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# Exploring AppInventory, a visual catalog of applications for assisting teachers and students

**Marco Corbatto**[1] · **Antonina Dattolo**[1]

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**Abstract**

We are witnessing a meaningful transformation of teaching and learning practices and widespread experimentation of new didactic methodologies. The availability of a huge amount of contents and learning objects on the Web is progressively transforming traditional learning design activity of teachers. However, the Web also offers another great opportunity in helping teachers adopt student centred methodologies: the availability of hundreds of Web 2.0 and mobile applications for creating and sharing digital artefacts. If incorporated into daily teaching and learning activities, they can improve the collaborative, cognitive and creative work of the students, enhancing and redefining traditional educational practices. Nevertheless, although these applications are generally easy to find and use, there is a lack of knowledge about their existence, their functions and their potential in an educational setting. In this paper we present AppInventory, a Web platform which enables teachers (and students) to visually browse through a catalog of 271 apps, semantically organized in a multi-dimensional, purpose-based taxonomy. Users can explore the catalog following personal associative paths; assign ratings, and leave comments.

**Keywords** Web 2.0 applications repository · App 2.0 taxonomy · Multimedia design and development for smart e-learning · Innovative smart teaching and learning technologies · Multimedia for user engagement and motivation in education · Visual organizers · Semantic knowledge structures

## 1 Introduction

A rapid transformation of methods, roles and practices is currently affecting all school grades. There are many factors contributing to this momentous change: a crisis in traditional

Both the authors contributed equally to this research.

✉ Antonina Dattolo
antonina.dattolo@uniud.it

Marco Corbatto
marco.corbatto@uniud.it

[1] SASWEB Research Lab - Department of Mathematics, Computer Science and Physics, University of Udine, I-34170 Gorizia, Italy

teaching methods; the availability of low cost mobile technology and easy access to global knowledge; the strong influence of new technologies on society and communication media and, not least, the desire of educators to find new ways to engage and motivate students.

An increasing number of teachers begins to experiment active learning scenarios and approaches, consistent with proficiency and skills development outcomes as stated, for example, in recent Italian School Reforms and in the European Digital Competence Framework for Citizens [31].

A recent investigation [9], that we carried out involving our target teachers, 178 from high school (K9-K13 grades), middle school (K6-K8), and primary school (K1-K5), highlighted the importance attributed to the design of activities compared to contents design, a marked interest in the role that technology could play in education processes, the importance of diversifying the learning activities and the need for a more extensive knowledge about applications to support the creative work and communication. Above all, the importance of adopting active methodologies emerged.

Nowadays, for implementing their Teaching and Learning Activities (TLAs), teachers have available a huge amount of contents and learning objects on the Web but also hundreds of Web 2.0 and mobile applications, which can support them in creating and sharing digital artifacts, aggregating, remixing and collecting heterogeneous materials and communicating within working groups. These applications represent a challenging opportunity for teachers who would like to experiment and adopt student-centred methodologies and use them into daily TLAs: they can improve the collaborative, cognitive and creative work of the students, enhancing and redefining traditional educational practices. Nevertheless, although these applications are generally easy to find and use, it is often difficult, for a teacher, to find the right one for a specific task, and to have a general awareness on their availability and their potential in an educational setting.

Our work is located in this context and is part of a wider project, called LDInventory [8], which intends to model and realize a novel lightweight Web-based tool for Learning Design (LD). An LD system is a computer based tool which supports teachers in the delicate task of designing, organizing and sharing TLAs with students and colleagues. On such a platform, a teacher can arrange the activities, attach appropriate contents and be guided in choosing relevant tools for the students' tasks. A meaningful module of this project is represented by AppInventory, which this paper will address.

AppInventory is a digital catalog of (at the moment, 271) Web 2.0 and mobile applications, whose main aim is to support teachers during the design and the implementation of TLAs.

The major *novelty* of AppInventory, respect other existing apps' catalogs, is the graphical modality to visualize the catalog, associated to a semantic mechanism for browsing through it:

- *graphical layout*: the catalog is shown using a unique holistic view, displayed using a multi-resolution circle packing diagram, which starts from a general view of the applications, organized using a taxonomy, and, applying different zooming levels, gets up to the details of the single application;
- *semantic browsing mechanism*: each application is a cognitive unit, semantically connected to the others, by specific, and upgradeable contextual dimensions, such as the complexity and/or Bloom level, the presence of advertising, the typology, the language, and so on. The user can dynamically select the semantic filter to apply on the catalog in order to browse through it following their expectations. We applied semantic structures,

called zz-structures [14, 16, 29], and browsing mechanisms based on zz-dimensions and zz-views.

A first prototype of AppInventory has been discussed in [9]; in this paper, we present the new online AppInventory platform, where we updated the data and created video-tutorials; introduced *statistics* about data and taxonomies; implemented an app's *rating schema* for collecting the opinions of the users, their comments, and suggestions; implemented a new *contextual navigation mechanism* between categories and applications, which is based on zz-structure; performed a qualitative and comparative *evaluation*.

The main objectives of this paper are the following:

– present *the AppInventory platform, highlighting its main features - graphical layout and semantic browsing mechanism*, which are new and different from the other catalogs;
– perform *a preliminary qualitative usability evaluation, focused mainly on its main original features*, with the aim to proof that the proposed visual model for organizing and browsing through the applications, although new in this domain, results simple and usable.
– Perform an additional, *comparative evaluation* with two other Web catalogs of applications.

The rest of this paper is organized as such: Section 2 discusses related work; Section 3 describes our proposal, the cataloging scheme, the purpose-based taxonomy, some statistics on the dataset; Section 4 proposes the architecture model and its implementation details; Section 5 presents the guidelines followed for the development of the Web platform, the new rating scheme and the semantic browsing, while Section 6 the results of two studies to evaluate the usability and the users' opinions on four specific aspects. Conclusions and future work end our work.

## 2 Related work

Several repositories exist which index applications, proposing classification [5] and evaluation [6, 23, 27] schemes; in this paper, our analysis is restricted to classifications that support teachers in identifying applications for specific purposes, excluding repositories deemed too general, such as App Store, Google Play, Chrome Web Store, Appszoom, or repositories which share learning objects and didactic resources and not tools, such OER Commons.

A positive example is EdShelf [18], a rich discovery engine of websites, mobile apps, desktop programs, and electronic products for teaching and learning. A user can filter the tools by price, platform, subject, age, category and keywords. Unfortunately, subject and category are two long *flat lists* of keywords. Interesting is the opportunity for users to rate and review the apps, and to create and share a shelf of apps. Essediquadro [20] is a service of documentation and orientation on the teaching software and on other resources for the learning process. The tools can be searched by subject of study (Mathematics, Italian, etc.) and by specific subject matter, but *the category of the tools is not considered*. Similar search fields are proposed by Apps4edu [2]. It is possible to list all the apps in it, but the result is *a flat, unusable, paged-list of tools*. CSE (Common sense education) [7] introduces the interesting, abstract concept of *purpose*, but it is used more as teaching context of use more than real purpose.

A comprehensive review of existing application classification systems is provided in [5]; it confirms that a good classification model needs to consider the purpose of the teachers and proposes a classification divided on skill-based, content-based and function-based applications, which implicates respectively the "Remembering and Understanding", "Applying and Analysing", and "Evaluating and Creating" levels of the Bloom's Taxonomy [1]. From our viewpoint, by the term "purpose" we mean the concrete objective of the teacher (or of a generic user), such as realize an infographic, or create a timeline, or plan a quiz. On this basis, we propose, in next Section 3.3, our original taxonomy.

Related work highlights some open challenges and weaknesses, which represent the start points in the modelling of AppInventory:

- the navigation and searching of tools do not offer a general overview, but long lists of applications, often difficult to read;
- there is a complete lack of graphic views which could offer users a visual, holistic idea of the existing tools;
- the concept of category is often thought of as a subject of study, or context of use and not as purpose for teachers. The existing taxonomies are not purpose-based;
- the semantic relations among the tools are not highlighted, and the degree of belonging of a tool to a cluster in the taxonomies is not clear;
- the interaction with the user, except for EdShelf, is limited to the search box.

Our contribution focused on these objectives and proposes a model and a Web platform which offer graphic and holistic views of the whole catalog, organize the applications in a purpose-based taxonomy, facilitate a semantic navigation among items for the users, and enable users to interact with the platform, rating and reviewing an app, leaving a comment or suggesting a new app.

## 3 Our proposal: AppInventory

AppInventory is an online platform, freely available for research and teaching, not for commercial purposes, at http://appinventory.uniud.it. It contains a visual multimedia catalog of 271 applications; it has been developed with the aim of supporting teachers in identifying the best tools to carry out specific tasks, improving the digital skills of teachers and students. In particular, AppInventory has been modelled for:

- providing detailed and multilingual information about each app, including an illustrated review, a video presentation and references to external documentation;
- cataloging the apps by means of an original taxonomy and semantic connections;
- offering intuitive and contextual navigation mechanisms;
- generating visual representations and holistic views of the catalog;
- proposing users some semantic paths through the catalog in order to help users discover new tools;
- inviting users to contribute with evaluation data, reviews, feedbacks, comments and use cases about the presented tools.

The AppInventory project is consistent with the objectives of the European Digital Competences Framework for Citizens 2.0 (DigiComp) [31]: in particular, it can contribute to the development of ten of the twenty-one competence dimensions stated in the DigiComp's conceptual reference model.

### 3.1 Creating the repository

The initial effort has been dedicated to build the App metadata repository, a database containing the multimedia catalog of the applications. The cataloging work has been carried out in two stages: in the first stage, we considered a first set of 111 applications and proposed a classification model; in the second stage we extended the analysis to other 160 new applications.

The selection of widespread and heterogeneous Web 2.0 and mobile applications has been carried out by analyzing several sources, from educational sites and dedicated blogs, such as [18, 19, 21, 22], to thematic link collections and search engines. From the examination of the first group of apps, we have identified common features and purposes of the applications in order to propose an original purpose-based taxonomy and establish a set of features for defining the cataloging scheme.

Subsequently each application has been analyzed and documented through a cooperative work involving a large group of higher education students, 112 for both stages. All the working documents and the coordination sheets have been hosted on a cloud platform, making possible the collaborative editing of documents, their subsequent refinements, the peer reviews of materials and the coordination of the project. A general check was performed from another group of 12 students to assure an homogeneous categorization criteria and the correctness of the collected information. An original video-presentation of each app has been recorded and another group of 5 students looked after their post-production in order to cut the inappropriate parts, add credits, titles, descriptions and tags and publish them on the dedicated play list of the project, accessible from Sasweb Lab's AppInventory project page - https://goo.gl/25DN6v, shown in Fig. 1.

Finally, a group of 8 students contributed to the creation of English subtitles for the videos and translated all the documents in English. The coordination of all these large groups has been possible thanks to the extensive use of a cloud platform. Due to the high number of people involved and the amount of documentation produced, the overall project has required a great and continuous organizational effort.

### 3.2 The cataloging scheme

We propose an open classification scheme which accepts user contributed use cases, since each application could have several uses also distant from those planned by its creators.

The initial items of the cataloging scheme are listed in Fig. 2, discussed in [9] and are visible in the cards of each application (see also the specific card proposed in Fig. 10).

### 3.3 The purpose-based taxonomy

Having observed recurrent purposes, we mapped the applications into 3 macro-categories, as illustrated in Fig. 3.

- *Interacting & Organizing* includes applications to manage groups, to collaborate on the same documents online, to support users in planning projects and activities, to interact in real-time on a virtual board or to collect data by surveys and quizzes.
- *Creating* includes applications that support users in building up digital artifacts, belonging to various typologies. Generally, after an initial registration, these applications offer users a personal dashboard to manage their digital products and an editing environment where to build and modify them. It is generally possible to share the

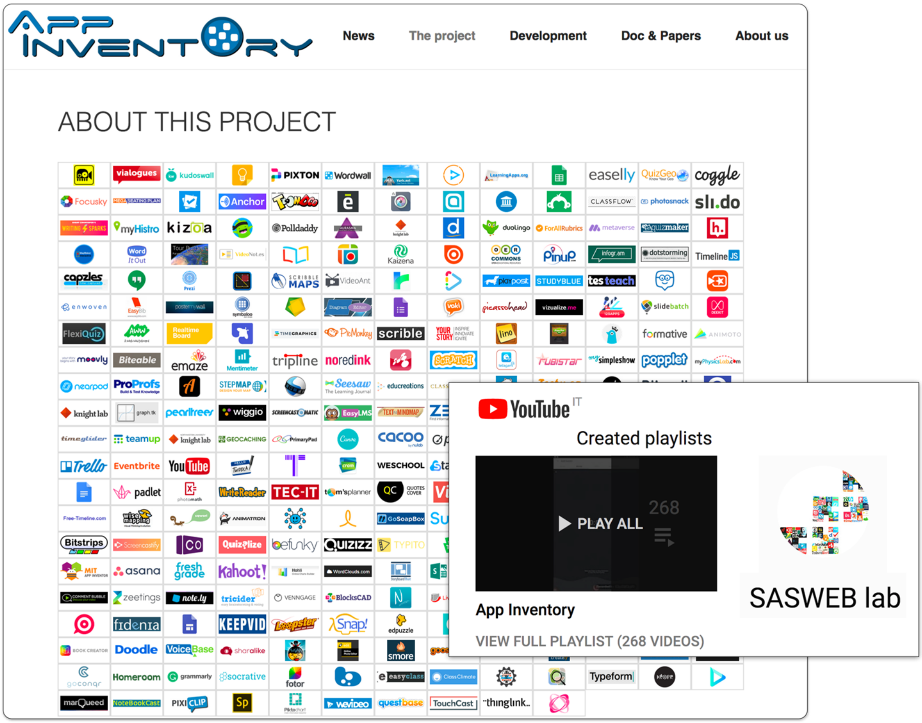


**Fig. 1** The Web page of the project, the applications' logos, and the Youtube playlist

artifacts by a specific url, an embed code or by directly publishing them on social platforms.

– *Aggregating* contains the applications which support users in collecting homogeneous or heterogeneous materials (for example links, images, videos, documents, maps, events) in order to semantically connect them, to keep notes about interests, to create stories, to distribute and share the resulting collections in a simple manner.

The macro-categories are structured in relative categories: 13 for the 'Creating', 7 for 'Interacting & Organizing', 4 for 'Aggregating', plus an additional generic 'Others' to capture

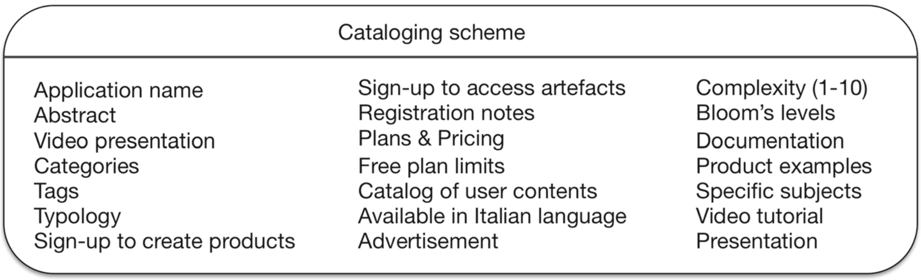


**Fig. 2** The cataloging scheme

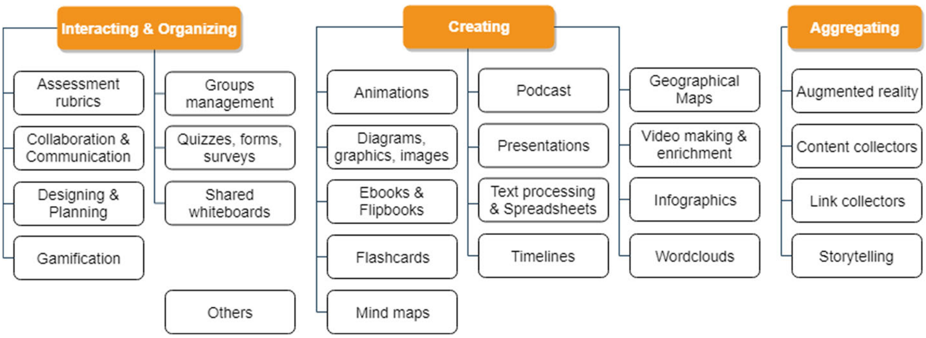


**Fig. 3** Our purpose-based taxonomy

unforeseen features. Each application often integrates various distinct features: for this reason, we have adopted a weighted attribution of an application to single categories in order to highlight the primary purpose compared to secondary ones.

### 3.4 Statistics on the dataset

The distribution of the 271 apps into the taxonomy is shown in Fig. 4. The total number of the apps is greater than 271 since each application can be assigned to more than one category.

Figure 5 shows the Bloom levels attributions for the set of considered applications, and additional statistics about the catalog.

We observe a relatively uniform distribution of the applications over the six levels of Bloom's taxonomy. This in part reflects the versatility of the analyzed tools: for example, an application to create online presentation can be used by teachers to support their students

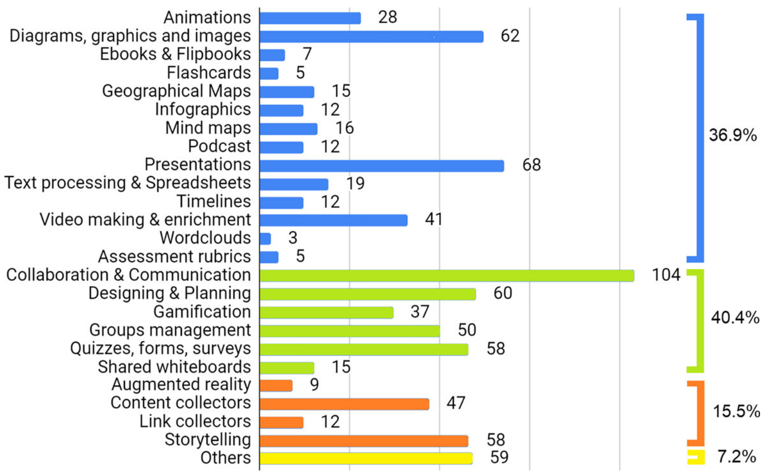


**Fig. 4** Distributions of the 271 apps into the macro-categories

| Bloom's level | # of apps |
|---|---|
| Creating | 203 |
| Evaluating | 101 |
| Analyzing | 183 |
| Applying | 136 |
| Understanding | 210 |
| Remembering | 225 |

| Sign-up policy for creating | # of apps |
|---|---|
| Compulsory | 175 |
| Optional | 56 |
| No sign-up | 40 |

| App typology | # of apps |
|---|---|
| Web | 241 |
| Flash | 29 |
| Android | 96 |
| IOS | 113 |
| Win. mobile | 13 |
| Win. desktop | 18 |
| MacOS | 18 |
| Linux | 4 |
| Chrome ext. | 13 |
| Firefox ext. | 12 |
| Google app | 8 |
| Other | 1 |

| Item | Count |
|---|---|
| Video-presentations realized | 269 |
| External video-tutorials incorporated | 385 |
| Links to external documentation | 1111 |
| App's screenshots incorporated | 1733 |
| Unique tags in Italian | 618 |
| Unique tags in English | 609 |

| Sign-up policy for accessing | # of apps |
|---|---|
| Compulsory | 55 |
| No sign-up | 216 |

| Advertising | # of apps |
|---|---|
| Presence | 44 |
| Absence | 227 |

| Availability | # of apps |
|---|---|
| Active apps | 264 |
| Inactive apps | 7 |

**Fig. 5** Distributions of the apps in the catalog

in the memorization and understanding of concepts but it also represents a tool to develop the analysis and the creativity skills when used by students to summarize a topic and create an effective presentation.

The app typology field describes the various forms in which an application is made available: due to the multiform nature of many applications, a multiple attribution to the various typologies is possible. Most of the analyzed apps are available as Webapps based on modern Web standards like HTML5, SVG, CSS3, ECMAscript, etc., and they are generally responsive and portable. A minority still adopts proprietary solutions like Flash that limit their portability to desktop devices, but there is a general tendency to progressively migrate towards Web standards: many applications provide both Flash and HTML5 versions and encourage users to choose the last one for the new creations. About 77% of the applications analyzed are app for mobile devices or are Webapps that also offer an optimized version for mobile device. Another significant aspect we took in consideration concerns the need for authentication in order to create artefacts or in general to access its functions. A large part of the analyzed applications (about the 65%) require users to register and authenticate before using them, about 20% of the applications can be used anonymously with limited features (for example without save or share functions), the remaining 15% of the analyzed apps do not provide registration and authentication procedures mainly because they offer simple services, like the generation of visual representations (i.e. wordclouds, qr-codes, etc.), the conversion of file formats or the editing of images with the direct download of the products and without the use of permanent remote resources. Figure 6 shows the distribution of the estimated complexity of the applications indicating the estimated difficulty level in using the application in a range from *1=straightforward* to *10=very complex*.

## 4 The Web platform and its architecture

AppInventory has been implemented as a Web application based on HTML5, SVG and CSS3 W3C standard languages and the D3js [17] framework. D3 provides a powerful DOM selection mechanism, based on declarative CSS patterns; a rich library of methods to create complex graphical representations and to act, with the same syntax, both on single DOM

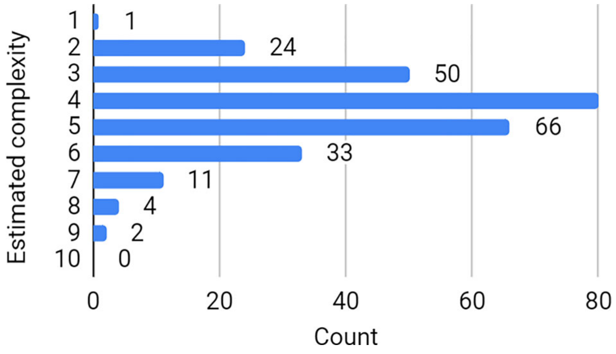


**Fig. 6** The distribution of the estimated complexity of the apps

elements and on sets. The idea behind D3 is to strictly tie data to HTML or SVG elements realizing a so-called data-driven approach to DOM manipulation without hiding the document structure with opaque software layers. We recently experimented the D3's versatility in realizing the application VisualBib [10]. AppInventory adopts AJAX techniques to improve a user experience by avoiding full page reloads during navigation, by dynamically loading or sending on demand only small chunks of data from/to the server.

The client-server architecture of AppInventory is schematically represented in Fig. 7 and the main components are discussed below.

**The SAX parser** is a Java component (Fig. 7-left) which support the system administrators during the process of adding new data to the *YouTube AppInventory playlist* and to the DBMS (DataBase Management System), parsing the new documents that become available in the *cloud platform*, used in the cataloging phase, as described in Section 3.1. For each new documented application, the SAX parser extracts and validates all the significant metadata from the XML versions and generates appropriate SQL statements in order to add new records into the database and to establish the opportune data relationships.

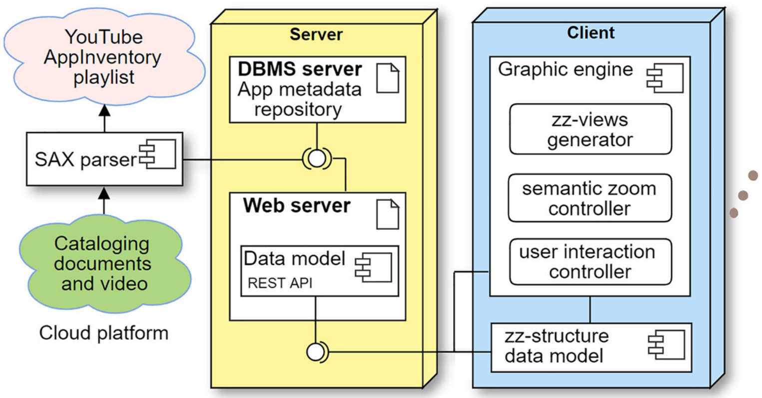


**Fig. 7** The architecture of the AppInventory framework

**The server node** (Fig. 7-center) contains the DBMS, where the data are modeled in a relational scheme implemented in a MySql server; it represents the *App metadata repository* of AppInventory. The *Web server* provides the static contents (html pages, images, scripts and stylesheets) to Web clients and manages, through the *Data model* component, the asynchronous requests for data retrieval/update, received on its REST API endpoint from the client side components of AppInventory.

**The client node** (Fig. 7-right) becomes active during the application running on the browser of each user. It contains two main components, zz-structure data model and graphic engine, which manage respectively the semantic browsing mechanisms and the graphical layout of the catalog.

The *zz-structure data model* uses a conceptual semantic model for structuring the data, the so-called zz-structures [13–16, 29]. It defines and manages the zz-dimensions, described in Section 5.2, which semantically connect applications, categories, external items and metadata. This component manages both the static zz-dimensions, which model the pre-established relationships between items, and dynamic zz-dimensions which are created on the fly, as a result of user actions. For example, a new zz-dimension is generated during a search session to semantically connect all the found apps. Another case occurs when user composes multiple zz-ranks by an AND / OR operator, using the semantic browsing mechanism, presented in Section 5. This component also maintains and synchronizes with the server the dynamic data generated during the user navigation, for example, when new ratings for apps are added, new user comments are inserted or the visit and use counters associated to the apps are updated.

The *graphic engine* generates the holistic, visual, and interactive representations of the domain data and supports the semantic zoom behaviour during the navigation, revealing/hiding contextual information. It implements specific zz-views to show and connect the elements of the catalog and manages users' interaction during the exploration, offering navigation mechanism like the current rank navigation window (Fig. 12-right) and the contextual rank selection and composition window (Fig. 12-center). It also generates the views of the app information cards, the link to external resources associated to each app and implements some protection mechanisms, based on cookies and invisible recaptcha techniques, to avoid multiple ratings of an item by the same user and to block spam attacks.

## 5 Modelling the graphical layout and the semantic browsing

We defined the following main guidelines for the graphical layout of the AppInventory catalog, with the aim to provide innovative and usable modalities of navigation, in according to the Shneiderman's mantra [30] - *"Overview first, zoom and filter, then details-on-demand"*:

- present an initial comprehensive view of the entire repository, without exposing details of the apps;
- offer a continue zoom mechanism in order to minimize users' disorientation and let them choose the appropriate level of visualization;
- propose a semantic zoom mechanism: each item becomes visible at an appropriate zoom level in order to enhance the understanding and minimize the cognitive load;
- users can freely navigate in multiple directions, using next-previous contextual move mechanisms.

For the implementation, we evaluated alternative interactive visual representations of the data in order to offer attractive solutions to user navigation and to highlight specific data relationships. The literature on visual interfaces and languages is rich of proposals [11]; a graphical review on visual languages from 1995 to 2014 is discussed in [12], where the authors gathered and analyzed the employed visual techniques (graph-based visualization such as collaboration, co-citation, and co-word networks) and adopted geographical views, alluvial diagrams, and timelined charts. An interactive visual browser is presented in [25], where the authors collected 430 different text visualization techniques. The catalog displays a card for each entry. The Web page also addresses a set of other surveys on some projects, such as BioVis [24] and SentimentVis [26] propose visual guide for data visualization techniques, in the fields of biology and sentiment analysis, respectively. Many live examples of interactive visual representations of complex data can be found in D3.js [3, 17] and Echarts [28] frameworks.

In order to represent our purpose-based taxonomy with multiple and weighted attribution of application to categories, we analyzed various solutions and finally chose to implement a multi-level version of a circle packing diagram, which we enriched with semantic zoom and browsing mechanisms (described in Section 5.2).

Figure 8 shows the initial holistic view of the AppInventory catalog; at the first zoom level the macro-categories are represented by separate circles, which contain the 24


**Fig. 8** The holistic view of the catalog

categories. The size of each circle is proportional to its populousness. Zooming in, taking the focus on the category 'Mind maps', a new view (Fig. 9-left) reveals the logos of the applications which populate this category. The size of each circle is proportional to the weighted attribution of an application in a single category and the gray color identifies apps that are no longer active. The next level of zooming (Fig. 9-center) enables users to visualize, in addition to logos, the names of the apps as well as a subtitle. In Fig. 9-right, we zoomed on the Mindmeister app by clicking on its name: further navigation elements appear to enable navigation towards similar applications in the same category (left and right arrows) and the other categories to which the app belongs (the four buttons visible on the bottom). In addition, two buttons appear on the top: the "compass" button opens the contextual rank selection window, discussed in next Section 5.2, while the "i" button opens the detailed information card of the app, partially visible in Fig. 10, where, on the top-right, there are five icons to:

– open the comment section of the app, discussed in next Section 5.1;
– open the rating section of the app, discussed in next Section 5.1;
– visualize if the app is known and used by the user;
– enlarge the window;
– close the window.

Next to the subtitle, the number of the visits and the number of users who declared to know and use the app, are visible. These counters are increased at most once per user's session. The information card visualizes all the fields proposed in the cataloging scheme (see Fig. 2), and among the others:

– a short description of the main purpose of the app;
– an original video presentation of the app, recorded by students of the work group; most of videos are accompanied by English subtitles: the translation work is still ongoing;
– a list of fields to describe the app according to the different taxonomies;
– a third-party video-tutorial in the currently selected language (Italian or English);
– a review of the app that describes its main features through text and images in order to give the user the opportunity to evaluate the adequacy of the app with respect to his/her goals.

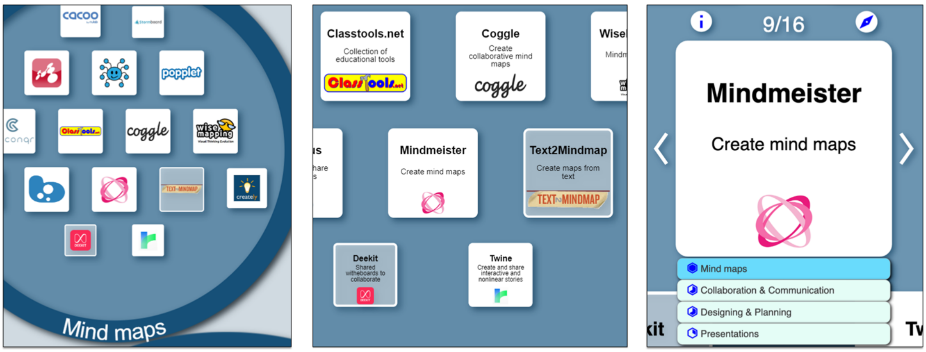


**Fig. 9** Zooming in the view, the apps' logos appear (left); additional zooming in makes visible names and subtitles (center); clicking on an app, appear new details (right)

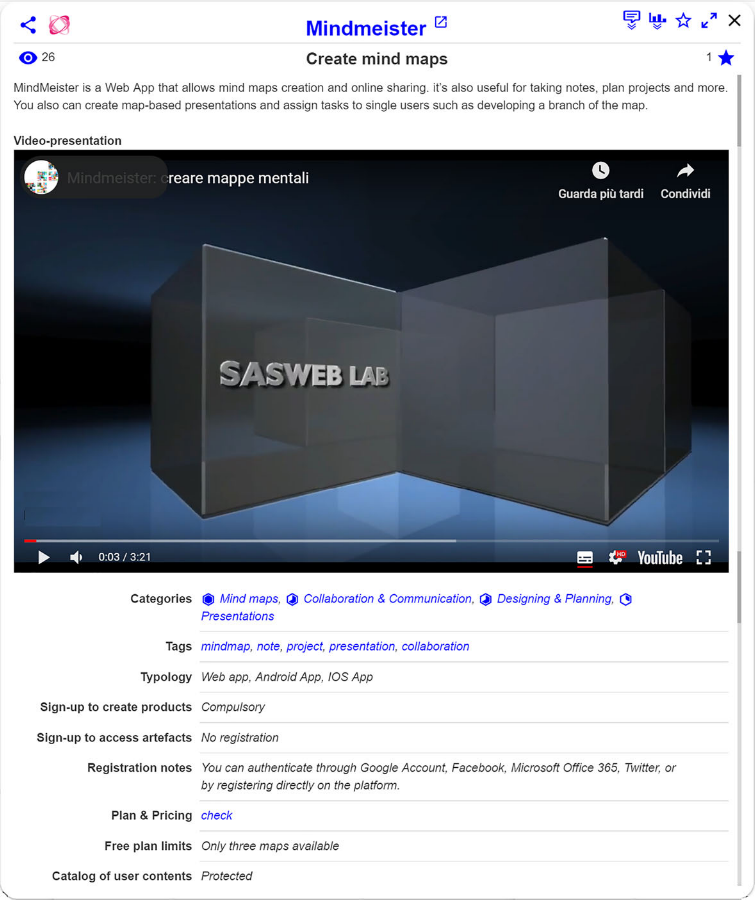


**Fig. 10** A partial view of the application's card

## 5.1 The rating scheme

In this new version of the catalog, we introduced the opportunity for the users to interact with the platform, enabling them to rate the applications, leave personal comments, annotate them as known and used, suggest new use cases or new applications to add to AppInventory. Figure 11 visualizes the possible ratings; each user can rate four features of any app, and express a general opinion in a 5-Likert scale:

- *functionality*: versatility of the app or the richness of the features provided;
- *applicability*: adaptability of the app to multiple contexts and tasks;
- *ease to use*: usability and the intuitiveness of the user interface;
- *originality* is referred to the features provided and/or the technical adopted solutions;
- *overall opinion* is the overall degree of appreciation of the app.

For each features, the user can see the rating and its distributions on the 5-Likert scale. In addition to ratings, users can leave five different types of comments in two contexts:

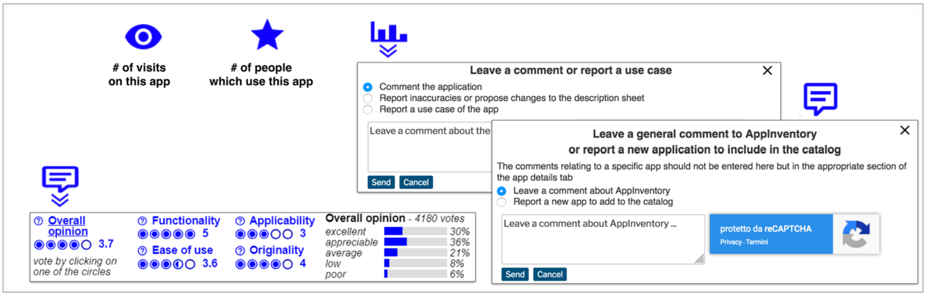


**Fig. 11** Rates, comments, suggestions

- local to a single app: comments to the app, suggestions of original use cases or reports of inaccuracies / proposals of changes in the description card;
- global: comments about AppInventory or suggestions of new apps to add in the catalog.

### 5.2 The zz-structure-based data model and the semantic browsing

The data model uses a conceptual semantic model for structuring the data, the so-called zz-structure [14–16, 29]; it provides data representation and exploring mechanisms. In zz-structure, data are linked in structures, called dimensions, which represent semantic relations between items. Each item may belong to many different dimensions. A general way to represent a zz-structure is an edge-coloured multigraph, where the vertices are the items of interests, such as the applications or, at different level of abstraction, the categories, and the colours of the edges are the dimensions. Each dimension may contain separate linear paths, called ranks. Examples of dimensions and ranks in AppInventory are:

- *d.category* connects each application to the others which have in common the same category;
- *d.categories* connects each application to all the categories it belongs to;
- *d.video-presentation* connects each application to its video presentation;
- *d.typology* connects each application to the others having in common the same typology;
- *d.registrationPolicy* connects, using 3 ranks, the set of applications which have the registration policy in common (mandatory, optional, not required);
- *d.search* connects the apps resulting from a search, and contains, for each specific search, the rank of the found apps.

Focusing on a view, it is possible to see the links that semantically connect the items to the others in the system. For example, Fig. 10 shows a set of these dimensions for Mindmeister: *d.categories* shows the five categories of this applications (*Mind maps*, *Collaboration & Communication*, *Designing & Planning*, and *Presentantions*); *d.video-presentation* shows the preview of the video. An example of navigation between semantic ranks is shown in Fig. 12.

Figure 12-left appears clicking on the "compass" button, located on the top-right of each application (as shown in Fig. 9-right). In the specific case, the user searched for the keyword "notes" and the result is a set of 19 found applications; they are visualized in a rank, in which any found application is part of a linear path, browsable using the arrows. A new dynamic rank may be created for example composing in AND three criteria: "Current category",

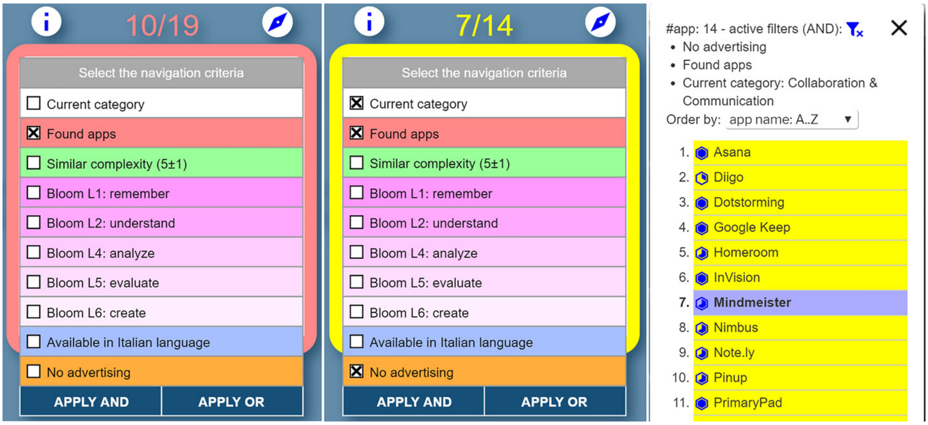


**Fig. 12** The rank selection window of the app Mindmeister after searching the keyword "notes" (left). Defining of a new dynamic rank composing in AND three ranks (center). The navigation set of the dynamic rank (right)

"Found apps", and "No advertising", as shown in Fig. 12-center, obtaining a rank of 14 apps. Also in this case, the user can browse the obtained dynamic rank using the arrows or the generated list, shown in Fig. 12-right.

These views are managed by the graphic engine module, which interacts with the App metadata repository through an intermediate data representation level, called data model, as discussed in previous Section 4.

## 6 Evaluation

In order to evaluate the impact of our visual catalog and state that the new graphical layout and semantic browsing mechanism are usable and appreciated by users, we carried out two studies: a preliminary qualitative evaluation of the AppInventory platform, discussed in next Sections 6.1–6.3, and a comparative evaluation with two similar tools, discussed in Section 6.4.

### 6.1 The preliminary qualitative study

The first study involved a sample of 53 persons (31 F, 22 M) who participated to a seminar for the presentation of the new platform and to the next workshop session. The age of the participants was fairly evenly distributed between 20 and 70 years, the declared profession was teacher/researcher (70%), student (17%) or other (13%). Among teachers, 20.5% were from primary school, 72% from high school, 5% from universities and 2.5% from other schools. During the workshop the participants:

– performed a list of 9 tasks in order to use AppInventory and become familiar with its features. The activities involved:

    – 4 tasks - the navigation through categories, using the cursors to move between apps and the "compass" button to change navigation criteria;
    – 1 task - the access to the information of some app;

  - 1 task - the use of the simple and the advanced search;
  - 1 task - the marking of known/used applications;
  - 1 task - the access to the rating section of the well known apps for inserting personal scores on the five evaluation criteria;
  - 1 task - the access to the comment section of the app in order to enter any comments on the application, to report inaccuracies in the information or to share a use case of the app;

- performed a set of 5 search operations and validated the results;
- filled a SUS (System Usability Scale) questionnaire [4] in order to evaluate the perceived usability level of the application (the results are described in next Section 6.2);
- filled a questionnaire of 21 questions on four aspects of the platform (the results are described in next Section 6.3).

### 6.2 Usability evaluation

In order to evaluate the general perceived usability of the application we ask the sample to fill a standard SUS questionnaire. The SUS value was computed, for each participant, with the formula

$$SUS = \left( \sum_{k=0}^{4} (A_{2k+1} - 1) + \sum_{k=1}^{5} (5 - A_{2k}) \right) * \frac{100}{40}.$$

where $A_i$ is the value (from 1 to 5) of the answer to the $Q_i$ question.

The distribution of SUS is summarized in Fig. 13, while Fig. 14, reports the distribution of the answers to each SUS question:

Q1 I think that I would like to use this system frequently;
Q2 I found the system unnecessarily complex;
Q3 I thought the system was easy to use;
Q4 I think that I would need the support of a technical person to be able to use this system;
Q5 I found the various functions in this system were well integrated;
Q6 I thought there was too much inconsistency in this system;
Q7 I would imagine that most people would learn to use this system very quickly;
Q8 I found the system very awkward to use;
Q9 I felt very confident using the system;
Q10 I needed to learn a lot of things before I could get going with this system.

| *Metrics* | Value |
|---|---|
| **Sample size** | 53 |
| **Min value** | 50.0 |
| **1st Qu.** | 72.0 |
| **Median** | 82.0 |
| **Mean** | 79.2 |
| **Std. dev.** | 13.0 |
| **3rd Qu.** | 90.0 |
| **Max value** | 100.00 |

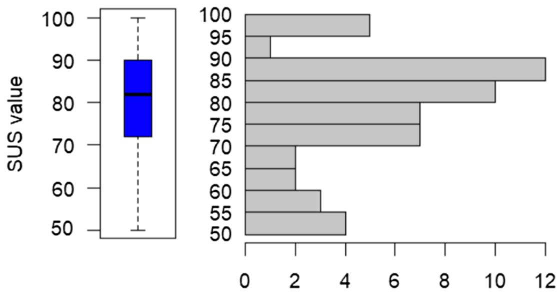


**Fig. 13** The SUS distribution (left), boxplot representation (center), and frequencies on the range 50...100 (right)

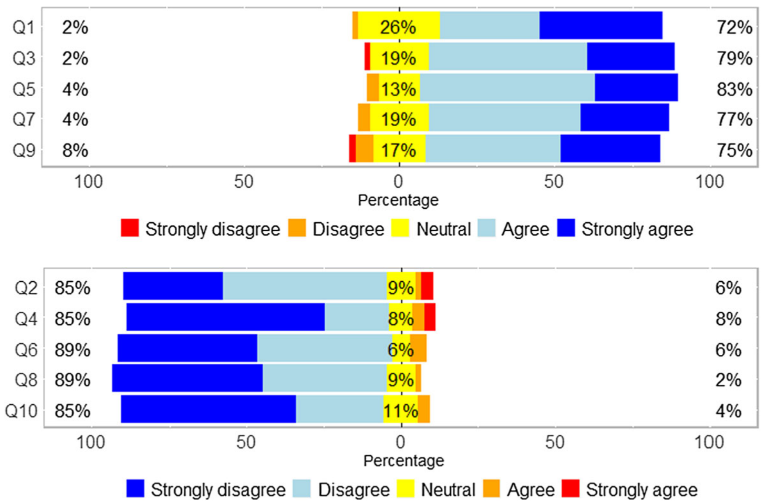


**Fig. 14** The distributions of the answers to the odd, positive tone, SUS questions (top) and to the even, negative tone, ones (bottom). In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

In order to minimize acquiescence response biases the questions have an alternate tone: positive for the odd ones and negative tone for the even ones. Despite the particularity and novelty of the visual and navigation adopted solutions, the perceived usability, being SUS mean = 79.2 and median = 82 (see Fig. 13), is between 73 = good, and 85 = excellent [4]. This first result is satisfying.

### 6.3 Analysis of specific aspects

Besides the general usability we gathered the users' opinions about four specific aspects of the platform, through a set of 21 questions, declined in positive and negative tones:

- user layout (UL1-UL5 questions);
- semantic structure (SS1-SS5 questions);
- navigation and research mechanism (NR1-NR4 questions);
- user contributions (UC1-UC7 questions).

**User layout** The first group of 5 questions was about the user interface:

UL1 I appreciate the presence of an overview of the catalog;
UL2 I find distracting to zoom and drag for exploring the catalog;
UL3 I think that the AppInventory graphic layout offers innovative elements;
UL4 I consider the adopted graphical layout less effective than a traditional one;
UL5 Overall, I appreciated the graphical layout of AppInventory.

Figure 15 provides the distribution of the answers to each positive tone question (top) and negative tone question (bottom). It emerges an almost complete appreciation of the adopted interface - question L1 (92% positive, 8% neutral, 0% negative responses) and of the presence of the catalog overview - question L5 (91% positive, 9% neutral, 0% negative

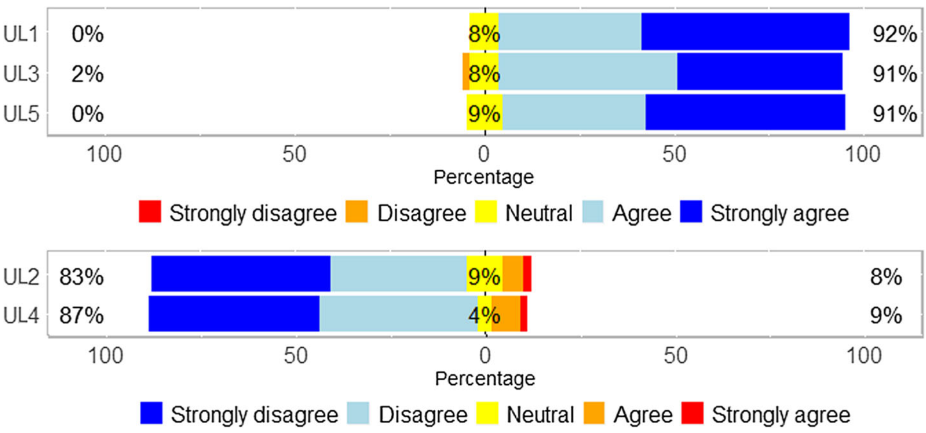


**Fig. 15** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the User Layout (UL) aspects. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

responses). With respect to the use of the zoom and drag for the navigation and the effectiveness of the adopted graphical layout compared to more traditional ones (questions UL2, UL4), we gathered slightly lower, but largely positive, values (on average 85% positive, 6.5% neutral, 8.5% negative).

**Semantic structure** With reference to the semantic structure of AppInventory, we asked the sample to answer the following questions:

SS1 I think appropriate the categories used in AppInventory;
SS2 I do not consider useful to assign an application to multiple categories;
SS3 I believe that the weighted attribution of an application in a category is an appropriate choice;
SS4 I found the information card of the app sufficiently complete and detailed;
SS5 The presence of a video presentation for each app is, for me, of secondary importance.

Figure 16 shows the distribution of the answers to the subset of positive tone question (top) and negative tone questions (bottom). Some aspects emerge: an almost complete (92% positive, 8% neutral, 0% of negative responses) appreciation of the completeness of the data provided in the apps' information cards (question SS4); a general agreement about the choice of categories and the introduction of multiple and weighted attribution of the app to them (questions SS1-SS3, on average: 82% positive, 12% neutral and 6% negative responses); a primary importance attributed to video presentations (SS5: 68% positive, 23% neutral, 9% negative responses).

**Navigation and search mechanisms** The next four questions investigated about the effectiveness of the navigation and search mechanisms:

NR1 I found understandable and functional the basic and advanced search mechanism;
NR2 I do not consider effective the forward / backward navigation mechanism between apps;

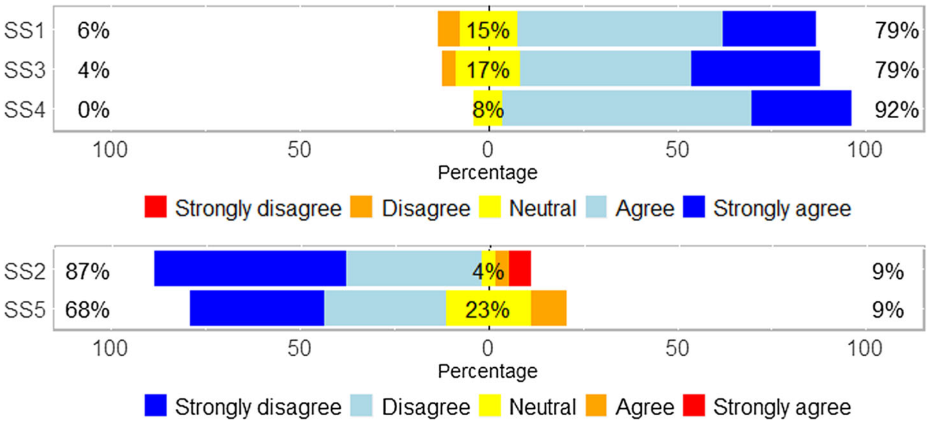


**Fig. 16** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the Semantic Structure (SS) aspects. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

NR3 I consider important to visualize the contextual list of apps through the general "compass" button, located at the top-left of the graphical layout;

NR4 I think it is of little use to select a new "navigation criterion" through the "compass" icon located at the top right of each application.

Figure 17 shows the distribution of the answers to each positive tone (top) and negative tone (bottom) questions. The appreciation appears generally high for the search section, for the presence of a contextual list of the apps and of the forward / backward navigation cursors (questions NR1-NR3; on average: 83.5% positive, 12.5% neutral and 4% negative responses). The effectiveness of the navigation mechanism for the single app gathered slightly lower appreciation (question NR4: 74% positive, 19% neutral and 8% negative) probably due to its particularity and the uncommon feature it offers.

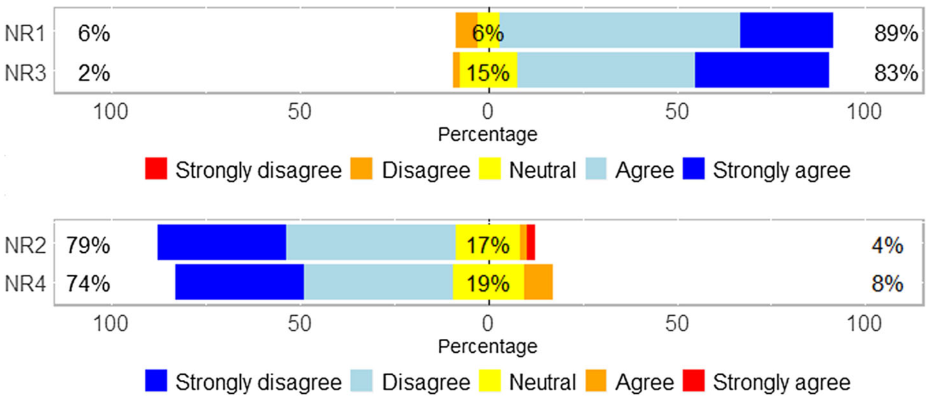


**Fig. 17** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the Navigation and Research (NR) features. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

**User contributions** The last seven questions investigated about the quality of the features, introduced for giving a score to each app, and the importance to leave comments, highlight inaccuracies and share use cases:

UC1 I consider useful for users to evaluate applications;
UC2 I find clear and understandable the five evaluation items (functionality, ease to use, applicability, originality, overall opinion);
UC3 I would have expected other evaluation parameters or changed existing ones;
UC4 I find useful for users to comment on applications;
UC5 I find important to have the opportunity to suggest changes and communicate inaccuracies in the information cards;
UC6 I consider significant to be able to share use cases of the application;
UC7 I would have preferred to login on the platform to post comments.

Figure 18 shows the distribution of the answers to positive tone (top) and negative tone (bottom) questions. The possibility of evaluating the apps has been generally considered useful and the evaluation items understandable (questions UC1, UC2: 86% positive, 13% neutral and 1% negative) while there is a considerable uncertainty about the choice of such evaluation parameters (question UC3: 55% positive, 40% neutral, 6% negative). Also, the possibility to comment the apps, suggest changes, suggest inaccuracies and share use cases (questions UC4-UC6) are valued positively from about 90% of the sample. Anonymous comments are approved from 53% of the sample (question UC7) with a significant part of users neutral about this choice.

Overall, the results of the user evaluation encourage us to continue experimenting with and improving the model in addition to explore new approaches.

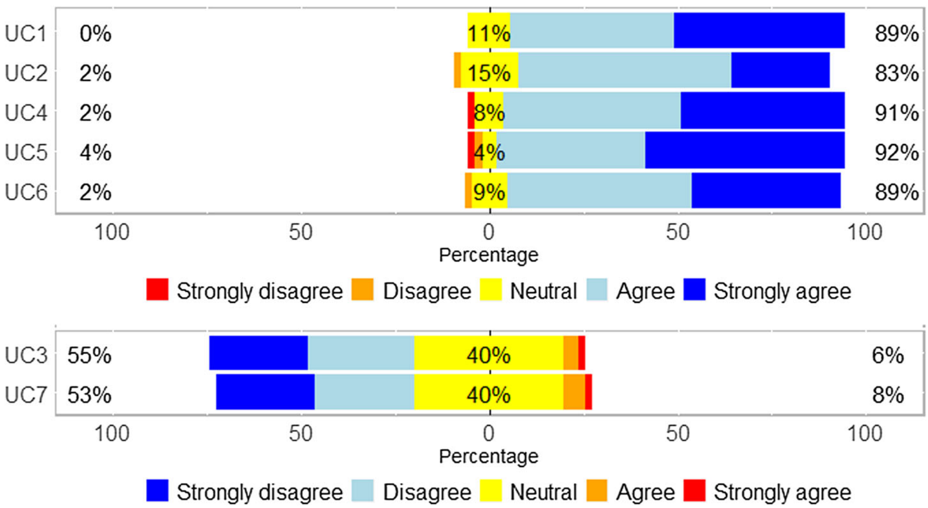


**Fig. 18** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the User Contribution (UC) features. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/blue colors

**Table 1** The SUS distributions of the three platforms

| Metrics | AppInventory | Edshelf | Essediquadro |
|---|---|---|---|
| Sample size | 31 | 31 | 31 |
| Min | 48.00 | 15.00 | 12.00 |
| 1st Qu. | 72.00 | 41.00 | 32.00 |
| Median | 80.00 | 58.00 | 42.00 |
| Mean | 79.29 | 57.52 | 43.39 |
| Std. dev. | 13.16 | 20.04 | 17.95 |
| 3rd Qu. | 89.00 | 73.50 | 58.50 |
| Max | 100.00 | 90.00 | 72.00 |

## 6.4 The comparative study

A second study involved 31 persons (28 F, 3 M) of age between 20 and 49 years, most of them were students (84%) attending a course of Web technologies in University of Udine. The aim of this study was to collect comparative user opinions about AppInventory and two other Web catalog of applications: Edshelf [18] and Essediquadro [20]. Before conducting the studio, the three platforms were presented to the participants, illustrating in details the specific features and proposing some tasks to familiarize with them: follow the guided tour, where available; explore some of the available categories; analyze the information cards of some applications and the related comment / evaluation sections; carry out a simple and advanced search and browse the results; apply different sorting criteria. The questionnaire was organized in sections in order to collect user opinions about the four aspects already considered in the preliminary study: User layout (UL), Semantic structure (SS), Navigation and search features (NR) and user contributions (UC). Next a SUS questionnaire was proposed for each platform and finally users were asked to assign an overall score to each platform.

Table 1 and Fig. 19 describe the distribution of the SUS for each platform. The results confirm very similar values of SUS for AppInventory in this and previous study (the differences between mean, median, 1st and 3rd quartile of the two distributions are lower than 2 units). In order to compare the results we applied a hypothesis test for the difference between $m_a$ and $m_e$ (the AppInventory and Edshelf SUS medians) and $m_e$ and $m_s$ (the Edshelf and Essediquadro SUS medians), fixing the null hypotheses $H0_{ae} : m_a = m_e$ and $H0_{es}$: $m_e = m_s$. Applying a Wilcoxon signed-ranks test we get $W_{ae} = 39$ and $W_{es} = 41.5$ which are

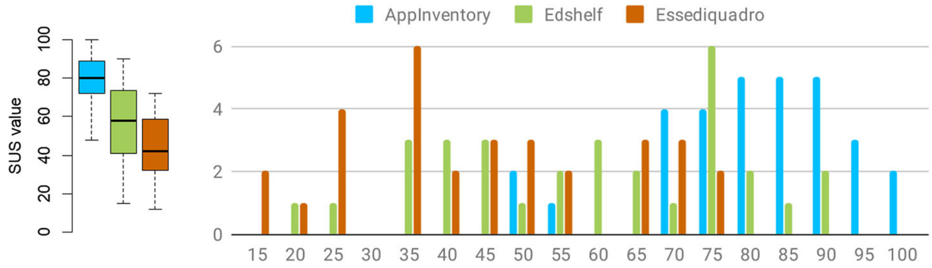


**Fig. 19** The comparison of the SUS distributions of the three platforms (left) and the absolute frequencies on 5-units intervals

below the respective critical values 120 and 92 for $p < .01$, leading us to reject both $H0_{ae}$ and $H0_{es}$ and assert the significance of the differences of medians.

Figure 20 shows the comparison of the answers to the single questions of the SUS questionnaire.

In order to investigate the four aspects (UL, SS, NR, UC) considered in the first study, we reformulated the questions in a more general form to make them applicable to the all considered platforms. About the *User Layout* (UL) we asked users how much do they agree with each of the following statements:

UL1-c I believe that the user interface adopted for the main page of the catalog is innovative and intuitive;
UL2-c I find that the main page provides an effective overview of the catalog;
UL3-c I find that the graphic elements (icons, titles, sections, ...) are understandable;
UL4-c I find it easy to identify the number of applications in the category;
UL5-c I believe that the platform offers effective tools to learn using it (eg. Quick start guides, guided tours, contextual help, FAQ and support pages, ...).

Figure 21 summarizes the results: the positive responses vary from 87% and 97% for AppInventory, from 19% to 48% for Edshelf and from 3% and 26% for Essediquadro.

About the *Semantic Structure* the six sentences we asked users to evaluate for the three platforms were:

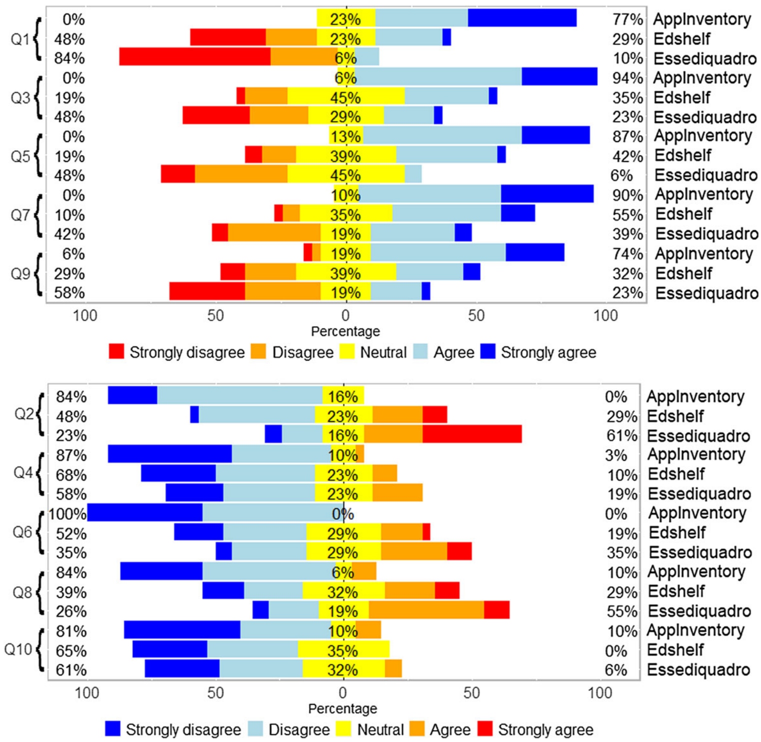


**Fig. 20** The distributions of the answers to the odd, positive tone, SUS questions (top) and to the even, negative tone, ones (bottom) for the 3 platforms. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

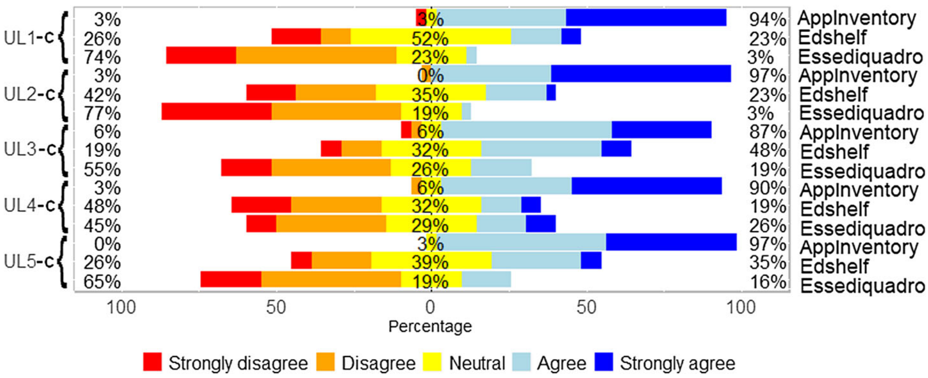


**Fig. 21** The distributions of the answers to (all positive tone) questions relative to the User Layout (UL) aspects for the three platforms

SS1-c I think the proposed classification helps me to orient myself between the apps;
SS2-c I think the number of categories provided is excessive or insufficient;
SS3-c I consider the information cards of the single applications complete and well detailed also for the presence of multimedia contents;
SS4-c I think that the information card does not contain important information regarding the application;
SS5-c Looking at the card, I can get a general and complete idea about the application;
SS6-c I believe that the card of an app provides me with comprehensive information on the classification of the application (eg. if the app is present in more than one category and with what degree, the associated tags, additional classification taxonomies, etc.).

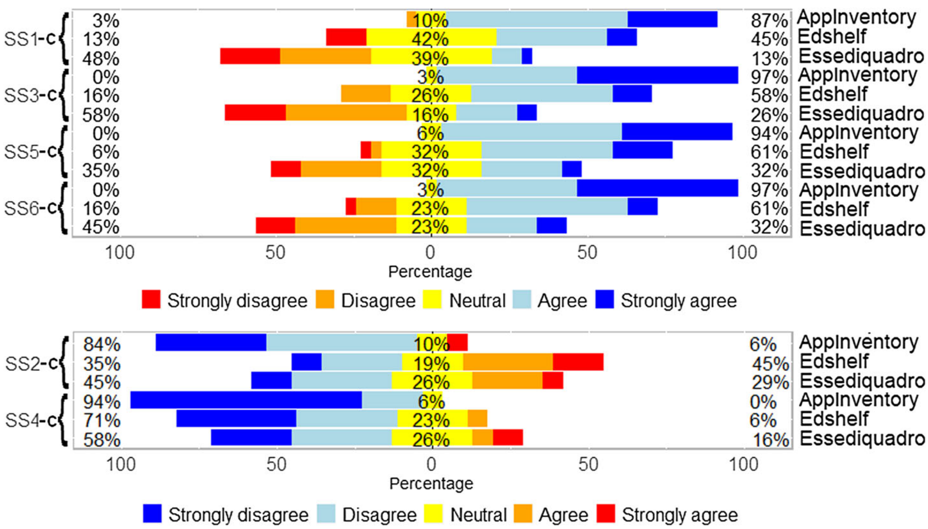


**Fig. 22** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the Semantic Structure (SS) aspects for the three platforms. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

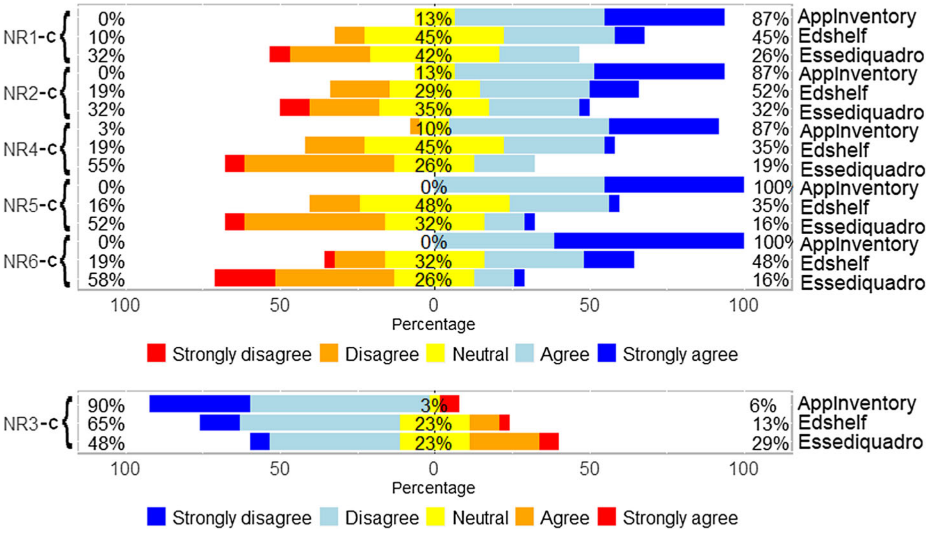


**Fig. 23** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the Navigation and Research mechanisms (NR) aspects for the three platforms. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

The results are presented in Fig. 22, separately for the positive and negative tone questions. For this set of questions AppInventory collected positive answers in a percentage between 84% and 97%, Edshelf between 35% and 71%, Essediquadro between 13% and 58%.

The *Navigation and Research mechanisms* were investigated through the following six questions:

NR1-c I think the search functions are easily identifiable and usable;
NR2-c I found the basic and advanced search understandable and functional;
NR3-c I find incomplete the search filters;

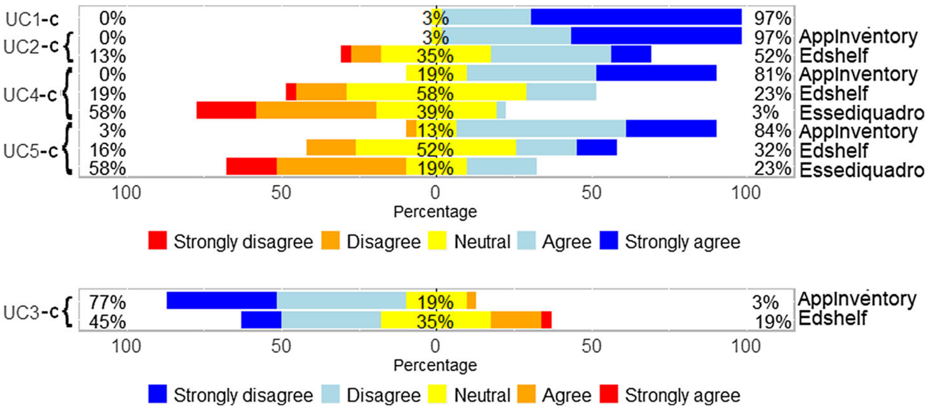


**Fig. 24** The distributions of the answers to positive tone (top) and negative tone (bottom) questions relative to the User Contributions (UC) features for the three platforms. In the second plot, the color scale has been reversed to map, as in the first plot, positive values to azure/sky colors

**Table 2** The comparison between the SUS medians and the normalized overall ratings of the three platforms

| Metrics | AppInventory | Edshelf | Essediquadro |
|---|---|---|---|
| SUS Median | 80.00 | 58.00 | 42.00 |
| Overall rating | 85.48 | 51.61 | 24.19 |

NR4-c I consider appropriate and complete the sorting criteria of the app;
NR5-c The platform helps me find similar apps by letting me choose the similarity criteria;
NR6-c The platform supports me in finding applications for a certain goal.

The results, illustrated in Fig. 23, show a percentage of positive answers for AppInventory between 87% and 100%, for EdShelf between 35% and 65% while for Essediquadro between 16% and 32%.

The last investigated aspect was about *User Contributions* features:

UC1-c I believe that user contributions are important in a catalog of applications;
UC2-c I believe that the platform provides good support for users to add comments on applications;
UC3-c I would have expected more evaluation parameters or change existing ones;
UC4-c I believe that the platform provides users with good support for suggesting integrations and reporting inaccuracies in the descriptions;
UC5-c I believe that the platform provides users with good support for sharing educational use-cases of the applications.

The first question was general and not referred to any platform, the questions UC2-c and UC3-c apply only to AppInventory and Edshelf since Essediquadro does not accept user comments and ratings. The results are presented in Fig. 24.

In the last question (G1-c) we asked users to formulate an overall rating, in a scale from *1=very bad* to *5=very good* of the three platforms. The results are very positive for AppInventory (94% of sample attributed a score greater or equals to 4), Edshelf is positively evaluated by the 32% of the sample with a large percentage of neutral scores while Essediquadro gets only 3% of positive scores.

A comparison between the SUS medians (Table 2) of the three platforms and the weighted average of the overall ratings normalized on a scale from *1 to 100* shows how the differences in the perceived usability, already revealed by the SUS, are more marked when we consider the overall features of the three platforms.

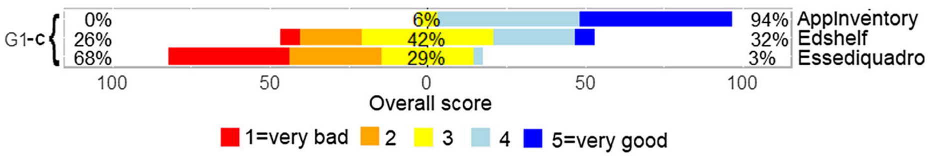


**Fig. 25** The distributions of the user overall ratings for the three platforms

## 7 Conclusion and future work

In this paper we presented AppInventory, a Web platform designed to allow teachers to browse a repository of applications, organized in a purpose-based taxonomy, using a visual approach. It offers a novel modality for representing and exploring the catalog. AppInventory represents the first, challenging step, in the construction of the LDInventory framework. A preliminary usability evaluation was performed applying qualitative and comparative tests. It was largely discussed in Section 6: the results are encouraging and highlighted the positive impact of our visual model, with respect to the general platform and also specifically to the four considered features. The last of them, that related to the user contributions, allowed us to collect interesting data, useful for next development of the platform. The final comparative study shows that AppInventory totals at least 30% more positive reviews by users than those of Edshelf and Essediquadro, on all analyzed aspects. Future work will involve the constant updating of the information published in the catalog; the development of new views and new features; the optimization of the Web interface for mobile devices; the experimentation of a recommender system based on zz-structures. Furthermore, we are working on the platform, with the aim that it complies with the WCAG 2 (Web Content Accessibility Guidelines) for a universal accessibility.

**Acknowledgements** We would like to thank all students that enthusiastically participated to this project and have contributed in different ways to the birth of this catalog. We have reported all their names on a dedicated page http://appinventory.uniud.it/en/about-us/ of the AppInventory site, hoping not to have forgotten anyone. We would like also thank Professor Alessandra Pallavicini for your support in proofreading.

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**Marco Corbatto** is a Computer Science teacher at the “Galilei” Technical High School in Gorizia, Italy. PhD student in Computer Science and Mathematical and Physical Sciences at the University of Udine is instructor for the Italian National Digital School Program - FVG. His research interests include Information Visualization, HCI design and evaluation methods, Semantic Web, Multimedia and Educational Applications.

**Antonina Dattolo**, PhD in Applied Mathematics and Computer Science, is founder and head of the SASWEB (Semantic, Adaptive and Social Web) research lab at Department of Mathematics, Computer Sciences and Physics of University Of Udine; she is also head of the Research Unit of the National Institute of High Mathematics (INDAM) at University of Udine. She taught various university, european master and PhD courses in the field of Computer Science (among others, Multimedia and hypermedia systems, Web technologies, Semantic Web) for both scientific and humanistic faculties.

Her research interests include visual and semantic knowledge representation; digital inclusion, accessibility and usability, information visualization, semantic Web, user adaption.