm to other actors in the innovation system: government laboratories, universities, policy departments, regulators, competitors, suppliers and customers" [28]. Moreover, "the supply of knowledgeable minds to which innovating firms have access is perhaps the most crucial aspect of the innovation systems approach and of innovation policy for it is individuals within organizations who are the elemental components of innovation systems" [23].

Even with these kinds of knowledge-oriented policies, innovation systems, and global cooperation, our results illustrate that interaction through open innovation platforms is neither easy nor straightforward. Though the literature on psychological problems that users may encounter is solid, the principles are not easy to apply [3], [4], [13]. Consequently, people encountering problems may give up the idea of sharing their respective knowledge on a particular innovation domain and in interacting via continuous feedback to improve the creative principles [26].

To avoid this potentiality, some proposals for remediation are offered. First, it must be determined how new users can obtain the correct mental representation of a wiki: its structure, functions, and the activities the user can perform. These can be represented through demos, and with various training procedures, such as sandbox and illustrative sitemaps. Second, the content of a wiki must be clearly distinguished from its functions. Third, because contributing to a wiki is an entirely new working culture, employees need a kind of usability that is different from the usability of a common interface. The platform should evoke understanding of the very idea of knowledge sharing, co-creating, and contributing within an open society. To succeed at all of these challenges, the developers should have a deep understanding of human psychology.

These kinds of portals, and especially the possibilities they can offer for global networked co-creation and innovation, demand the ease of usability. For the portal in this study, the remediation we suggested is already in process. In the wider perspective, work and other activities in networked environments and open innovation with peer experts or other users already are creating a global working model that is growing fast. The users should be able to use these portals easily, without wasting time learning another new tool, new application, codes, or action model. They should be able to simply concentrate on the sharing their expertise of the subject as it evolves, thereby partaking in and adding to the knowledge of the societies involved.

Designers should rethink how user-created content [48], especially in open innovation [6] context, can best be used by people with low levels of computer knowledge. The current usability problems with wikis, as illustrated here, may compromise the very idea of open innovation. In this experiment, the subjects were postgraduate students of information systems and computer science, and thus may be looked upon as experienced users. Nevertheless, they still experienced problems with relatively elementary tasks on this platform. This shows that poor understanding of human psychological requirements can lead even quite sophisticated users into problems. This runs counter to the very philosophy of open innovation. All people should be able to participate in open societies and knowledge production. Therefore, it is essential to eliminate as many of these user psychological problems as possible.

With the rapid expansion of wiki use in organizations and between them, users are faced with problems in finding the core knowledge they seek. One of the most fascinating approaches in addressing this difficulty is the Semantic Web [45], which includes ontologies and reasoning on domains, as seen on the Gene Functions Wiki [15], Semantic MediaWiki, IkeWiki [19], and EKOSS [19]. As stated in [33], "We believe that by combining rich XML (DITA) structure, collaborative DocumentSpaces and wikis, we can help organizations break down the barriers that prevent them from achieving cross-departmental collaboration." This perspective can be expanded from the organizational context to the cooperation and co-work between organizations and to their whole supply chain [28], which is one of the sources of innovations made via cooperation.

Our continuing work involves an inquiry into the barriers of using these kinds of innovation portals the users encounter in their work. It is necessary to understand the various psychological hindrances people meet at the individual, group, organizational, and corporate levels in participating in decentralized innovation societies. In the future, such societies will be the most prominent sources of new, breakthrough innovations and the starting points for new economic growth in the global economy.

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APPENDIX 1

	Classification of the usability problems and proposals for solving them [41]
Concepts	1. Group facilitator and Support facilitator are not obvious concepts for the user.
	2. While making groups, the concept KR1 is not obvious for the user.
	3. There is no easy way of adding new information in correct form: The Help-section is needed to understand the task. There is confusion about the concepts of article, page, file and Wiki-type information. Only 4 of 14 subjects were able to contribute without the help of the researcher.
Content clarification	4. On the Search results page, the color of links and the color and size of fonts for the text are confusing. The primary heading must be clearer so users do not cast down their gaze.
	5. The main page of dictionary is necessary.
	6. The Category: Research group page is, at the moment, confusing. G, G Cont and T are not obvious for users.
	7. The purpose of the Special Pages page is not comprehensible to users.
	8. Technical pages or content generation and using of them are confusing.
	9. It is not obvious where the information is stored and how it is connected and linked.
Function clarification	10. The differences between the links on the left, at the top of the article, and at the top of the page are not obvious to users.
	11. There is no page map. The user should know his/her navigation point all the time.
	12. The difference between the function of the Go button and the Search button is not obvious to users. Experienced users use the Return key without thinking, thus it functions as the Go button.
	13. Scanning the Search Results page is confusing when there are not many pages. The results page should include information regarding the number of pages returned.
	14. The use of the namespaces at the bottom of the page is not comprehensible to users.
	15. The difference between Quick Guide and the Help page is not comprehensible to users
	16. On the Help page, the Creating New page steps 1, 2 and 3 are explained well, but are confusing, because the last step includes the text “This way isn’t recommended.”
	17. The picture on the User’s Guide page is illustrative, but it divides the page. The instructions mislead users to start adding groups and ideas, when they should add information.
	18. There should be clear hierarchies and routes to execute functions.
Page elucidation	19. The grouping of the information on the pages of the various communities is confusing. The information in the areas between lines should belong together.
	20. The headings on the Community Portal page are not clear: First a black heading, then the same in green.
	21. In the Help page before the Creating New page is the Editing Images & Files –section. Users do not scroll/read long texts.
	22. The site has too much text, and too little visualization that would make it easier to understand the functions available in this portal.
	23. The Welcome texts are not needed.
Function automation	24. The Research Group list should be updated automatically when new research groups are created.
	25. There should be an Add button for inserting new information that should link directly with a template where the users could write the content, and it should function in the WYSIWYG-mode. The application should at least ask about the text formatting before saving.
	26. There should be an online Help site with the option to jump directly to the sought place in the Help page.
	27. The cursor hovering on a link should give a Popup text with more information about the link.
	28. New links should be provided in blue and visited links in red, in line with the standard in Web interfaces.
Training	29. Many of the subjects would have stopped inserting information and tried to get help from someone else. There should be one trained expert for this application in every research unit.
	30. There is no working culture of this kind of wiki societies, so it should be created by training.
	31. The site contained so much text that only highly interested users would use it. A clear demo can make it easier to get a mental picture of it. There are several domains that can induce problems: Using Wiki, the FFCRP interface, and the domain of the forest sector. There is no active working culture yet for this kind of application. [However, this culture has evolved quickly since our experiment.)