AppInventory: a Visual Catalogue of Web 2.0 and Mobile Applications for Supporting Teaching and Learning Activities

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***Abstract*—The availability of hundreds of Web 2.0 and mobile applications represent a great opportunity in helping teachers adopt student centred methodologies. These applications support users in creating and sharing digital artefacts, in aggregating, remixing and collecting heterogeneous materials and in communicating within working groups. When incorporated into daily teaching and learning activities (TLA), such applications 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 describe AppInventory, a novel platform which contains a digital catalogue of applications: they are organized by applying an original taxonomy; the users can browse among them benefiting from a visual approach and semantic connections modelled using zz-structures.**

***Index Terms*—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.**

I. Introduction

Our current research is situated in the context of a wider project, called LDInventory [1], which intends to model and realize a novel lightweight Web-based tool for Learning Design (LD). An LD system is a computer based tool to support teachers in the delicate task of designing, organizing and sharing teaching and learning activities (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 pertinent part of this project is represented by AppInventory, which this paper will address. AppInventory is a digital catalogue of Web 2.0 and mobile applications, currently in development stage, conceived to support teachers during the design and the implementation of TLAs. AppInventory enables teachers to visually browse the catalogue in order to find appropriate tools for specific learning, collaborative or organizational activities. In actualising AppInventory we have:

- analysed 283 of *Web 2.0 and mobile apps*;
- proposed an *original taxonomy* for them;
- modelled a digital catalogue, where the knowledge is organized by means of innovative *semantic structures*, and the user interface is based on *graphic organizers*.

The rest of this paper is organised as such: Section II describes the context and motivation of this work, and presents the results of a preliminary study; Section III discusses related work, while Section IV describes our proposal, the system architecture, the cataloging scheme and a purpose-based taxonomy. Section V presents the guidelines for the development and a first prototype. Conclusions and future work end our work.

II. Context and Motivation

A rapid transformation of methods, roles and practices are currently affecting all school grades, from primary to higher education. There are many factors contributing to this momentous change: a crisis in traditional 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. There is an increasing number of teachers experimenting with 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 [2].

The complexity of the design task is considerable. The adoption of specific methodologies can help teachers reduce the intricacy with the use of templates and formats in order to steer phases and activities.

How can technology support educators during the design and the implementation of TLAs?

A complete LD systems should support teachers in all eventual design issues. There is a plethora of applications that favour the design and implementation of lesson plans, for example to support creative, organizational and educative tasks, to engage students in many different learning activities and games, to assess knowledge and skills, to collect and share materials as well as collaborate in virtual environments. For this reason, we believe that the integration of a catalogue / recommender system within a LD system can effectively support and inspire the teachers during the TLAs' design and implementation stage.

In order to investigate current practices, opinions and needs with regard to learning design aspects that fall within a teach-

ers remit, we carried out a preliminary study on a group of teachers from Friuli Venezia Giulia, a region of North-East of Italy, attending professional training courses on methodologies and technology for didactics. The research was carried out in the period of April-May 2017 and involved 178 teachers, 50% from high school (K9-K13 grades), 28.7% from middle-school (K6-K8) and 21.3% from primary school (K1-K5). The proposed survey consisted of 55 questions covering many aspects; here we report only a subset of them related to the role of activities, methodologies and technology in the TLA. We asked how much the introduction of the following Q1-Q6 items could affect the motivation of students and the quality of learning.

- Q1 a careful planning of activities;
- Q2 the availability of mobile technologies in the classroom;
- Q3 the privileging forms of active learning;
- Q4 the use of social platforms to communicate with students;
- Q5 the use of diversified resources and tools;
- Q6 a better knowledge of existing applications for creating digital artefacts.

And, furthermore:

- Q7 How much could a better knowledge of existing applications for collaboration and communication help teachers in design for learnings?

Table I summarizes the results. What emerges is 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.

TABLE I
PRELIMINARY INVESTIGATION

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Not at all	0%	3%	0%	4%	1%	2%	1%
A little	8%	22%	2%	35%	14%	12%	12%
Much	67%	53%	47%	51%	66%	61%	66%
Very much	25%	22%	51%	10%	19%	26%	21%

III. Related work

Several repositories exist which index applications, proposing classification [3] and evaluation [4] [5] [6] 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, or Chrome Web Store or Appszoom, or repositories which share learning objects and didactic resources and not tools, such OER Commons. A positive example is EdShelf [7], 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. Essediquadro [8] is a service of documentation and orientation on the teaching software and on other resources for the learning. 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 [9]. 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) [10] invites one to find the 'perfect tool'; it 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 [3]; 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 Blooms Taxonomy [11]. From our viewpoint, by the term purpose we mean the concrete objective of the teacher or of the student, such as realize an infographic, or create a timeline, or predispose a quiz. On this basis, we propose our original taxonomy in this paper (see Subsection IV-D).

Related work highlights some open challenges and weaknesses:

- 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 as a tool 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.

Our contribution focuses on these objectives and proposes a model and a prototype of digital catalogue, which offers graphic and holistic views of the applications, organizes them in a purpose-based taxonomy, and facilitates a semantic navigation among items for the user.

IV. Our proposal: AppInventory

AppInventory is a multimedia, visual catalogue of 283 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;
- cataloguing the apps by means of an original taxonomy and semantic connections;
- offering intuitive and contextual navigation mechanisms;

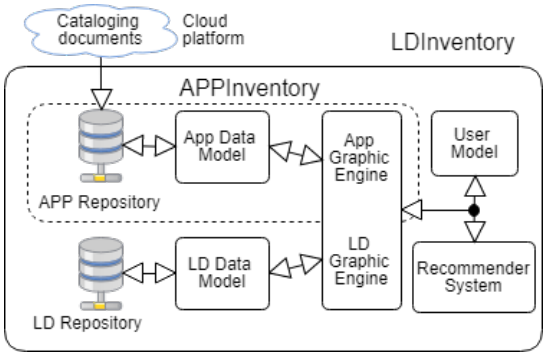

Fig. 1. The architecture of the LDInventory framework.

- generating visual representations and holistic views of the catalogue;
- proposing users some exploration paths through the catalogue 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;
- offering users a private cloud space where to collect their own set of preferred applications and use-cases.

The AppInventory project is consistent with the objectives of the European Digital Competences Framework for Citizens 2.0 (DigiComp) [2]. In particular it can contribute to the development of ten of the twenty-one competence dimensions stated in the DigiComps conceptual reference model.

A. The architecture

Figure 1 synthesises the overall architecture of LDInventory. The following modules of the LDInventory framework will not be the subject of focus:

- the *LD repository* which maintains all the data about the TLA designs proposed by teachers and enhanced by student contributions during the implementation;
- the *LD data model* and the *LD graphic engine* modules.

We describe AppInventory, which proposes the following main modules:

- the *App repository*, which contains the catalogue of the applications and the users' data contributions. The data are hosted in a MySql database management system; in order to efficiently perform the import of the data of the catalogue, we have implemented a Java module, based on a XML SAX parser, which extracts and validate all the significant data from the set of documents in the cloud, and generates the appropriate SQL statements to insert them into the database;
- the *App data model*, which is based on zz-structures [12] [13], semantic data structure used for representing and managing multi-level information and dimensions;
- the *App graphic engine*, which generates the graphic layout and offers: holistic visual interactive representations of the domain data; an exploration mechanism of the zz-structures dimensions; the updating of the data model according to user actions;
- the *User Model* and the *Recommender System*, which are shared with the rest of the system; they respectively: collect, organize and store the profiles, the preferences, the habits and expectations of the users; they provide personalized suggestions about tools, contents and actions. These modules are not presented in this paper.

B. Building the App repository

The initial effort has been dedicated to build the App repository, a database containing the multimedia catalogue of the applications. The cataloging work has been carried out in two stages: in the first stage, we considered a first set of 113 applications and proposed a classification model; in the second stage we extended the analysis to other 170 new applications.

In the first stage of the work, we selected a list of widespread and heterogeneous Web 2.0 and mobile applications from educational sites and dedicated blogs, such as [14] [15] [7] [16] and others. Then, 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.

Each application has been analysed and documented through a cooperative work involving 57 higher education students. All the working documents and the coordination sheets have been hosted on a cloud platform, making the collaborative editing of documents possible, their subsequent refinements, peer reviews of materials and the coordination of the project. A final general check was performed to assure an homogeneous categorization criteria and subsequently a group of 7 students have translated the documents in English language. The videos have also been checked and another group of 8 students looked after the post-production, cutting the inappropriate parts, adding credits, titles, descriptions and tags in order to publish them on the SASWEB Labs AppInventory project page [17]. Finally, the group of translators transcribed each video in order to provide English subtitles.

The second stage of cataloging activities is still going on and currently involves 73 students, which are cooperating to carry out the tasks described above on a new set of applications. The coordination of all these large groups has been possible thanks to the extensive use of the 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. Furthermore, in order to keep the catalogue updated, it is necessary to periodically check the evolution of the applications, their possible disposal and the integration of new ones.

C. Our cataloging scheme

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

The cataloging scheme consists of the following fields:

- **basic metadata**: the application name, its url and logo, the date of analysis;
- **abstract**: a short textual description of the relevant features;
- **a reference to a video-presentation** created by the reviewer in order to present the application in a live context;
- **category of the application** in the taxonomy: a multiple weighted attribution to categories is adopted in order to represent primary and secondary purposes;
- **typology**: multiple attribution to the identified typologies;
- **registration requirements** to create new contents or to access shared materials;
- **registration opportunities** using accounts of third-party platform, such as, for example, Google or Office365;
- **availability of a repository of users generated contents**;
- **plan & pricing**. We included in AppInventory only applications offering at least a time unlimited, free of charge plan;
- description of **the limits of the free plan**;
- **availability of an Italian version**;
- **presence of advertising** in the pages of the application;
- **links to video-tutorials** in English and Italian languages;
- **references to additional documentations**;
- **references to significant products** created using the app;
- **evaluation of the difficulty level** in using the application, on a scale from 1 to 10;
- **a mapping into the Blooms taxonomy [18]** in order to identify which human cognitive levels can be supported by the application. We adopt the cognitive process terminology proposed in the revised version [11], shown in Table II;
- **the list of specific disciplines**, if applicable;
- **a list of tags** to describe specific purposes;
- **review**: an extended description that illustrates the interfaces of the most significant pages (the dashboard, the authoring page, the sharing options, ...) in order to give users an overview of the application without having to actually try it.

In addition to the above fields, a series of user contributed data will be collected to enrich the model with dynamic data:
- **data on visits**: to keep track of the most visited apps;
- **rating data**: we are planning to collect ratings on a set of dimensions in order capture user opinions and evaluations;
- **feedbacks**: the platform will accept comments and feedbacks about the published information;
- **use cases**: users could contribute with original use cases about the presented tools. Collecting and sharing original use cases of single applications could inspire the teachers' community with new ideas. All contributions will be moderated in order to preserve the quality and the consistency of the repository.

D. Our purpose-based taxonomy

We have observed recurrent purposes, which have permitted us to map the applications into 3 macro-categories, as illustrated in Figure 2.
- *Authoring tools*: applications to support users in building up digital artefacts of 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 artefacts by a specific url, an embed code or by directly publishing them on social platforms;
- *Aggregators*: 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;
- *Collaboration & Communication tools*: in this group, we include 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.

Authoring tools	Aggregators
Animations	Augmented reality
Diagrams, graphics and images	Content collectors
Ebooks / Flipbooks	Link collectors
Flashcards	Storytelling
Geographical Maps	**Collaboration & Communication tools**
Infographics	Assessment rubrics
Mind maps	Online collaboration
Podcast	Designing & Planning
Presentations	Gamification
Texts / Spreadsheets	Groups management
Timelines	Quizzes / Forms / Surveys
Video making & enrichment	Shared whiteboards
Wordclouds	**Others**

Fig. 2. The purpose-based taxonomy.

The macro-categories are structured in relative subcategories: 13 for the 'Authoring tools', 4 for 'Aggregators' and 7 for 'Collaboration & Communication tools', plus an additional generic 'Others' to capture unforeseen features. Each application often integrates various distinct features: for this reason, we have adopted a weighted attribution (between 0 and 1) of an application to single categories in order to highlight the primary purpose compared to secondary ones.

The distribution of the first 113 apps into the three macro-categories of the taxonomy is reported in Figure 3. Each application is generally mapped on multiple levels of the taxonomy. Table II shows the Bloom levels attributions of the set of considered applications. We observe a relatively uniform distribution of the applications over the six levels of Bloom taxonomy. This in part reflects the versatility of the analysed tools: for example, an application to create online presentation can be used by teachers to support their students in the memorisation and understanding of concepts but it also represents a tool to develop the analysis and the creativity skills when used by students to summarise a topic and create an effective presentation.

V. The Prototype

The prototype of AppInventory is implemented as a Web application based on HTML5, SVG and CSS3 W3C standard languages and the D3js [19] framework. D3 provides

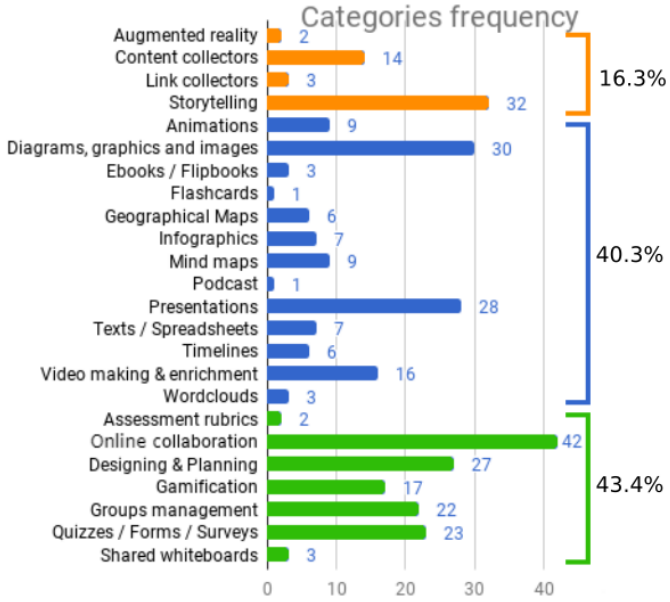

Fig. 3. From the top: Aggregators - Authoring tools - C&C tools.

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 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 [20]. AppInventory adopts AJAX techniques to improve 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. We have fixed some implementation guidelines for the graphic engine:

- it must present an initial comprehensive view of the entire repository without exposing details of the apps;
- it must offer a continue zoom mechanism in order to minimize users disorientation and letting them choose the appropriate level of visualization;
- a semantic zoom mechanism: each item must become visible at an appropriate zoom level in order to enhance the understanding and minimize the cognitive load;
- users must be able to freely navigate in multiple directions, using the next-previous move mechanism of zz-structures to move focus along specific dimensions.

TABLE II
DISTRIBUTION OF APPLICATIONS IN THE BLOOM TAXONOMY

Bloom's level	# of apps	Bloom's level	# of apps
Creating	81	Applying	47
Evaluating	39	Understanding	78
Analyzing	71	Remembering	85

The graphic layout of our prototype proposes a holistic overview of all applications; at the first level of zoom, see Figure 4, the three macro-areas are represented by different circles, which recursively contain the 24 sub-categories. The

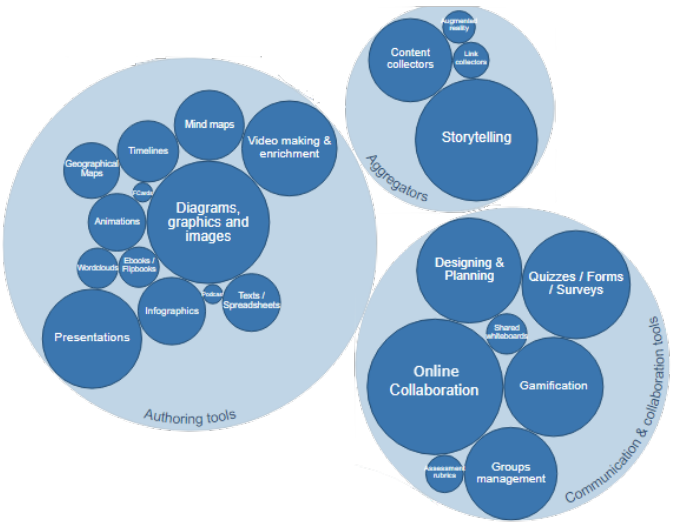

Fig. 4. The overall view of the catalogue.

size of each circle is proportional to its populousness. Zooming in, taking the focus on the subcategory 'Mind maps', a new view (Figure 5-left) reveals the logos of the applications, which populate this sub-category; we note that the size of each circle is proportional to the weighted attribution of an application in a single category. The next level of zoom enables users to visualize the details of a specific application, to access the preview of the video presentation, to connect the application in a weighted-node graph to its categories enabling navigation towards similar applications in the same category. In Figure 5-right, we zoomed on the Plickers app. We see the preview of the video presentation, the four subcategories of this application, which are Gamification - Quizzes, Survey, Forms - Groups Management - Augmented Reality, while the next/previous arrows are for browsing towards similar applications. Furthermore, a detailed form relative to this

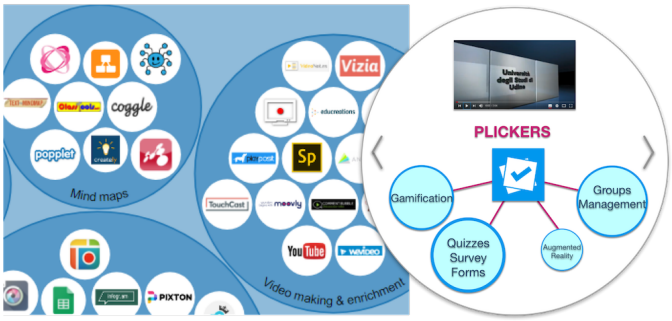

Fig. 5. Zooming in the view, the single apps'logos appear (left); additional zooming in goes on a single application (right).

Fig. 6. A partial view of the detailed form of the selected app.

application appears, as shown in Figure 6. These views are managed by the graphic engine module (see Figure 1), which interacts with the App Repository through an intermediate data representation level, we called App data model. The data model uses a conceptual semantic model for structuring the data, the so-called zz-structure [12] [21] [22], [23] [13]; it provides data representation and exploring mechanisms. In zz-structure, data are linked in structures called dimensions, which represent semantic relations between the 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. Examples of dimensions in AppInventory are:

- *d.category* connects each application to the others having 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); and so on.

Focusing on a view, it is possible to see the links that semantically connect the items to the others in the system. For example, Figure 6 shows a set of these dimensions for Plickers: *d.categories* shows the four subcategories of this applications; *d.video-presentation* shows the preview of the video and *d.category* is proposed by means of the previous/next arrows.

VI. Conclusion and Future Work

In this paper we have presented AppInventory, a Web application prototype designed to allow teachers to browse a repository of applications, organized in a purpose-based taxonomy, using a visual approach. AppInventory represents the first, challenging step in the construction of the LDInventory framework. Future work will involve the implementation of the definitive graphic framework, with the introduction of a user model and a recommender system, in order to support the teachers in an effective use of existing applications during the design and the implementation of TLAs.

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