

A Web-Based Knowledge Hub for Special and Inclusive Education

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Abstract— The need of a common environment where to share information and knowledge is of particular interest in the field of special education not only to support the access to a large amount of available information (along with the ability to derive value from this information) but also to foster synergistic actions involving different special education operators. In this paper we present the results of a research aimed at defining a Web-based environment for special education providing, to operators of the field, personalized information and digital assets covering both their expressed and latent information needs. Offered personalization features are based on the definition and the implementation of a hybrid recommender system based on a mix of cognitive and collaborative approaches, the first based on the similarities among digital objects, the latter leveraging on similarities among user profiles. By combining these two approaches the system is able to provide meaningful but not obvious recommendations with a fair level of serendipity. The encouraging results of an experimentation with real users are also reported.

Index Terms— digital repositories, recommender systems, adaptive learning, special education.

I. INTRODUCTION

The principal aim of educational system is to promote the active participation of all people in the process of learning and skills acquisition. Education is to employ the appropriate materials, techniques and forms of communication. Effective individualised support measures are provided in environments that maximise academic and social development, consistent with the goal of full inclusion. School is a place of normal life, a place to grow up and learn in, a place to interact with people of one's own age and with adults.

On December 13, 2006 the General Assembly of the United Nations adopted and proclaimed the Convention on Rights of Persons with Disabilities, at the United Nations Headquarters in New York. Following, this convention was signed by most Countries worldwide, included the European Commission.

The Convention marks a "paradigm shift" in attitudes and approaches to persons with disabilities. It takes to a new height the movement from viewing persons with disabilities as "objects" of charity, medical treatment and social protection towards viewing persons with disabilities as "subjects" with rights, who are capable of claiming those rights and making decisions for their lives based on their free, and informed consent as well as being active members of society.

In the Convention on the Rights of Persons with Disabilities the article 24 is related to education. Education of persons with disabilities must foster their participation in society, their sense of dignity and self-worth and the development of their personality, abilities and creativity. According to Guidelines for Inclusion [1], Education for All means ensuring that all students have access to basic education of good quality. This implies creating an environment within schools and basic education programs, in which students are both able and enabled to learn.

Inclusion is seen as a process of addressing and responding to the diversity of needs of all learners through increasing participation in learning, cultures and communities, and reducing exclusion within and from education. It involves changes and modifications in content, approaches, structures and strategies, with a common vision, which covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children.

Inclusive education is considered by UNESCO: an ongoing process aimed at offering quality education for all while respecting diversity and the different needs and abilities, characteristics and learning expectations of the students and communities, eliminating all forms of discrimination [2].

During last years many European countries have enacted laws and adopted measures to facilitate the education for disabled people and with special educational need. However, this is not enough to ensure an adequate and functional access to knowledge to all people with special needs. In this context ICT offers a precious contribution to the instruction of people with special needs, in particular they can provide access to flexible learning opportunities and socializing.

Furthermore, the evolution of the use of Internet as a social space and the dynamics related to Social Computing have led to the establishment of a new communicative paradigm based on collaboration, horizontal information and knowledge sharing. Users have taken on a new role; after having been consumers of information, they now share content, build connections, assess cultural artefacts and produce digital content

Teachers and trainers often lack both technological and methodological skills to design special education experiences and access information about targeted educational initiatives. Some important issues need to be tackled: how to support SEN students in their educational path? How to foster teachers to get skilled in designing special education initiatives?

Hence the importance of ICT in special education is not only as a teaching aid, but also as a tool to foster synergistic actions between those who work in contact with the disadvantaged learners as well as between the world of research and the potential users. In this area, the need for a common environment for the sharing and the capitalization of knowledge and experiences among those who are involved, in different ways, in special education (teachers, educators, parents, researchers, volunteers, associations, local authorities, etc.) is particularly felt.

To meet this requirement we proposed, in the context of a research project named WISE [3], a Web-based repository of digital resources for special education, named Knowledge Hub (KH), capable of combining the functions of a knowledge base with custom and profile-based recovery of information also providing social features. Among the key aspects of the KH, this paper mainly focuses on the application of filtering and recommendation techniques to continuously supporting the user with information and resources capable of satisfying expressed and latent information needs.

After having briefly described the related research on educational repositories (section II), the paper focuses on the objectives of the WISE project (section III) and, after that, on the main functions provided by the KH as well as on its logical architecture (section IV). Models and methodologies we have defined to support the most advanced KH features like filtering and recommendation of relevant resources are then described (section V), followed by the analysis of experimentation results obtained so far (section VI). Conclusions and references close the paper.

II. RELATED WORK

The term digital repository is commonly used to indicate the virtual place where digital resources can be stored and retrieved. In educational contexts these systems are known as Learning Object Metadata Repositories (LOMR) and act as containers of educational resources and related metadata allowing the user to access them via special search interfaces or supporting external software such as Learning Management Systems. Classic LOMRs like MERLOT [4] are centralized systems that contain only metadata and point to remote learning objects. Others systems like the Campus Alberta Repository of Education Objects (CAREO) maintain both digital learning objects and the associated metadata.

Semantic Learning Object Repositories (SLOR) [5] [6] are special kind of LOMR that make use of tools like ontologies for the formal representation of knowledge. The objective is to enable users to perform advanced searches and to benefit from useful resources identification and recovery features based on Semantic Web principles [7].

An example of SLOR is ELENA [8], a system offering personalization features based on the semantic annotation of learning objects. The central component of ELENA is a personal learning assistant with an advanced search interface that interacts with an ontology to build a query about represented concepts. An additional service extends the user's query by placing additional constraints and variables that are not present in the original formulation and taking into account both the ontology and the user profile.

The VICE (Virtual Continuing Education) project [9] was aimed at the development of innovative e-learning applications based on semantic technologies. The MILOS

(Multimedia Learning Object Server) repository, developed within VICE, allows the storing and the retrieval of learning objects through different modalities. Users can formulate queries based on the resource content or metadata but can also browse the resource collection by following semantic associations through resources. Additionally, results of performed searches can be adapted basing on the user profile.

The WIKINGER (Wiki Next-Generation Enhanced Repositories) project [10] is purposed to define a semantically indexed repository of knowledge that supports the generation of new knowledge and its representation through a semantic topic network. The available digital objects are processed by the system which identifies the main information entities included therein and relates them to available topics. In a second phase the system tries to generate new classes from unclassified entities and to associate them to those included in the existing semantic network.

Within the IWT (Intelligent Web Teacher) system [11], learning resources are represented through metadata conforming to main standards of the field but concepts explained therein are organized at a higher abstraction level through an ontology-based domain model [12]. The defined model allows not only advanced searches but also the automatic building of personalized and contextualized learning experiences [13] and can be enriched by leveraging both on social tags expressed by system users [14] and through the interpretation of the resource content through knowledge extraction techniques [15].

Despite there are many existing digital repositories for e-learning, there are still few specific initiatives for special education. As an example of the category we mention ePKhas a digital learning objects repository for special education developed in the Malay Archipelago to allow management and retrieval of digital educational resources, the creation and sharing of such resources as well as search, evaluation and collaborative discussion among members [16]. Digital resources included in ePKhas can be used for special instruction programs within different contexts.

III. THE WISE PROJECT

The research presented in this paper is supported with the investment funds for basic research of the Italian Ministry of Education, University and Research under the project WISE "Wiring Individualised Special Education" [3]. WISE aims to design and develop a system which bridges homebound people educational needs with information, resources, initiatives and tools that fit with them.

The term homebound (HB) refers to people who find difficult to leave home by illness or disability. These obstacles often prevent them from attending traditional education courses or professional training and requalification ones, excluding them from educational opportunities and from the possibility of building their professional and life perspectives.

An objective pursued by WISE is the development of a complex system offering support to HBs and their caregivers combining informative, educational and relational issues. This objective was drawn up on the following core-processes:

- the definition of a user-model based on the International Classification for Functioning (ICF) [17] to personalize the fruition of services and material available

in the system, supporting user in the personalization of search and in the sharing of contents, experiences and practices;

- the development of a system of knowledge management & sharing (the KH), integrating functions proper of a knowledge base with those related to semantic retrieval. The KH offers recommendation functionalities besides personalized search of resources, making moreover available a set of social functionalities such as social rating and bookmarking.

WISE user-model descriptors concerning the characteristics and the context of the referential HB play a fundamental role both in the personalization of users searches and in the development of the automatic inferences at the base of the suggestions and the recommendations provided by the system. This specific set of descriptors, fully described in [18], has been derived from a mapping against the World Health Organization's International Classification for Functioning, Disability and Health (ICF). This choice allows to embed the ICF philosophy into the WISE system and the services provided by it.

This classification puts the notions of *health* and *disability* in a new light, since the health status of a *person* is defined in relation to the *functions* he/she is able to perform in a specific *environment*; thus, it records the impact of the environment on the person's functioning and takes into account the social aspects of disability in terms of levels and ways of *participation*.

The classification system based on the ICF provides the possibility of collecting an exhaustive and detailed body of information of a *person*, on his/her *environment*, and on the way that person *participates* in the activities which characterize the context in which he/she lives. On the basis of such information, one can therefore describe the health status of the subject, taking into account not only pathologies, but also the functions that the subject is able to perform in his/her environment.

IV. THE KNOWLEDGE HUB

As introduced in section I, the Knowledge Hub (KH) is a Web-based repository of digital resources related to special education. The KH is accessible by different types of users including homebound learners, parents, teachers, health workers, educators, etc. The material contained therein can be found through browsing or by exploiting advanced filtering and recommendation features based on user profiles and on meta-information connected to digital resources [19].

This section describes the main features offered by the KH including the management of digital resources as well as the editing and publishing processes. This section also describes the implemented filtering and recommendation functions as well as the provided social features. A high-level snapshot of the KH architecture closes the section. Models and methodologies we have defined to support the most advanced filtering and recommendation KH features are deepened in section II.

A. Management of digital resources

The KH deals with several types of informative and didactical resources connected to special needs in education as reported in the following list:

- *communities* i.e. formal associations, informal groups or institutional networks of actors operating in fields related to special needs in education;
- *projects* i.e. actions linked to special needs in education, with dedicated resources and finite duration made in order to achieve a set of goals in specific contexts;
- *experiences* i.e. good practices related to special needs in education that can be either connected or not to specific projects or communities;
- *educational processes* i.e. pedagogical models and processes involving homebound learners, both developed at national or international levels;
- *bibliographic resources* i.e. relevant documents that are related to one or more issues coming from special needs in education.

The digital resources contained in the KH are mutually connected in order to allow a semantic navigation through them. Figure 1 shows a graphical representation of the interdependencies between the classes of managed resources.

In particular, projects, communities, and bibliographic resources are special cases of information resources while experiences and educational processes are special cases of educational resources. In addition, each experience can rise in a project or a community and define one or more educational processes; every community can, in turn, propose projects.

In the KH, a digital resource is generally made up of two components: the actual content that can be a document, a file archive or a link to an external Web resource and the metadata which are a set of pairs (descriptor, value) where the descriptor belongs to a predefined scheme, that changes depending on the type of resource. Depending to the scheme of metadata to which a descriptor pertains, its value can be a free text or chosen within a vocabulary or a taxonomy of feasible values [18].

B. The editorial workflow

The KH is open to different types of users. Such users can access the system with three different roles as explained below.

- *Visitors* do not have credentials and access the system anonymously. They can see (and use) any KH resource but they can't propose new ones.
- *Registered Users* have an associated profile (based on the model defined in [18]). They can create and propose new resources in accordance with the defined editorial workflow.

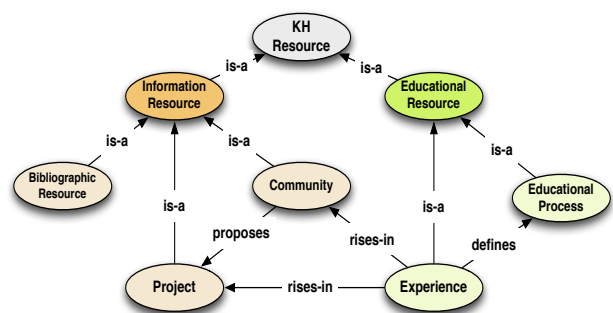


Figure 1. Relationships among digital resources of the KH.

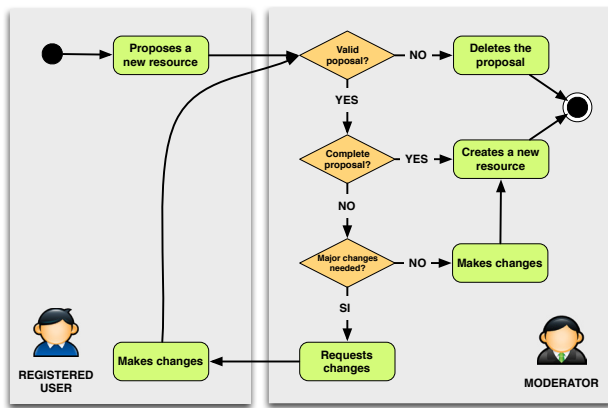


Figure 2. The editorial workflow.

- *Moderators* are special registered users that have the rights to publish new resources on the system, while certifying the quality and completeness of the information. The role of moderators within the KH is currently played by the WISE scientific committee.

Figure 2 shows the editorial workflow implemented by the system: registered users may propose new resources that do not directly appear in searches made by other users until they are approved by a moderator. Figure 3 shows the implemented Web interface for the definition of a new resource proposal.

After having received a new proposal a moderator may decide to remove it, if he considers the proposal not relevant for the KH, or to accept it, if he considers the proposal valid and complete. If the proposal is valid but not complete, the moderator can decide to complete it independently unless substantial changes are needed. Otherwise, a change request is forwarded to the proponent that can proceed to the completion and the re-submission of the proposal. The process is repeated until the moderator does not transform the proposal into a resource or decides to throw it permanently.

C. Filtering and recommendation features

The KH provides several searching facilities to access, through different routes, the digital resources of the repository.

A basic search facility is accessible from every page of the Web portal. It is a keyword-based search engine allowing users to find all resources that contain one or more words among those specified in a text box. The basic search tries to find matches between the query and all fields of metadata as well as the resource content.

An advanced search, acting on metadata fields, is also provided. Within a specific section, a user can specify one or more search criteria acting on every single metadata descriptor. For each selected descriptor it is possible to establish a single value or a set of relevant values. Depending on the kind of feasible values for the specific descriptor, relevant values can be specified in free text as well as selected from a list or a taxonomy.

The advanced search can be applied simultaneously to one or more resource types. Since different resource types have different metadata schema, in the case where multiple types are simultaneously selected, the system allows users to specify criteria only for common descriptors. Figure 4 shows a snapshot of the list of results for an advanced search. For each outcome, the resource title, type, author, and description are shown. By selecting a resource, it is possible to see all descriptors as well as to access the digital resource content.

The system is also able to customize basic and advanced searches through the application of user profiling algorithms that detect the informative needs of users basing on the analysis of the interactions between users and the system. By checking a specific box, in fact, a user can reorder the results of both basic and advanced searches with respect to the relevance with his user profile. In this way the most relevant information is shown on the top of the list.

Another profile-based filtering facility is provided through a specific section named recommended resources that is available for each user. Here the system selects and lists all digital resources included in the repository that are deemed to be of most interest to the user. For each recommended resource a degree of estimated interest is calculated by the system and represented through star rating. Applied algorithms for profile-based filtering and resource recommendation are described in section V.

Nuovo Progetto

I campi contrassegnati con * sono obbligatori

[Visualizza glossario completo](#)
[Note della scheda](#)

Descrizione Generale del Progetto

- * **1.1 Nome/Titolo** Indicare il nome ufficiale del progetto. In mancanza di un nome ufficiale, indicarne uno sufficientemente descrittivo (es. "la matematica a distanza nella scuola XY")
- 1.2 Indirizzo web di riferimento [raccomandato]** Inserire l'indirizzo web del progetto, se esistente
- * **1.3 Breve descrizione** Descrivere brevemente il progetto (max 3000 caratteri), evidenziandone gli aspetti salienti. In particolare esplicitare finalità e obiettivi del progetto
- * **1.4 Status** Indicare lo stato di avanzamento del progetto

Glossario

- * **1.5 Recapiti di riferimento del progetto** Indicare l'indirizzo del luogo geografico dove il progetto è stato/sarà avviato (via, numero e cap). Se disponibile indicare anche un recapito telefonico.
 - 1.5.1 Indirizzo [raccomandato]** Indicare l'indirizzo del luogo geografico dove il progetto è stato/sarà avviato (via, numero e cap)

Figure 3. Web interface for the proposition of a new digital resource.

#	ID	Titolo	Tipologia di risorsa	Autore	Breve descrizione
1	3	Esperienza di Webconference di A.	Esperienza	Marzio Ghezzi	Si sperimenta la partecipazione remota con strumenti di videoconoscenza di una bambina di sette anni alle attività didattiche della classe anche nei mesi invernali durante i quali, in occasione delle influenze, una patologia genetica le rende impos...
2	4	Scuola .NET - Esperienza videoconoscenza Scuola S. Cesario PacinottiLarco	Esperienza	Marzio Ghezzi	SCUOLA .NET. L'esperienza ha coinvolto 3 alunni, due della Scuola Secondaria di 1° grado di S. Cesario e una della scuola Primaria di Plumazzo. Sono stati coinvolti i docenti della classe degli alunni, le famiglie, gli educatori comunali e il referent...
3	8	Esperienza di A.C. presso l'Università "La Sapienza" di Roma	Esperienza	Marzio Ghezzi	(esperienza citata a pag. 5) Il presente contributo ha per oggetto lo studio di un caso: il successo della didattica integrata aula-rete in uno studente disabile, che si colloca all'interno della cornice rappresentata dal progetto sperimentale di d...
4	9	Informativa esami di certificazione per candidati diversamente abili	Esperienza	wise	Descrizione delle normative e procedure ADA (Americans with Disabilities) necessarie alle persone disabili per conseguire certificazioni specialistiche Microsoft e CS3.
5	11	Silvia va a scuola con il video	Esperienza	enza	Silvia è una bambina di cinque anni e quattro mesi affetta da atrofia muscolare spinale. L'impossibilità di spostarsi e di frequentare la scuola per non contrarre infezioni polmonari che potrebbero essere fatali per lei, ha incoraggiato la scuola e l...
6	15	L'esperienza di Roberto	Esperienza	enza	Roberto è un ragazzo affetto da tetraparesi spastica che è riuscito, nonostante le notevoli difficoltà, a portare a termine il suo percorso di studi presso il Corso di Diploma a Distanza in Ingegneria Informatica del Politecnico di Torino.

Figure 4. List or results for an advanced search.

D. Social functions

The KH offers some social features that allow users to comment on system resources, to assess their quality and to participate in moderated discussions related to them. In particular, the user is able:

- to assess a resource through star rating and to see the average rating of a resource both within search results and while accessing a specific resource;
- to associate free tags to resources, to share tags with other users, to see public tags associated by all users to a specific resource;
- to access resources through a tag cloud by selecting a tag, and all associated resources, from a graphical representation where the used fonts are as larger as the tags are frequent;
- to comment repository resources by participating in organized discussions associated with each of them and moderated by the same creator of the resource.

E. Architecture of the Knowledge Hub

Figure 5 shows a logical view of KH that describes the components and their interactions with stakeholders and external systems. The Application Framework layer provides basic functions related to user management, collaboration, information sharing, process and document management. It is implemented on the top of Microsoft SharePoint 2010.

The Portal layer customizes the Application Framework for the KH needs with appropriate tables and forms for managing metadata associated with documents and profiles associated with users. It identifies the types of documents and groups them in special collections, it defines the types of users and their permissions, it defines and implements the resources editing and publication process, it implements the available search types and configures the collaboration tools.

The Profiler component provides user modelling and document recommendation features on the basis of the models and algorithms defined in section V. By applying these algorithms, it updates the information needs included within the profile of each user according to his behaviour and his interactions with the system components. In

this sense, it receives information from the Portal layer, processes them and returns the result back.

The Adapters are additional components that deal with the connection of external repositories and allows the (semi)automatic generation of new resource proposals linking to external content. Each adapter is specific for a given external repository. When possible, adapters can partially fill the KH resource metadata basing on the information available on the external repositories. The generated proposals must be, in any case, reviewed and validated by a system moderator. A specific adapter for importing bibliographic resources from the Zotero repository has been implemented.

The Web Service Interface layer allows to query the search and filtering engine of the KH from external systems and search engines so that the resources of KH can be smoothly accessed by third parties. In particular, all standard searches are also available for external engines. Given the search results, it is possible to proceed with the download of a single resource and the related metadata.

V. FILTERING AND RECOMMENDATION TECHNIQUES

Recommender Systems (RS) are purposed to give users personalized recommendations on the utility of a set of objects belonging to a given domain, starting from the information available about users and objects. The KH uses RS techniques in order to calculate the potential utility of each resource in the repository for each registered user by approximating, in this way, his information needs.

The defined algorithm for utility calculation is based on a mix of cognitive and collaborative approaches, the first based on the similarity of a new resource with past resources found useful by a given user, the latter leveraging on similarities between user profiles. The calculated utility is then used either to customize the results of basic and advanced searches as well as to obtain, for each user, a list of recommended digital resources.

After introducing cognitive and collaborative approaches to recommendation, this section details the method we defined to estimate the utility of KH digital resources for each user and how we use this value to customize searches and provide useful resource recommendations.

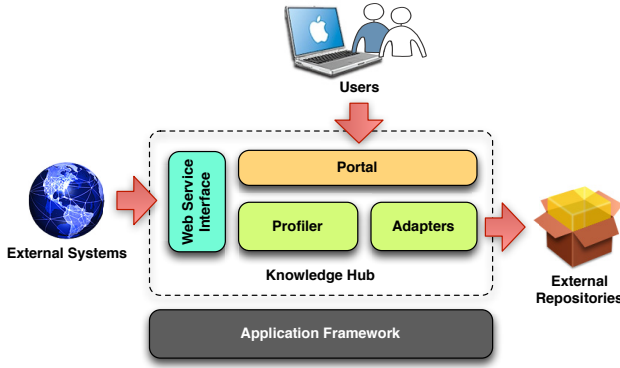


Figure 5. Logical architecture of the KH.

A. Background on Recommender Systems

A formal definition of the recommendation problem can be expressed in these terms [20]: C is the set of users of the system, I the set of objects that can be recommended, R a totally ordered set whose values represent the utility of an object for a user and $u: C \times I \rightarrow R$ a utility function that measures how a given object $i \in I$ is useful for a user $c \in C$. The purpose of the system is to recommend to each user c the object i that maximizes the utility function so that:

$$i'_c = \operatorname{argmax} u(c, i). \quad (1)$$

The central problem of recommendation is that the function u is not completely defined on the space $C \times I$. In fact, in typical applications of such systems, a user never expresses preferences on each object of the available catalogue. A RS shall then be able to estimate the values of u in the space of data where it is not defined, extrapolating it from the points of $C \times I$ where it is known.

Several techniques for RS exist. In *cognitive approaches* [21], the value of the utility function $u(c, i)$ of the user c for the object i is predicted by considering the values $u(c, i_k)$ to be assigned to items found similar to c . In general, each object $i \in I$ is associated with a profile, i.e. a set of attributes able to characterize its content, that is a vector $\text{content}(i) = (w_{i,1}, \dots, w_{i,k})$ where w_{ij} is the weight of the j -th attribute or an indication of how the j -th attribute is able to characterize the object i . The weights of attributes can be created automatically by the system or manually set by a user.

As for the objects, users are also associated with a profile based on the attributes of the objects preferred in the past. The profile is defined as $\text{profile}(c) = (w_{c,1}, \dots, w_{c,k})$, where each weight $w_{c,j}$ denotes the importance of the j -th attribute for the user c . The profile of user c can be obtained, in the simplest formulation, averaging all profiles of the objects for which c has expressed a rating and weighting them on the basis of the rating itself. Obviously, the profile varies over the time depending on the assessments that the user gradually provides.

Once the profiles that characterize objects and users have been defined, the utility of an object i for the user c is calculated basing on the similarity between the two profiles. Several similarity measures can be used for this purpose: one of the most common is the so-called cosine similarity based on the calculation of the cosine between two vectors using the following formula:

$$u(c, i) = \frac{\sum_{j=1}^k w_{c,j} w_{i,j}}{\sqrt{\sum_{j=1}^k w_{c,j}^2} \sqrt{\sum_{j=1}^k w_{i,j}^2}} \quad (2)$$

The main advantage of cognitive approaches is that the recommendations are only based on data related to the domain objects: first useful recommendations are then made immediately, with only one assessment made by the user. This feature is important in environments where it is necessary to produce immediate results or in which new users are added frequently. On the other hand this approach tends to over-specialize predictions, therefore making them uninteresting.

In *collaborative approaches*, unknown values of the function $u(c, i)$ are estimated from those made available by people considered similar to c [22]. The basic idea is that users who evaluated in the same way the same objects are likely to have the same tastes (and are therefore similar). Such methods calculate the utility $u(c, i)$ as aggregation of the utility expressed for i by users similar to c :

$$u(c, i) = \operatorname{aggr}_{c' \in C'} u(c', i) \quad (3)$$

where C' is the set of n users considered most similar to c (with n chosen between 1 and the total number of system users). The simplest aggregation function is the average of ratings given to the users of C' or, as expressed below, the average of such ratings weighted on the degree of similarity between users who have expressed them:

$$u(c, i) = \frac{\sum_{c' \in C'} u(c', i) \cdot \operatorname{sim}(c, c')}{\sum_{c' \in C'} |\operatorname{sim}(c, c')|} \quad (4)$$

where $\operatorname{sim}(c, c')$ indicates the degree of similarity between users c and c' calculated using similarity measures such as the cosine similarity or the Pearson's coefficient. These measures are applied to vectors $(w_{c,1}, \dots, w_{c,m})$ that characterize users, where $w_{c,i} = u(c, i)$, if defined.

By computing recommendations basing on the similarity between users, the advantage is to provide less obvious advice. Conversely, the main problem occurs in domains with a large number of objects and/or users. Preferences in such environments are extremely sparse and the utility function is defined on a tiny part of the space $C \times I$. In these scenarios, it is difficult to calculate the correlation between users, so the recommendations are generated in an inaccurate way. Linked to this limit, there is the *cold start problem*, that occurs in the early days of life of a system, when the available number of assessments is still lower than those of a fully operational system.

B. Profile and utility of a KH resource

The recommendation technique defined for the KH hybridizes cognitive and collaborative approaches in order to ensure the benefits of both trying to minimize, at the same time their drawbacks. The first step of the proposed approach is the construction of a resource profile able to characterize each digital resource included in the KH.

As described in section IV, KH resources may belong to different types. As detailed in [18], each KH resource has associated metadata that, apart from a common core of fields, differ from type to type. Most of metadata fields also allow free text. This limits the possibility of applying a cognitive recommender algorithm only to non-textual

fields common to each type. The table I lists these fields and related feasible values.

TABLE I. METADATA FIELDS OF THE RESOURCE PROFILE

Metadata field	Feasible values
Typology	Project, Community, Experience, Educational process, Bibliographic resource
Activity	Training, Information, Research, Aid
Context	Formal, Non-formal, Informal
Clinical diagnosis	Principal chapters of the ICD-10 standard [22]
Technology	In presence without technology, In presence with technology, Remote
Special policies	L. 104/92, L.68/99, L. 440/97, L. 17/99, L. 53/2000

On the basis of the selected fields, it is possible to build a resource profile. Let be $F = \{f_1, \dots, f_{|F|}\}$ the set of selected fields and $S_j = \{s_{j,1}, \dots, s_{j,|S_j|}\}$ the set of feasible values for each field, we can define the profile of a resource i as:

$$content(i) = (w_{1,1}, \dots, w_{1,|S_1|}, \dots, w_{|F|,1}, \dots, w_{|F|,|S_{|F|}|}) \quad (5)$$

where $w_{j,k} = 1$ if the field f_j of the metadata of the resource i , takes the value $s_{j,k}$ (allowing multiple selections of values for each field) while $w_{j,k} = 0$ otherwise.

The second step of the algorithm is represented by the definition of the utility function. The utility that the user c attributes to a given resource r is expressed by $u(c, r)$ and can assume a real value between 0 and 1. It is inferred through the analysis of a series of actions performed by the user during the interaction with the KH including the explicit evaluation of the resource (star rating), the resource tagging and the participation in a discussion related to the resource.

Therefore, to calculate $u(c, r)$, we consider three components. The first component $u_1(c, r)$ takes the value of the rating expressed by the user (an integer between 1 and 5 in the case of evaluation expressed, 0 in the case where the user has not assessed r). The second component $u_2(c, r)$ takes the value of 4 if r was tagged by c , 0 otherwise. The third component $u_3(c, r)$ takes the value of 3 if c participated in a discussion about r , 0 otherwise. Once calculated these 3 components, $u(c, r)$ is calculated as follows:

$$u(c, r) = \begin{cases} \frac{u_1(c, r) + u_2(c, r) + u_3(c, r)}{3} & \text{if } u_1(c, r) \neq 0 \\ \frac{u_2(c, r) + u_3(c, r)}{2} & \text{if } u_1(c, r) = 0 \text{ and } u_2(c, r) \neq 0 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

In other words, if the explicit evaluation exists, that is used. Otherwise an implicit evaluation is built by assimilating the resource tagging to a 4-stars evaluation and, taking part in a discussion related to the resource, to a 3-stars evaluation. The value for $u(c, r)$ is then normalized between 0 and 1.

C. Estimation of unknown utility

In order to estimate the utility of unrated resources we use a weighted hybridization algorithm [23] i.e. a cognitive and a collaborative algorithms are contemporarily used and, as final result, a combination of predictions from the two is used. In other words, the value of the utility

function $u(c, i)$ of a resource i for a user c is obtained with this equation:

$$u(c, i) = \alpha u'(c, i) + (1-\alpha) u''(c, i) \quad (7)$$

where $u'(c, i)$ is the cognitive component of the utility, $u''(c, i)$ is its collaborative component and α is the hybridization rate: a real number ranging from 0 (highest priority to the collaborative component) to 1 (highest priority to the cognitive component).

As introduced in subsection A, in cognitive approaches to recommendation, the value of the utility function is calculated basing on the similarity between the profile assigned to the user c and those assigned to the resource i . For the construction of the resource profile $content(i)$, the ad-hoc technique defined in subsection B is used. The user profile $profile(c)$ is then calculated by averaging the profiles of resources for which c has expressed an evaluation, weighted according to the evaluation itself with the following equation:

$$profile(c) = \frac{1}{|I'|} \sum_{i' \in I'} u(c, i') \cdot content(i') \quad (8)$$

where I' is the set of all resources for which the user c has provided an implicit or explicit assessment. Once defined the profiles characterizing objects and users, the cognitive component $u'(c, i)$ of the utility of the object i for the user c is calculated using the equation (2).

For the calculation of the collaborative component we use an item-to-item algorithm [24] that computes the utility $u''(c, i)$ as aggregation of the utility expressed by c for objects similar to i with a variant of the equation (3):

$$u''(c, i) = \text{aggr}_{i' \in I'} u(c, i') \quad (9)$$

where I' is the set of the n resources considered most similar to i (with n chosen between 1 and the number of available resources) and the aggregation function is calculated with the following variant of (4):

$$u''(c, i) = \frac{\sum_{i' \in I'} u(c, i') \cdot \text{sim}(i, i')}{\sum_{i' \in I'} |\text{sim}(i, i')|} \quad (10)$$

where the similarity between two resources is computed using the cosine similarity applied to $(w_{i,1}, \dots, w_{i,n})$ which characterize the resources where $w_{i,c} = u''(c, i)$, if defined.

This approach can provide fairly accurate recommendations also to users who have rated only one KH resource. It is therefore useful in systems with many users and/or objects and when the number of available ratings is low. Once both $u'(c, i)$ and $u''(c, i)$ are calculated for each user and resource, the final estimation of $u(c, i)$ is then obtained through the equation (7).

The advantage of providing recommendations based on a hybrid approach that combines a cognitive component and a collaborative one consists in being able to combine the advantages of both techniques [23]. As for cognitive algorithms, it is possible to provide acceptable recommendations even in cases where the starting data is minimal and, as for collaborative approaches, the system is able to generate not obvious and interesting recommendations with a fair level of serendipity.

VI. EXPERIMENTAL RESULTS

An experimentation with real users was performed in order to investigate the validity and the usability of the main functionalities offered by the KH as well as of the defined filtering and recommendation techniques [25]. To do that, 3 key experimentation scenarios have been identified, each corresponding to a specific operational need and including several actions to be performed by the user within the KH. The table II summarizes defined scenarios.

TABLE II. THE DEFINED EXPERIMENTATION SCENARIOS

Scenarios	Actions
Management of digital resources	Resource browsing, creation and submission of a new proposal, filling of metadata fields, modification of the proposal.
Resources retrieval and filtering	Basic search, advanced search, customization of the searches through the user profile, resources recommendation.
Participation in social activities	Resource tagging, resource rating, participation in a discussion about a resource, accessing resources through the tag cloud.

The experimentation involved 17 users (16 females and 1 male) with an average age of 42 years. The group included 13 training operators (support teachers and home tutors), 2 teachers of hospital schools and 2 researchers of special education. The involved parties claim a high level of technological expertise, an average of 15.41 on a scale from 0 (no competence) to 20 (maximum competence). They use ICT solutions in daily work and are frequently updating.

The trial was run in presence during one day within a computer lab and was supervised by 3 conductors. The official speaker presented the environment and the scenarios to be tested and led the experimentation activity. Two technicians have directly supported users during the operational phase based on each scenario. After the completion of each scenario users had to fill a questionnaire designed to collect a structured feedback on what they have experienced.

The analysis of the answers provided to all questionnaires (37 questions in total) allowed us to evaluate KH functions belonging to each scenario both in terms of usability (17 questions) and capability to meet user needs (20 questions). Each question was a *Likert item* i.e. a statement which the respondent was asked to evaluate according to a subjective criteria. The level of agreement or disagreement was expressed in a five ordered response levels (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree). The table III summarizes obtained results in terms of usability and capability to meet user expectations.

TABLE III. SUMMARY OF EXPERIMENTATION RESULTS

Scenarios	Usability	Meeting of user needs
Management of digital resources	4.27 (from 1 to 5)	4.37 (from 1 to 5)
Resources retrieval and filtering	4.35 (from 1 to 5)	4.28 (from 1 to 5)
Participation in social activities	4.31 (from 1 to 5)	4.15 (from 1 to 5)

In particular, the ability to obtain recommendations is considered very or extremely useful by 16 users (average 4.59). The same users consider recommendations received during the experimentation as relevant with respect to their information needs. The recommended resources are clear and easy to read for 15 subjects (average 4.29) and 16 subjects claim to be able to easily locate them within the system (average 4.35).

The ability to view the results of basic and advanced search reordered with respect to the user profile is considered very or extremely useful by 16 subjects (average 4.35). For the same number of participants the order in which their search results are presented reflects their needs (average 4.18).

The ability to have consistent and personalized recommendations of potentially useful resources for individual users has been greatly appreciated and users have also found a very high level of relevance with respect to their interests. Experimenters have also appreciated the use of similarities between peers as a strategy to recommend resources potentially interesting because already rated and appreciated by other colleagues.

VII. CONCLUSIONS AND FUTURE WORK

In this paper we have presented the WISE Knowledge Hub: a semantic repository of digital resources related to special education enabling both storing and retrieval of personalized information and digital assets covering expressed and latent information needs of the operators in the field. Offered personalization features are based on the definition and the implementation of an hybrid recommender system based on a mix of cognitive and collaborative approaches to provide meaningful but not obvious recommendations with a fair level of serendipity.

Experimental data show that the KH has obtained satisfactory scores both in terms of usability and capability to meet user needs. It is perceived as a useful and innovative system for those involved in special education. The positive perceptions of the experimental users return an image of consistency of the environment and demonstrates an accurate design and integration of its components. The variety of resources present in KH and the ability to reach them through different search paths is the element which has been most appreciated. Despite that, the positive feedback about the usability has to be weighed with caution because the presence of continuous support during the trial allowed participants to experiment the system in a secure and guided environment.

The next step to improve KH capabilities will be in the direction of semantics. Metadata and taxonomies indexing digital resources will be represented through Semantic Web languages such as RDF(S) and OWL/OWL2. This will enable the expression and the execution of more complex queries also based on description logics inference by also guaranteeing additional semantic interoperability with external systems, resources and data sets. Moreover, by connecting with Open Linked Data, KH resources will be also related to external data set such as DBLP, Pub-Med, Geonames, etc.

In this way, for example, it will be possible to automatically link relevant scientific articles with KH resources or to geographically contextualize them according to the query or the user profile. A further benefit of the Semantic Web would be to model the entire research community

through existing ontologies like SWRC. This would provide the opportunity to semantically represent not only digital resources but also other researchers' assets, their profile and their professional network in order to ensure support not only during resource filtering but also for co-operation among peers [26].

REFERENCES

- [1] United Nations Educational, Scientific and Cultural Organization, *Opening New Avenues for Empowerment ICTs to Access Information and Knowledge for Persons with Disabilities* UNESCO, Paris, 2013.
- [2] United Nations Educational, Scientific and Cultural Organization, *48th International Bureau of Education, Conclusions and recommendations of the session of the International Conference on Education*, UNESCO/IBE, Geneva, 2008.
- [3] Trentin, G., *Il progetto WISE (Wiring Individualised Special Education)*. *Journal of e-Learning and Knowledge Society*, 5 (2), 2009, 117-123.
- [4] Malloy, T. E., Hanley, G. E., *MERLOT: A faculty-focused Web site of educational resources*. *Behaviour Research Methods, Instruments, & Computers*, 33 (2), 2001, 274-276. <http://dx.doi.org/10.3758/BF03195376>
- [5] Soto, J., Garcia, E., Sánchez-Alonso, S., *Semantic learning object repositories*. *Int. Journal of Continuing Engineering Education and Life-Long Learning*, 17 (6), 2007, 432-446. <http://dx.doi.org/10.1504/IJCEELL.2007.015592>
- [6] Sicilia, M. A., Sánchez-Alonso, S., Soto, J., *Resource descriptions for semantic element repositories: addressing flexibility*. *Proc. of m-ICTE 2005, 3rd Int. Conf. on Multimedia, Information & Communication Technologies in Education*, 2005, 1045-1049.
- [7] Berners-Lee, T., Hendler, J., Lassila, O., *The Semantic Web*. *Scientific American*, 284 (5), 2001, 34-43. <http://dx.doi.org/10.1038/scientificamerican0501-34>
- [8] Henze, N. Dolog, P., Nejdil, W. *Reasoning and Ontologies for Personalized e-Learning in the Semantic Web*. *Educational Technology & Society*, 7 (4), 2004, 82-97.
- [9] Acquaviva, M., Benini, M., *VICE: e-Learning nell'era del Semantic Web*. *Proc. of the National Conference Expo e-Learning*, Ferrara, Italy, 2004.
- [10] Bröcker, L., Paal, S., *WIKINGER - Wiki Next Generation Enhanced Repositories*. *Proc. of the German e-Science Conference*, Baden-Baden, Germany, 2007.
- [11] Adorni, G. Battigelli, S., Brondo, D., Capuano, N., Coccoli, M., Miranda, S., Orciuoli, F., Stanganelli, L., Sugliano, A., Vivanet, G., *CADDIE and IWT: Two Different Ontology-Based Approaches to Anytime, Anywhere and Anybody Learning*. *Journal of e-Learning and Knowledge Society*, 6 (2), 2010, 53-66.
- [12] Capuano, N., Gaeta, M., Marengo, A., Miranda, S., Orciuoli, F., Ritrovato, P., *LIA: an Intelligent Advisor for e-Learning*. *Interactive Learning Environments*, 17 (3), 2009, 221-239. <http://dx.doi.org/10.1080/10494820902924912>
- [13] Capuano, N., Gaeta, M., Salerno, S., Mangione, G., *An Ontology-Based Approach for Context-Aware e-Learning*. *Proc. of the 3rd International Conference on Intelligent Networking and Collaborative Systems (INCOS 2011)*, Fukuoka, Japan, 2011. <http://dx.doi.org/10.1109/INCOS.2011.53>
- [14] Capuano, N., Gaeta, A., Orciuoli, F., Paolozzi, S., *Exploiting Tagging in Ontology-based e-Learning*. *Proc. of the Int. Workshop on Ontology for e-Technologies (OET 2009) held in conjunction with ICEIS 2009*, Milan, Italy, 2009.
- [15] Capuano, N., Dell'Angelo, L., Orciuoli, F., Miranda, S., Zurolo, F., *Ontology Extraction from Existing Educational Content to Improve Personalized e-Learning Experiences*. *Proc. of the 3rd Int. Conference on Semantic Computing (ICSC 2009)*, Berkeley, CA, USA, 2009.
- [16] Wah, L. L., *An open-access repository of multimedia resources to support special needs instruction*. *Proc. of the 4th International Convention on Rehabilitation Engineering & Assistive Technology*, Singapore, 2010.
- [17] World Health Organization. *International Statistical Classification of Diseases and Related Health Problems: Instruction Manual*. 10th revision, vol. 2, 2010.
- [18] Benigno, V., Repetto, M., Alvino, S., Capuano, N., Corti, P., Monticelli, M. *La modellizzazione e la catalogazione delle informazioni sui contesti di riferimento di WISE. Reti e inclusione socio-educativa: il sistema di supporto WISE*, Franco Angeli, Milano, Italy, 2012, 91-112.
- [19] Capuano, N., Mangione, G., Salerno, S., *Un repository semantico per la special education: il Knowledge Hub. Reti e inclusione socio-educativa: il sistema di supporto WISE*, Franco Angeli, Milano, Italy, 2012, 113-140.
- [20] Adomavicius, G., Tuzhilin, A., *Toward the next generation of recommender systems: a survey of the state-of-the-art and possible extensions*. *IEEE Transactions on Knowledge and Data Engineering*, 17 (6), 2005, 734-749. <http://dx.doi.org/10.1109/TKDE.2005.99>
- [21] Balabanovic, M., Shoham, Y. *Fab: Content-based, collaborative recommendation*. *Communications of the ACM* 40 (3), 1997, 66-72. <http://dx.doi.org/10.1145/245108.245124>
- [22] Konstan, J. A., Miller, B. N., Maltz, D., Herlocker, J. L., Gordon, L. R., Riedl, J., *GroupLens: applying collaborative filtering to user news*. *Communications of ACM* 40 (3), 1997, 77-87. <http://dx.doi.org/10.1145/245108.245126>
- [23] Capuano, N., Mangione, G., Pierri, A., Salerno, S., *Learning Goals Recommendation for Self Regulated Learning*. *Int. Journal of Engineering Education*, 28 (6), 2012, 1373-1379.
- [24] Linden, G., Smith, B., York, J., *Amazon.com recommendations: Item-to-item collaborative filtering*. *IEEE Internet Computing*, 7 (1), 2003, 76-80. <http://dx.doi.org/10.1109/MIC.2003.1167344>
- [25] Mangione, G. R., Monticelli, M., Corti, P., *La sperimentazione del Knowledge Hub. Un repository semantico per la special education: il Knowledge Hub. Reti e inclusione socio-educativa: il sistema di supporto WISE*, Franco Angeli, Milano, Italy, 2012, 259-274.
- [26] Mangione, G., Faiella, F., Palloff, R. M., *Le tecnologie nelle KBC. QWERTY, Interdisciplinary Journal of Technology, Culture and Education*, 6 (2), 2011, 127-156.

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