Lecture Notes in Social Networks

Mehmet Kaya
Reda Alhajj *Editors*

Influence and Behavior Analysis in Social Networks and Social Media

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Social Network to Improve the Educational Experience with the Deployment of Different Learning Models

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1 Introduction

Until November 2017, Facebook recorded a 731.43% increase in the number of active users[1]; while YouTube, meanwhile, increased by 3000% its number of video hours uploaded[2] and Twitter 2000% its number of tweets published,[3] compared to 2009. This is evidence of the rapid growth of social networks (SNs) in recent years [1]. The pervasiveness of SNs empowers them to be present in every aspect of our lives: from comfort, security, entertainment, and e-commerce to political campaigns [2–4]. Education is not a process alien to this phenomenon, since the way in which students communicate, collaborate, and learn is being significantly modified [5]. In this sense, although SNs were initially designed solely to support interpersonal relationships, they can be used as valid tools for student-teacher purposes, particularly to innovate student/teacher relationships.

[1] https://www.socialbakers.com/statistics/facebook/.

[2] https://fortunelords.com/youtube-statistics/.

[3] https://www.omnicoreagency.com/twitter-statistics/.

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On the one hand, they help to enhance the learning environment, achieving a greater commitment between the class and its participants, promoting a sense of belonging to a community of studies, which is of vital importance for the development of a correct educational process [6, 7]. They also facilitate outreach to experts in various fields, improving knowledge transfer [8]. On the other hand, from a technological point of view, today's mobile devices incorporate powerful electronic and telecommunications systems, which promote the use of different learning models through SNs [9]. This can be seen in the academic reasons why they are used. For example, when a wiki is consulted, a book or a scientific database is accessed, and self-learning has happened [10]; instead, when video material from any platform is viewed or an instant messaging service is used to specifically contact an individual, it initiates tutorial or peer learning, depending on whether the contact is with a teacher/expert or a classmate [11, 12]; and, finally, when a forum is used or virtual communities are created—whose members have common affinities—to resolve any concerns, collaborative learning is the key [13, 14]. In this way, the geo-temporal barriers of formal and teacher-centralized learning are broken down to encourage informal and student-centralized learning, giving the possibility of accessing and sharing knowledge when necessary [15].

Despite all the advantages offered by SNs in education, different studies have found serious difficulties that cannot be ignored [6, 16–18]. Firstly, their levels of security and privacy are not adequate, facilitating the possibility of tracking any user, whether students or teachers, and accessing their personal lives [16, 17]. They can also be used for nonacademic purposes, while a learning/teaching process is being carried out, which leads to a waste of time and, therefore, a decrease in the quality of study. Continuing with the same problem, since there are no records of the activities carried out by students, it is not possible to monitor their progress, preventing teachers from improving their teaching techniques [18]. In addition, students have a different view of the use of SNs, as they focus solely on using them for social purposes, which may result in a lack of motivation when it comes to using them as a means of learning [17]. Finally, there may be a process of information isolation or over-information, in which it is not possible to contact experts who manage each study topic in an optimal way, losing their valuable knowledge [19].

To solve the problems described, in this paper we broadened the concept of OPPIA (OPPortunistic Intelligent Ambient of learning), a social platform focused on developing different models of informal learning, according to the needs and preferences of each individual. It brings students closer to teachers or experts in different subjects, supporting better educational opportunities [20].

OPPIA is a platform that provides services with the necessary resources to strengthen and facilitate knowledge transfer among its users. Furthermore, the deployment of sporadic learning networks (SLNs)—a type of SNs that is created for a limited period of time—enables the formation of collaborative groups, which connects students with users who can resolve their concerns, regardless of whether or not prior contact has been established between them [20, 21]. In this way, the problem of information isolation is broken. It also incorporates different databases that store statistical information on the progress of its members.

This paper is organized as follows. Section 2 shows the theoretical development of SNs in education and how current technologies are being used by teachers and students. Section 3 presents the development of sporadic learning networks, which are one of OPPIA's most significant contributions. Section 4 describes OPPIA, its layer model, architecture, and main services. In Sect. 5, a first implementation of the platform is developed, and its acceptance by students is evaluated. Finally, Sect. 6 presents the main conclusions and future work.

2 Social Networks in Education

Social networks (SNs) are defined as *a group of Internet-based applications that builds on the ideological and technological foundations of Web 2.0 and that allows the creation and exchange of user-generated content* [22]. Thus, it is possible that they may be seen as a set of technological systems related to the collaboration and formation of communities for interpersonal purposes, being their most significant applications social platforms, wikis, blogs, and multimedia platforms [5].

Because of their ability to form communities, where students, teachers, and experts are grouped in the same virtual space, they can be considered educational tools [23]. However, for them to play this role, they must fulfill three conditions: boundary condition, heterogeneity condition, and responsibility condition [24, 25]. That is, they must have limits that allow common objectives to be achieved, must be conformed with heterogeneous groups of members that ensure a correct interaction, and must motivate a continuous socialization among their members [24].

The boundary condition defines the goals and rules about the behavior allowed for members of a community. On the other hand, the heterogeneity condition expresses that a community should be made up of members with different seniority (new-veterans), who have the capacity to resolve doubts (teachers-experts) and the predisposition to participate (students) in proposed activities. Finally, the responsibility condition establishes the characteristics that allow to describe each member according to the role that plays and the activities in which he/she participated.

When the conditions are analyzed, it is observed that they are present in most SNs because the majority of these have a usage policy that must be accepted by each user before registering as a participant (boundary condition). In addition, they allow the formation of self-organized communities, whose participants have the common goal of exchanging information (a condition of heterogeneity), and, through the implementation of a user profile, guarantee the temporary stay of each participant, giving access to their personal information (condition of responsibility) [24]. Thus, any SN can be seen as a valid learning tool and, according to its use, can be classified into three principal categories [26–28]:

- Horizontal social networks: They are aimed at a general public, without focusing on a specific topic. Among the most popular are Facebook, Twitter, and Google+.

- Professional social networks: Give sustenance to content related to work ambit. They allow stablish professional contacts, as well as the search for job opportunities. Among the most prominent is LinkedIn, Viadeo, and Xing.
- Social content networks: They form links between their participants through the generation and dissemination of content in different formats. Among the main ones are YouTube, Pinterest, Instagram, and SlideShare.

Of the before examples, Facebook, Twitter, and YouTube are the most widely used globally.[4] Students employ SNs for different purposes, including discussion of classes, out-of-school learning, and planning of educational collaborative activities [29]. However, the main reason students turn to its support is the exchange of information and knowledge [30]. In the remainder of this section, a review of these SNs is described.

2.1 Facebook

Facebook is currently the most used SN to establish interpersonal relationships at a global level. According to the statistics collected by the website *"We Are Social"*, until January 2017, it reached a total of 1871 million active users. Its main characteristic is to allow social interaction between its users. For this reason, it includes a set of technologies such as social groups, personal pages, instant messaging services, socialization of multimedia files, VoIP, and video calls. However, much of this interaction is achieved through the publication of content by each user [31].

Due to the characteristics presented and the welcome it has, Facebook can be used as a valid educational tool. As a result, several research studies have been carried out which focus on highlighting the benefits it offers. The authors of [32] assert that by providing different forms of communication, student/teacher relations have improved. To corroborate their hypothesis, they developed a research to analyze students' opinions regarding the use of Facebook as a study tool. Thus, 180 questionnaires were distributed to postgraduate and undergraduate students, from which they received 140 completed. These questionnaires were designed based on four variables: student perception, academic contribution, relationship with the student's faculty, and privacy and distraction concerns. The results show the students' willingness to use Facebook and SNs for educational purposes. Likewise, in [33], authors propose a study to explore the use of a Facebook page and group managed by teachers, with the aim of complementing and improving educational experiences. Through surveys, first- and second-year medical students at the university stated that they have found in this SN an effective form of communication with easy access to learning material.

[4] https://wearesocial.com/special-reports/digital-in-2017-global-overview.

On the other hand, in [31], the authors investigate the use of a closed group on Facebook to stimulate student participation in scientific events and to generate an open communication channel that allows optimal access to information and exchange educational resources. For the analysis, the group's records and questionnaire responses are used, concluding that Facebook helped improve access to information and motivate student participation in scientific events. For these reasons, it has proven to be an interactive and collaborative tool that can be used in educational practices. While, in [34], authors collect teachers' opinions on the use of Facebook in education, hence a group of volunteer teachers, primary and secondary, took a face-to-face course, supported by online activities. At the end of the course, teachers responded to a survey in which it was determined that through Facebook, students cannot only improve their teamwork but also their learning skills. Finally, in [35], they describe a series of recommendations for Facebook to be conceived as a learning tool for students. Among them, teachers should distinguish between personal and professional relationships, using a page rather than a private profile. In this way, they will be able to prevent students from accessing their personal information. In addition, they emphasize the importance that educational institutions play in this process, since it is necessary to deploy training programs that encourage the use of SNs in the learning/teaching processes. They stress the importance of using Facebook groups for educational purposes.

2.2 Twitter

Twitter is a SN that allows communication and interaction between its users through tweets. A tweet is a burst of information, with a maximum length of 280 characters, used to tell a story or to attract the attention of a user about specific topic [36]. Tweets can be connected to additional information such as links to external pages and multimedia content. Twitter manages a communication scheme in which each user "follows" to some authors for the content posted; this means that, after "following" an author, all the content that he/she publishes becomes visible to the "follower" [37]. Furthermore, according to the website *"We Are Social"*, until January 2017, it reached about 317 million active users.

In the educational field, Twitter is a microblogging tool that enhances social interaction, as students are motivated to engage with both their peers and teachers [38, 39]. Therefore, the literature presents several studies that evaluate its usefulness as a learning/teaching tool. In [40], authors seek to understand the practices of academics using Twitter. They then qualitatively analyzed 45 tweets to determine the dominant themes of their publications. Among these were the socialization of information and resources of their professional area, the socialization of information of their courses, the request for help, the recommendation of suggestions, the participation in social conversations, the establishment of contacts, and the manifestation of their presence in other SNs. Thus, they understood in a better way the academic participation in SNs. Continuing with the same theme, in [41], they investigated the habits of using Twitter with undergraduate students. The data obtained were analyzed with

SPSS[5] software using percentage, frequency, and average statistical techniques. The results showed that students spend most of their time on Twitter, but that educational content was shared less frequently.

In [42], authors study the educational experience of three groups of students who used Twitter to work on different discussion topics throughout a course, motivating the implementation of SNs as a learning tool. To obtain results, they conducted evaluations with a questionnaire at the end of the course and collected tweets related to participation in each discussion. Therefore, they observed the students' commitment to this activity, the impact on their learning and understanding of the subject, resulting in positive perceptions about the deployment of SNs in education. On the other hand, the authors of [43] encouraged university students to use Twitter to communicate with their tutor and peers throughout a course, thereby increasing participation in academic activities. While, in [44], they expose the existence of users, which they call experts, who generate content of interest in any subject, which can be used by students to improve their knowledge. For this reason, they propose an algorithm based on automatic learning, which makes it possible to recommend, with an accuracy of 78%, who can follow to. Finally, in [36], the authors argue that, just as marketing professionals use Twitter for brand advertising, teachers can do so to generate interest in a course. They mention that students feel better prepared when they are involved with the teacher through this technology.

2.3 YouTube

YouTube is an any-kind video socialization platform—education, entertainment, and marketing, among others—in personal profiles called *channels*. It is considered a SN, because each user can access the channels of other users, according to their needs or preferences. By January 2017, a total of 1 billion active users were registered, according to the website *"We Are Social"*. In addition, it includes the possibility of both commentary writing—which leads to the dialogue of its users with each other— as well as the possibility of tracking who is watching each video [45].

From an educational point of view, it allows each student to access video tutorials, which are valuable study resources [38]. Thus, we found several studies examining how YouTube can improve the quality of learning/teaching. On the one hand, the authors of [46] design a teaching module, in which they compiled a series of videos on nursing techniques. This module was given to undergraduate students, increasing their participation and critical awareness, so they consider the platform as a possible study tool, even though, on certain occasions, they found unregulated or equivocal content uploaded by amateurs. With the same theme, in [47], a study was conducted to evaluate the perceptions of students of anatomy when using videos

[5] www.ibm.com/analytics/data-science/predictive-analytics/spss-statistical-software.

as study tools and, therefore, their effectiveness in learning based on problems. They also launched a channel with their own content, named *"Human Anatomy Education"*. In the statistical data recorded, they found that 98% of students used YouTube and 86% accessed the channel, claiming that it improved their study quality.

Computer literacy is researched in [48] by observing the acceptance of YouTube content to support different academic needs through the analysis of the feedback generated by each individual's comments. Meanwhile, in [49], the authors evaluate the quality of videos on clinical skills in YouTube and stated that only 1 out of 100 could be classified as "good." In addition, 60% were classified as "satisfactory." In this way, they highlight the need to implement a rigorous filtering of content, based on its informative quality. Finally, in [50], the authors filtered videos of dentistry by relevance and number of visits, as well as in the "All" and "Education" categories. They then scored the first 30 results of each of the criteria and developed a statistical analysis, which revealed that there is a wide variety of information for entertainment, advertising, and education purposes. So, they conclude that the content belonging to the "Education" category is more useful than that of the "All" category.

Although SNs are considered as a valid learning tool, they contain several significant difficulties such as a lack of privacy and security that allows for the disclosure of personal information, indirectly they encourage a lack of attention or loss of time, do not keep a record of all activities performed, are not seen by the entire educational community as a study tool, and do not focus on contacting students with experts in different topics (isolation of information and over-information). To solve these problems, the implementation of OPPIA is proposed. Because the creation of sporadic learning networks (SLNs) is one of their main characteristics, to avoid information isolation and over-information, this will be analyzed in the next section.

3 SLNs: Sporadic Learning Networks

Sporadic learning networks (SLNs) are SNs that are created for a limited time—hence the name sporadic—and operate according to specific social exchange policies that encourage the transfer of knowledge, which depends on the learning needs of their members [20, 21]. These networks are based on a networking organization, so they are implemented through the Internet. However, they need to work in tandem with intelligent systems to incorporate a more robust learning structure, since it is necessary to group different users in the same time space (according to their affinities and dispositions) to share knowledge and resources. In addition, due to their creation-death nature, according to the disposition of users, they focus on supporting informal educational paradigm.

SLNs facilitating the creation and operation of short networks, which allow each user (student, teacher or expert) to communicate with their peers to exchange information. This is achieved by configuring the organization of the network, since it is not taken into account if its members know each other; the only important thing is that they share related topics and have the need to learn at a certain time. A similar concept, known as ad hoc transitional communities, is proposed in [24]. There are some differences with the SLNs, the most notorious being the lack of collective activities focused on meeting collaborative learning objectives, the lack of assignment of roles dependent on the needs and competencies of the participants, and the lack of guidance from a tutor during the process. Participants in this type of community do not share a learning goal; they help their peers achieve their own particular goals. Among the main features they share are:

- Their period of existence is limited in comparison to the time a student spends on fulfilling their full apprenticeship program. While a program can last several months, an SLN will last a maximum of a couple of hours, depending on the skills to be developed.
- The exchange of knowledge is not organized by an educational institution, it occurs spontaneously when each student requires it. Therefore, it is necessary to guide the training process of each SLN.
- The exchange of information takes place in different forms and can be declaratory (questions who, when, and where), procedural (questions how), or conditional (questions why). However, the potential value of a discussion within the community varies according to the type of question, as declaratory questions can be answered with the use of a book and procedural or conditional questions are best resolved with the opinion of others.
- Information sharing among community members is achieved through synchronous communication with one another.

On the other hand, the overall performance of an SLN is a product of the behavior of its members and the way in which they interact. Thus, the authors of [24] identified five theories, also present in the SLNs, that detail how group interactions affect community behavior:

(1) Self-organization theory: This theory says that the behavior of a system is a complex aggregation of the interactions of all parties. Since no one party controls the whole, such systems are "self-organized," and the behavior of the inputs of each component is said to be "emergent." Therefore, it can be expected that SLNs do not need a central organization to emerge and function.
(2) Systems theory: It sees groups as systems of interacting individuals. However, according to this theory, it is the task of the group to analyze inputs, provide feedback to members, and generate decisions regarding group actions. The analyses focus on input information, as well as the individual characteristics of each member (skills, experience, training, motivation) and group level factors (group structure and cohesion), the processes during group work (communication, planning, conflict, and leadership), and the products generated as output. The organization is an emerging property, without imposing the system itself and may undergo gradual or rapid change. Systems theory supports the idea that the

implementation of SLNs, in the context of a learning network, is feasible. One can, at least to some extent, rely on the system to ensure that the characteristics of individuals are taken into account, that feedback is given and decisions are made.

(3) Social exchange theory: Group members negotiate through mutual interactions. They then receive personal rewards (education) while minimizing costs. People no longer fully control their results, and interdependencies are created: individual actions can influence the results and actions of all other individuals.

(4) States of expectation theory: It focuses on the cognitive processes that occur in each individual within the group. Newcomers make an impression and seek information about other members. Group members search their memories for stored information about the group and the tasks they face; take note of each other's actions and try to understand what caused each other's behaviors. Members with most status-winning features will rise to the top. The theory of the states of expectation, as well as the theory of social exchange, points to the importance of keeping a record of the various characteristics of SLN members. The value attached to the answer to a particular question that has been asked depends, for example, on the experience of the person providing the answer.

(5) Fast trust theory: If a community is to function, its participants must show a little trust in each other. Therefore, a specific form of trust known as "fast trust" can arise in temporary teams that form around a clear purpose and common task. These are precisely the conditions that apply to SLNs. According to the theory of rapid confidence, there is a willingness to suspend doubt about whether one can count on others, who are "strangers," to be able to work on the group's task. According to the theory of rapid confidence, SLNs will improve relatively quickly the social integration of learning network users.

In addition to the above, it is necessary to perform a more personalized filtering of the preferences of each user. So, personal and institutional relevant resources must be accessed, such as educational profile, experience, and learning interests. The target is to provide a smart and ubiquitous learning environment that encourages its users to collaborate with each other to achieve diverse goals in their educational processes. With this, the problems of information isolation and over-information, present in the SNs, are solved, since the students are put in contact with experts who can solve their academic doubts.

As can be observed in Fig. 1, SLNs base their structure and operation on relevant information extracted from formal information sources (*Institutional Learning Objects*) and informal sources of information (*Web Learning Objects*). This information is the starting point of the OPPIA platform for structuring of SLNs, since it allows to group users who have similar study preferences in the same virtual-temporal space. On the other hand, OPPIA has in mind the profiles, interests, and personalities of the users that are going to be grouped, which allows establishing cooperative education. Then, once a selected user agrees to join a SLN, OPPIA offers a range of learning resources and activities—both individual and group—

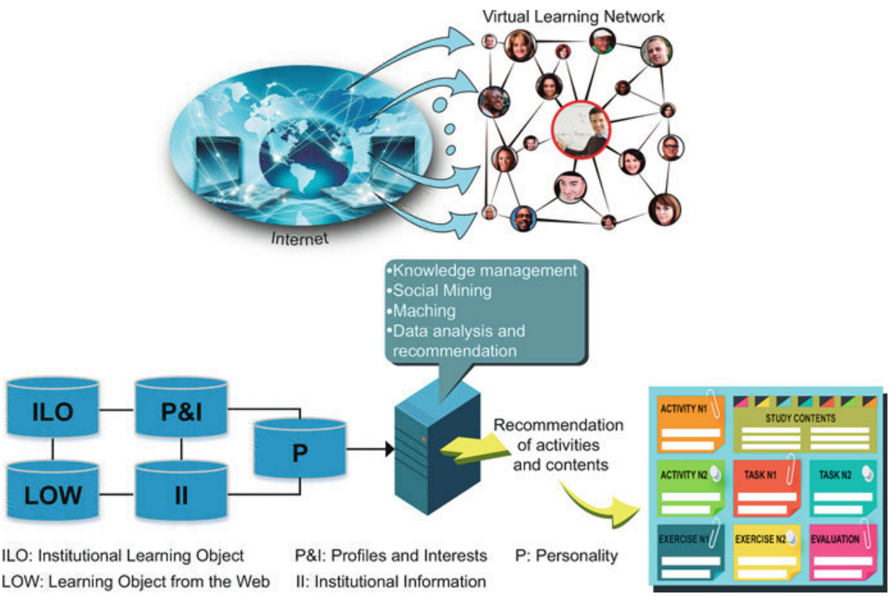

Fig. 1 Sporadic learning network: structure and operating

that needs to be developed over a given period of time. Three types of SLNs are possible [21]:

- Physical sporadic learning networks: In this type of network, thanks to geo-location, the system can determine a group of individuals close to each other, who may be potential members of a learning network. In this way, users who are selected according to their interests and profiles can configure a network in the same physical environment. The system will support the configuration of the network and the structure of the work to be developed.
- Virtual sporadic learning networks: In the case of a pure virtual network, potential candidates are physically distant from each other but connected to the system via the Internet. In this case, the interaction is carried out through intelligent tools and services provided by the platform. As in the previous case, the system will provide activities to be developed and learning resources.
- Hybrid sporadic learning networks: Hybrid networks, on the other hand, are a combination of the two previous ones. These networks make it possible to increase the possibility of interaction between students and to integrate experts or teachers geographically distant from the group and who, through their expertise, can enhance learning.

In the following section, the layer model, architecture, operating modes, and services offered by OPPIA are described.

4 OPPIA Platform

OPPIA (OPPortunistic Intelligent Ambient of learning) is an educational social platform that deploys different modes of informal learning, according to each student's needs. It helps to solve the difficulties of other SNs, as it focuses on providing opportunities for establishing interpersonal relationships, but from a more professional point of view. Thus, like any other Web 2.0 technology, it allows users to express their different opinions and personalities, with the difference that it has a more educational and private approach. In this way, it limits student/teacher relations to a field of study, in order to avoid compromising the private information of each user. This is achieved, to a large extent, by the simple fact that any user who accesses OPPIA's services is willing to learn or teach. In addition, the creation of sporadic learning networks (SLNs), one of its main characteristics, helps to undertake educational processes that connect students with experts in different subjects, improving the efficiency of knowledge transfer. On the other hand, it keeps a record of all the activities carried out, making it easier for teachers and educational institutions to monitor the progress of each student and thus improve academic quality. Finally, it deploys a recommendation system aimed at creating an environment that is attuned to unique preferences, creating a personalized and student-centered learning environment, with which you will feel comfortable while performing your academic activities.

In order to deploy all the features of OPPIA, it was necessary to use a number of technological tools. Therefore, the following subsections will describe its layer model, architecture, and operation.

4.1 Layer Model

The OPPIA platform relies on a fully interactive multilayer model organized in several layers and services. Conceptually, it has five layers (see Fig. 2) that will be described in the following subsections.

(1) Communication Layer This layer is responsible for providing the necessary mechanisms to establish connections proactively and transparently to users whenever deemed appropriate by the information from higher levels. So, the SLN relies firstly on ad hoc networks laid dynamically among mobile devices of the people (students, teacher, or experts), who happen to be close one to another at a given moment. Communications with network members in remote locations, with knowledge bases and learning services (upper layers), are done through links to hotspots or 3G/4G connections available. All protocols and mechanisms for establishing links and maintaining the necessary QoS levels are housed in this layer too.

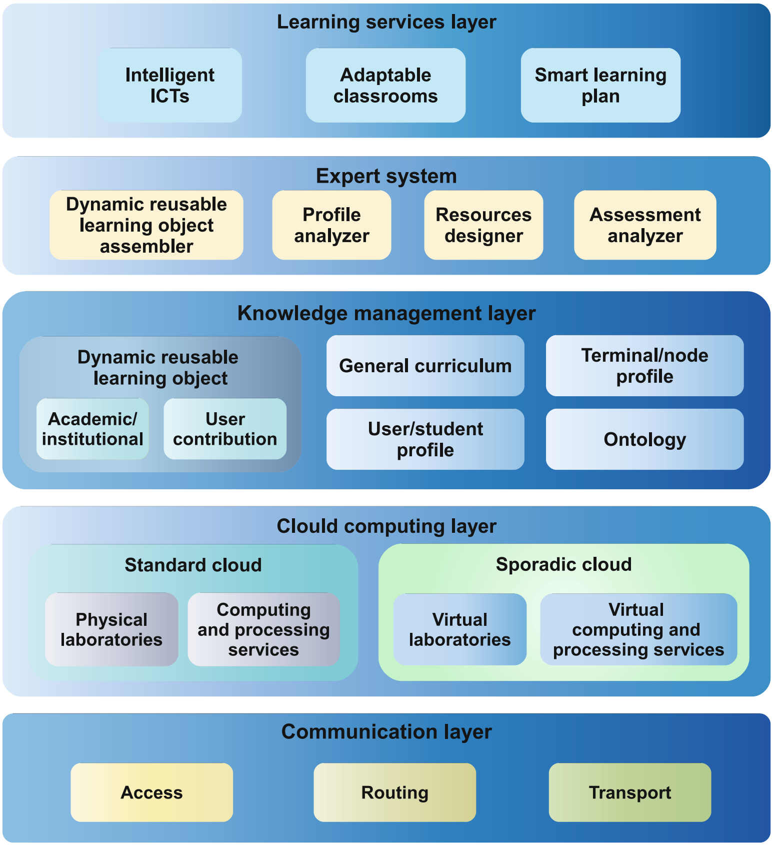

Fig. 2 The conceptual layers of the OPPIA platform

(2) Cloud Computing Layer The second layer aims to enable efficient sharing of resources available to each device within an SLN. The tandem between mobile devices and cloud computing works perfectly, due to handheld terminals that are constrained by their processing, battery life, and storage capabilities, whereas cloud computing provides the illusion of "infinite" computing resources [51, 52].

The extra resources required by the handheld devices can be provided either by (1) centralized servers in the cloud, depending on connectivity to the Internet; (2) cloudlets supported by fixed nodes at Internet edge; or (3) mobile terminals connected in the ad hoc network. With this in mind, OPPIA takes advantage of the concept of sporadic cloud computing (SCC) [53, 54], in which the devices of the user exploit both the resources available in the rest of terminals connected to the ad hoc network and those provided from external data centers. In this platform, SCC allows to generate virtual and distributed laboratories, conformed with existing resources in the devices of the different members of each SLN, who are physically close to each other. This avoids—as far as possible—dependence on access to the

Internet to perform tasks and gives students access to specialized software not suitable for low performance devices. Hereby, cloud computing layer provides the following services:

- Storing information in spaces in the cloud, linked to source/target devices, creating/consuming users, location, etc.
- Accessing and serving information of user profiles of high-level during the formation of ad hoc networks.
- Synchronizing multiple flows of information coming from the connected devices.
- Managing of the simulation and programming resources available on the user mobile devices, which will be used in a transparent manner (virtual and distributed laboratories).
- Providing access to cloud services on the Internet such as databases, semantic repositories, physical laboratories, etc.

(3) Knowledge Management Layer OPPIA platform uses information derived from personal or institutional sources to provide users the best resources (according to their personal learning styles and characteristics of their access devices) and activities (both individual and group) that stimulate their learning. By this way, the academic achievement of each student is enhanced, satisfying their needs. The “knowledge management” layer is the place to develop solutions from areas such as data mining, recommender systems, and Web semantic, to automatically select best profiles to form a learning network. To do this, it is necessary to rely on techniques for modeling user preferences, considering different profiles (students, teachers, and experts) and contents (institutional and personal). Moreover, in this modeling process, OPPIA takes advantage of the academic information stored in the institutional bases such as general curriculum, teaching activities, and learning outcomes.

In OPPIA, contents are modeled through *dynamic reusable learning objects* (DRLOs) [55], provided by the institution (institutional DRLOs), students, teachers, or Internet. In the same way, the platform needs to use recommendation strategies that select the most appropriate contents for each member or group. In addition, it requires modeling techniques to infer knowledge about future learning interests of the members, by keeping track their academic activities, Web surfing habits and preferences, and profiles in SNs (obviously, with the explicit consent from the users). Finally, to efficiently manage metadata associated with the learning process, information storage, analysis, and inferences, it is necessary to use learning ontologies, especially designed for this purpose.

(4) Expert Systems Layer To achieve the desired results, both in motivation and performance of users, OPPIA relays selection and design of contents, educational resources, and learning activities, to the “expert systems” layer. With this aim, the platform incorporates an assembler able to create DRLOs.

Educational institutions create official DRLO—developed in different formats (video, image, text, and audio) to meet the learning styles of students—that cover the main contents related to the curriculum. In turn, DRLO repository can be expanded with learning objects from users themselves or the Internet. Furthermore, OPPIA has the ability to produce new learning objects and educational resources, from DRLOs existing in the repository. For this, the Profile Analyzer, Resource Analyzer, and Assessment Analyzer are used.

(5) Learning Services Layer In order to access different services and learning objects that are provided by the intelligent learning ambient, “services” layer incorporates three main elements: a set of intelligent ICTs (mobile apps, desktop, and Web applications, including functionalities as sporadic chats, forums, renderers of learning objects, etc.), adaptable classrooms (virtual classrooms that are set to the user profiles), and smart learning plans that are dynamically designed for a particular learning session.

4.2 *OPPIA Architecture*

OPPIA is a modular system that is hosted in a hybrid cloud, so the information processing is developed between a public and a private cloud. This architecture can be seen in Fig. 3.

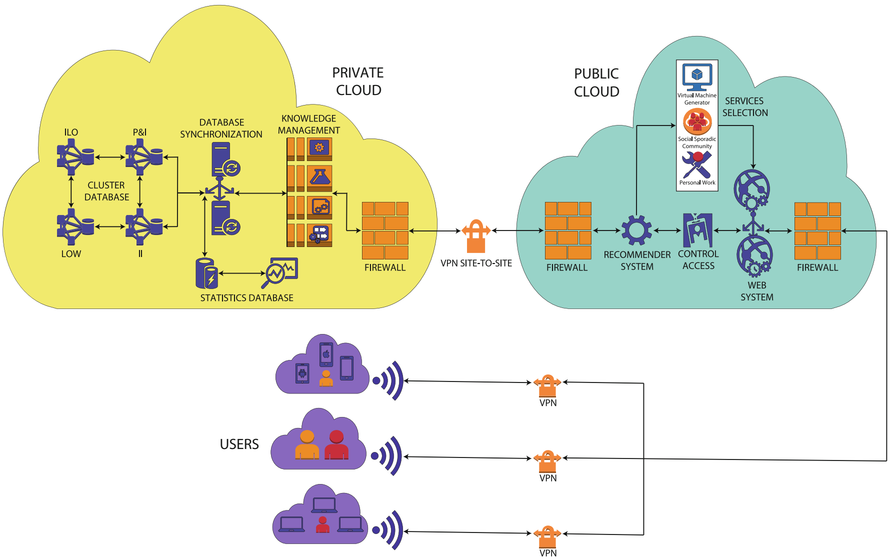

Fig. 3 Architecture of OPPIA, it manages a private and a public cloud

Public Cloud
The public cloud is hosted on Azure Microsoft's paid infrastructure,[6] because it helps with the deployment and provision of virtual machines, enabling an elastic, scalable, high-availability system. For this reason, for our infrastructure, we combine a Web application development API, relational databases, and calculation function systems. In addition, its structure implements a perimeter security system represented by Azure's security center application, which offers perimeter security services and IPS/IDS. Also, the access is done through a VPN in site-to-site and site-to-client mode. The site-to-site VPN interconnects the private cloud with the public cloud, ensuring end-to-end transmission of information, whereas the site-to-client VPN enables customers to access OPPIA services, ensuring confidentiality and integrity of information. The public cloud consists of four layers: Web service, access control, recommendation, and services.

(1) Web Services Layer This layer contains functions that allow access to a wide variety of learning resources, grouped by different topics of interest or courses. In this way, learning resources are provided to support the training process of students. Multimedia and mobile services are also found in this layer, as Azure tolerates parallel execution, in conjunction with Web applications, from a single orchestration system. Likewise, a component known as Azure AD is used to validate access through a connection API, an AAA (Access, Authorization, and Audit) service, and interaction with the system. It also adds a load balancer, which distributes the load of users, according to their consumption of system resources, among the application servers, and offers high availability in Web services.

(2) Access Control Layer Allows to validate, create, and manage users, performing audit functions. The software selected for these tasks is Microsoft's Azure Active Directory.[7] Additionally, system access profiles have minimal privilege, which is a security policy to prevent unauthorized access to infrastructure resources. Thus, each account is valid for 30 days, administering policies through group policies (GPO), which update software versions of the platform and access to resources.

(3) Recommendation Layer The main function of the referral system is to motivate students to join an SLN and exchange information with its members. Therefore, it handles critical processes in which algorithms are executed that generate a series of options to be recommended to the end user. For this process, we use collaborative filtering through the *recommendation algorithm of the nearest neighbor*. The main objective of this algorithm is to identify users who have preferences similar to those of the user to whom the recommendation will be given. Thus, by means of the qualification that each user gives to different learning resources, it is possible to obtain a similarity with their similar ones, in order to recommend other learning

[6] https://azure.microsoft.com/en-us/.

[7] https://azure.microsoft.com/en-us/services/active-directory/.

resources or invite them to be part of an SLN [56]. In this implementation, we have chosen the Pearson correlation coefficient to establish similarity in user preferences:

$$sim(a,b) = \frac{\sum_{p \in P}(r_{a,p} - \bar{r}_a)(r_{b,p} - \bar{r}_b)}{\sqrt{\sum_{p \in P}(r_{a,p} - \bar{r}_a)^2}\sqrt{\sum_{p \in P}(r_{b,p} - \bar{r}_b)^2}} \quad (1)$$

where:

- $P = p_{1,\ldots,p_m}$, denotes the learning resources.
- $sim(a, b)$, similarity between user a and b.
- $\bar{r}_a$, average rating of user a.
- $\bar{r}_b$, average rating of user b.
- $r_{a,p}$, valuation of user a to learning resource p.
- $r_{b,p}$, valuation of user b to learning resource p.

In this way, in order to predict the qualifications that each user will give to the different learning resources, OPPIA uses the relative proximity of the nearest k-neighbors:

$$pred(a, p) = \bar{r}_a + \frac{\sum_{b \in N} sim(a,b)(r_{b,p} - \bar{r}_b)}{\sum_{b \in N} sim(a,b)} \quad (2)$$

(4) Services Layer The services offered by this layer are hosted in different instances of the cloud, because their nature is different and heterogeneous. Three different types of services are handled, which are:

- Virtual machine generator (VMG): This service is based on the IaaS model (infrastructure as a service) and allows each user to access a virtual machine—hosted in the cloud—which has features, both hardware and software, according to their educational needs. VGM systems were provided by Nutanix Enterprise Cloud, a hardware and software platform that combines the agility and simplicity of the public cloud with the security and control required by a private cloud. Based on the leading hyperconvergence infrastructure technology (HCI), it integrates computing, storage, virtualization, and networking into a complete stack solution that runs almost any application.
- Social sporadic community (SSC): A service that runs in a different instance from the public cloud, since it requires scalability and high availability. Its main function is to generate temporary virtual spaces, in which SLNs are formed between users with common affinities.
- Personal work (PW): Like SSC, it is a service that runs in a different instance from the public cloud, due to its scalability and high-availability requirements. This service is responsible for presenting individual learning tasks to each user in order to reinforce their knowledge or initiate a self-learning process.