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From Web to Apps in Massive University On-line Learning

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Abstract: Universities today have an incredible variety of opportunities for improving their services, thanks to the new information and communication technologies and opportunities. This paper describes the Politecnico di Torino strategy for online and distance learning, both from the technological and the methodological points of view, focusing on the response to the continuously evolving teaching paradigms: from traditional distance learning models to hybrid and blended models, up to the recent MOOC approaches.

The on-line educational environment has been designed for a very large number of users: 33,000 students enrolled in 51 curricula, B.S. and M.S. in different areas of Engineering, and it is suitable both for face-to-face students and remote ones. At present the number of logins per months exceeds 1,000,000 and the system provides access to about half a million of educational documents; in total, the number of downloads per yearis over 10,000,000. The paper specifically describes the video-lecture service, that makes about 3,000 hours of lectures available every year (80 courses are involved) and generates about 1,200,000 video streaming/downloads per year.

Mobile devices are becoming more and more the favorite tool for accessing university services and content, and Politecnico di Torino followed the technological evolution to improve its services from the traditional web approach to the mobile App model, passing through a number of intermediate steps such as the responsive web and the mobile web models. The paper describes the strategies and the technological choices used to design and deliver the Educational Portal of Politecnico di Torino, that includes the new official App (PoliTO App). This App allows students, teachers and university staff to access quickly and easily educational content and to use the main university and territorial services.

Finally, the paper includes an analysis that shows a positive correlation between the use of video-lectures and the success in the exams, thus validating the proposed educational model.

Key words: learning technologies, mobile learning, blended learning

1. Introduction

Last six years showed an increasing diffusion of mobile devices, with a consequent higher and higher demand for services for mobile users. University cannot ignore this trend, and have to adapt to the change, improving their offer to this kind of users. Figure 1 shows how the accesses to Politecnico di Torino educational

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web services through a mobile device have increased in the past eight years. In 2008 only 0.2% of the accesses were through a mobile device; in 2013 the percentage was 15% and in the following three years it doubled, reaching 32% in 2016.

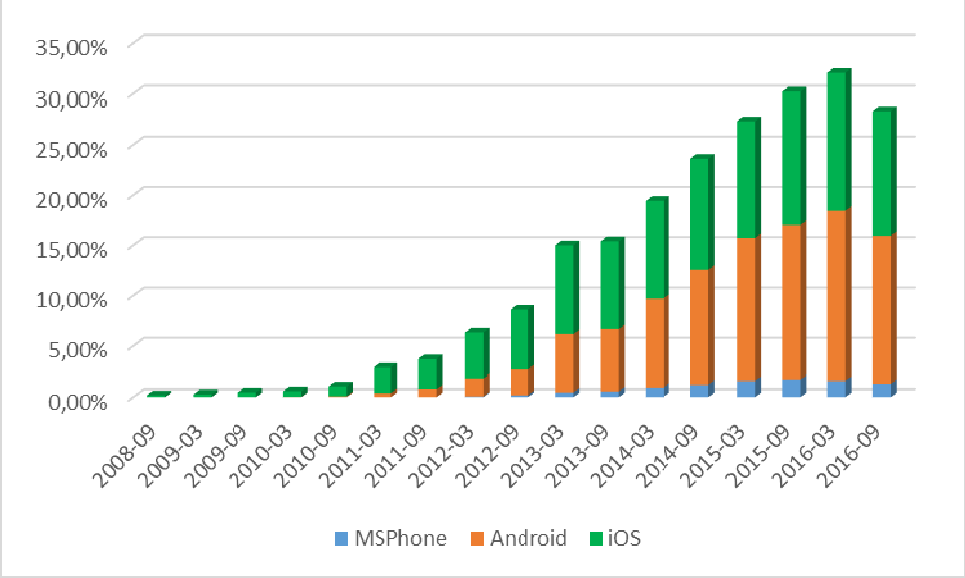

Figure 1 Evolution of Mobile access to Educational Web Services at Politecnico di Torino

Figure 1 represents the aggregate percentage of mobile accesses, colored according to the different operating system. The decrease starting on May 2016 relates to the delivery of the University mobile App "PoliTO App": the access to educational services and material no longer requires web browsing via the mobile device (see section "The PoliTO App").

The need to optimize the educational services and content fruition for any kind of device, from mobile phones to powerful workstations, forced the rethinking and the redesign of the production and distribution processes (Castaldo et al., 2013).

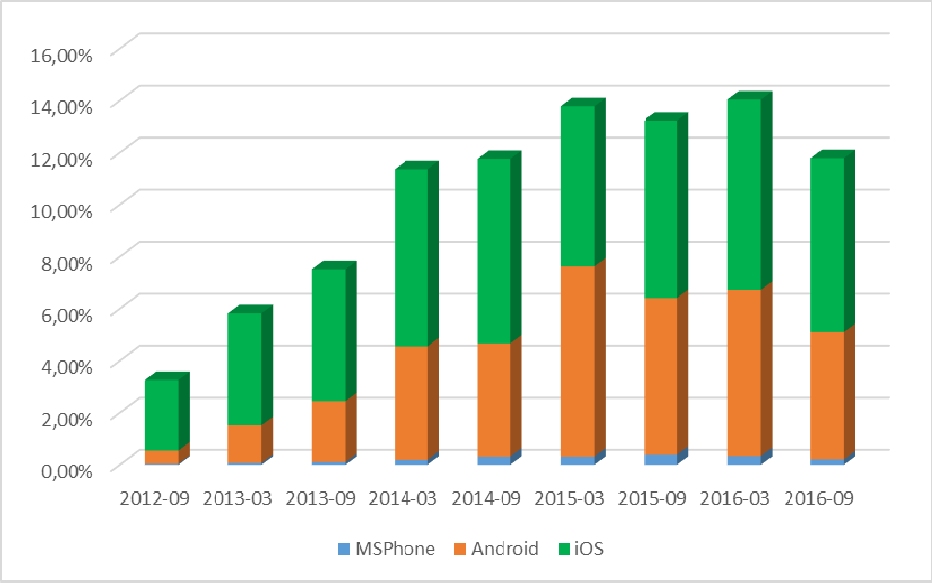

Figure 2 Web Access to Multimedia Content via Mobile Devices (Percentage of the Total accesses to Multimedia Content)

The access to multimedia content, such as the video-lectures (live lectures that are recorded in the classroom) deserves specific attention and it is shown in Figure 2; this material is available in streaming for all web-enabled devices, including mobile ones.

The comparison between Figure 1 and Figure 2 shows that, considering only mobile devices, the access to educational content in general is much higher that the specific access to multimedia content; as an example, in 2012, 9% of the educational content was accessed via a mobile device, but only 3% of the total accesses to multimedia content was done through a mobile device.

In 2015, however, the first percentage tripled (from 9% to 27%) while the second one grew even faster, passing from 3% to 14% (more than four times). This growth, of course, is partially due to the improvement of the mobile devices, that are more powerful, and to the rise of the network connectivity; however, it also depends on the social factor that students (and young people in general) are developing more and more a familiar attitude towards multimedia content (Gedera, 2014).

A recent survey proposed to students at Politecnico di Torino (about 6,000 responses were collected) demonstrated that smartphones are one of the favorite devices for accessing university services: Figure 3 shows that preferred devices are smartphones and laptops, while tablets are not used frequently (students were asked to sort their preferences with a number from 1 to 4) (Moser et al., 2015). Besides, the survey showed that most students use their smartphone for more than two hours a day.

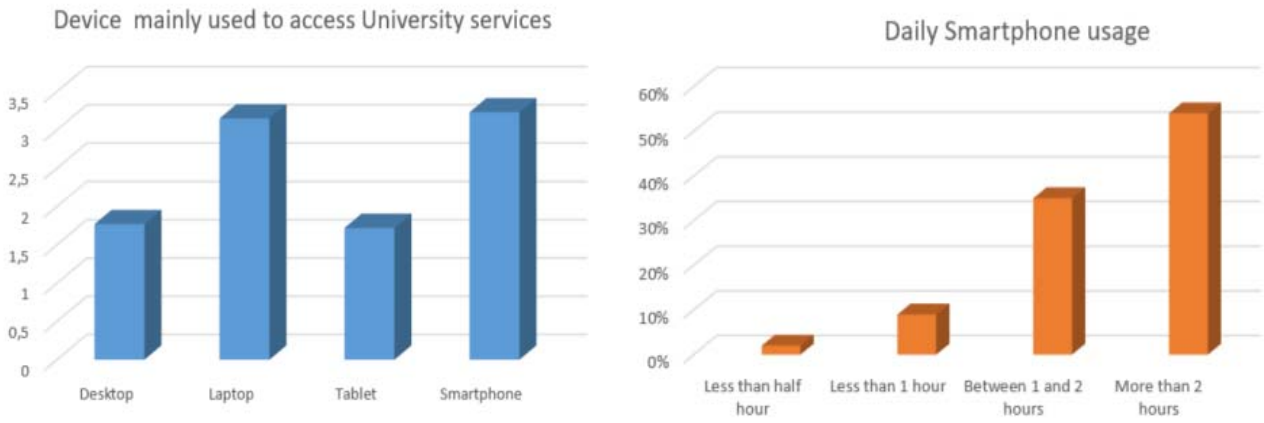

Figure 3 Students' Preferred Devices for Web Access

However, even though smartphones are widely used for accessing services, the percentage of accesses to multimedia content via mobile device did not increase after 2015 (see Figure 2): the preferred device for this kind of content remains the desktop. Figure 2 also shows the effect of the release of the App "PoliTO App" in March 2016, with a consequent reduction of 2.25 percentage points.

2. The Context

Politecnico di Torino offers 31 B.S., 32 M.S. and 16 PhD curriculain different areas of engineering and architecture, and it currently enrolls about 35,000 students. It is reputed as one of the top technical university in Italy.

Students can access a virtual space ("Portaledella Didattica", i.e., "Educational Portal") where teachers and students can meet each other proactively (Dominic et al., 2014). Students there find more than 400,000 text files,

indexed educational content like slides, notes, exercises and exam texts, and they can participate in forums; each course represents a different context. In this virtual space, students can also find useful information such as Erasmus calls or stage and job opportunities, and they can access services like exam booking.

In 2010, the university started to deliver a blended learning model, based partially on face-face lectures but also introducing distance learning elements: Politecnico di Torino started to video-record all lectures of the courses of the first year of the B.S. in Engineering (the first year is common to all B.S. engineering curricula), all the lectures of the B.S. curricula in Mechanical Engineering, Computer Science Engineering and Electronic Engineering, and all lectures of the M.S. curriculum in Computer Science Engineering (Barbagallo et al., 2011). Every year over 60 courses are fully live recorded, for a total of about 3,000 video-lectures available in video-streaming to the 15,000 students involved in these curricula.

For organizational and education reasons Politecnico di Torino prefers a MOC (Massive Online Courses)model, and provides access to video-lectures to its students only. However, it also experimented for several years a different model, more similar to MOOC (Massive Open Online Courses), where two courses of the first year (Computer Science and Chemistry) were freely available to the general audience (Castaldo et al., 2014). In the case of the Computer Science course, as an example, the forty 90-minutes recorded lectures got about 50,000 accesses every year by people outside the Politecnico di Torino community (Abeer et al., 2014).

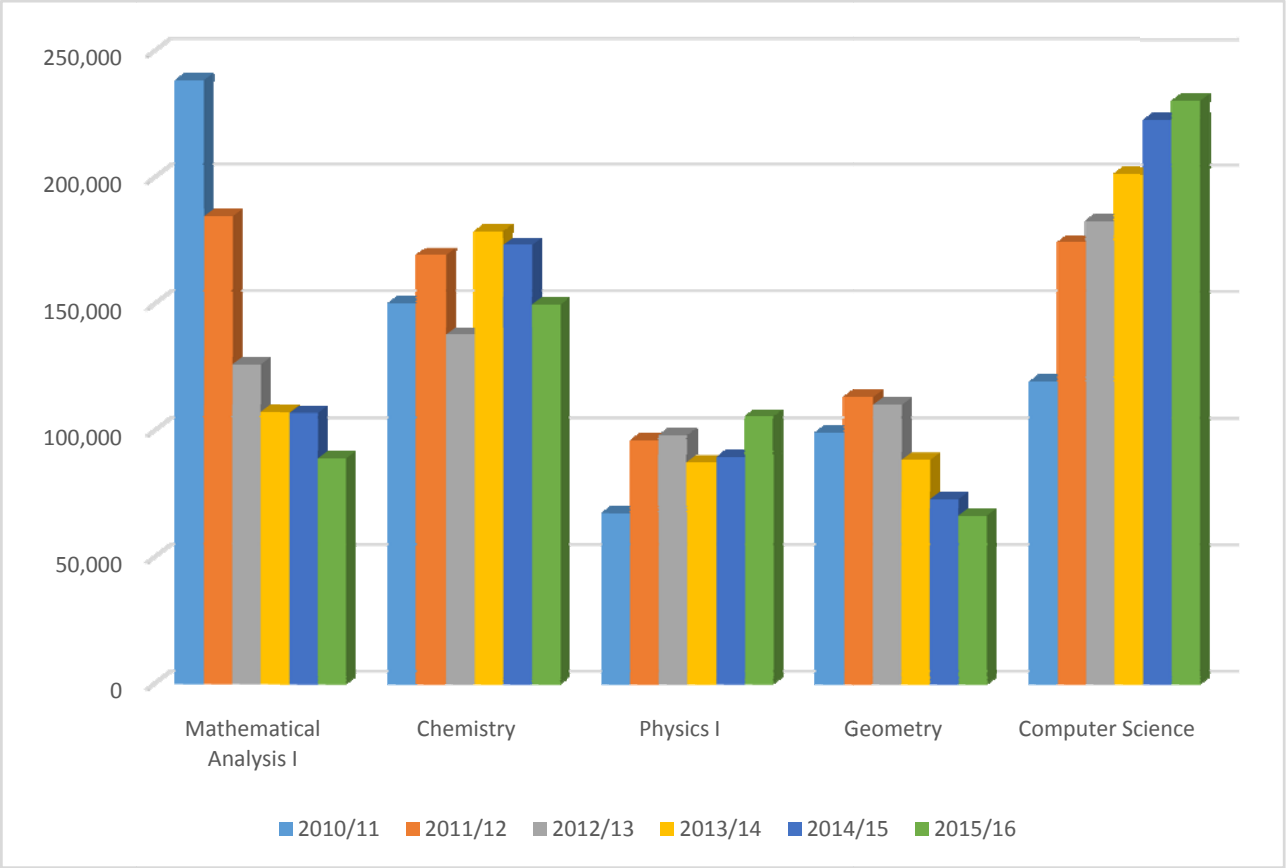

Figure 4 Access to the Video-lectures, in Streaming, of the Courses of the First Year of the B.S. Curricula in Engineering

Figure 4 shows the number of accesses to the six courses that are common for the about 7,000 students enrolled in the first year of all the B.S. curricula in Engineering, in the last six academic years. The total video-lecture streaming accesses are about 700,000 per year, which means an average of 100 accesses per student.

Given the very high number of students enrolled in the first year, there are 22 different groups of students, and each group has a different teacher for each of the courses. Only one of the 22 teachers of Computer Science (as an example) is video-recorded in the classroom, and therefore only one group out of 22 accesses the lectures of "his or her own" teacher, while the rest use the content of a "unknown" teacher. Nevertheless, Figure 4 shows that all students value the video-lectures, no matter of the familiarity with the teacher. This result is due to a serious effort of standardization of course syllabi and contents shared by the 22 parallel teachers, so that each student is guaranteed to have the same study material, assessment and grading criteria.

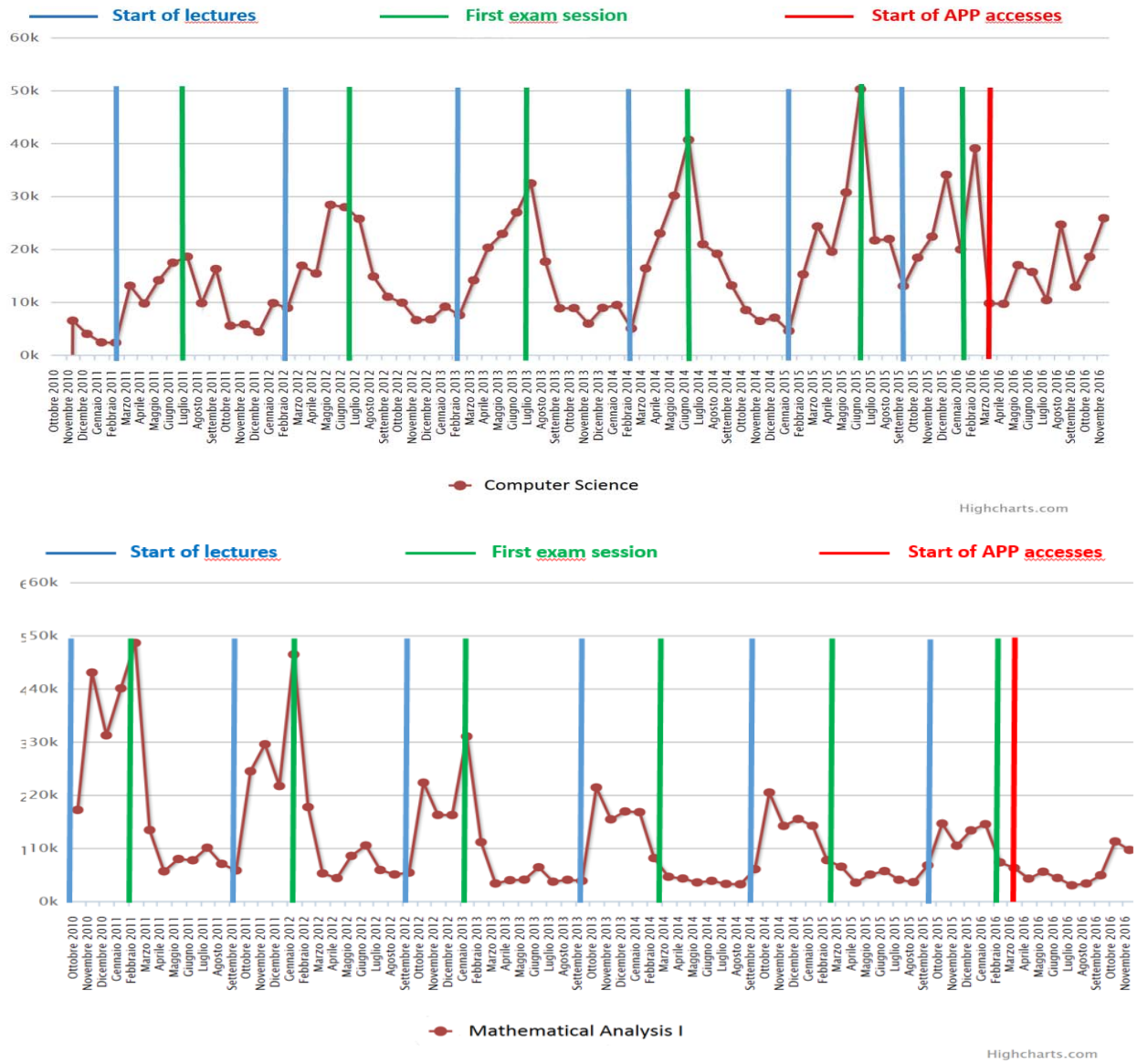

Figure 5 Video-lectures Monthly Web Access

Not every course is video-recorded every year, though. Figure 4 shows the effect of this factor: for example Computer Science (that is recorded every year), has a very large number of accesses that increase year after year. On the contrary, Mathematical Analysis I (that was recorded only twice, in 2010/11 and in 2013/14) has a lower number of followers that decrease year by year. If it evident, therefore, that students appreciate most the video-lectures that are recorded recently (even though the syllabus of courses like Mathematical Analysis practically do not change).

Figure 5 shows the monthly accesses to two sample course, Computer Science and Mathematical Analysis I. Compared to the MOOC model, that is typically characterized by a large number of accesses to the first lectures of the course and by lots of drop-offs (inverse exponential access chart), the figure shows the success of the chosen MOC model (Barbagallo et al., 2012). Accesses, in fact, are distributed in the whole period, with a curve similar to a Gaussian with the maximum corresponding to the first exam session. Figure 5 shows also other peaks, each of which is related to a corresponding exam session (Onah et al., 2014).

Looking specifically at the case of Computer Science (which is live recorded every year), accesses show a constantly growing trend, both within a single academic year and across the academic years. The situation is different in the case of Mathematical Analysis I, where the course was recorded only twice and then deployed in the following years: the trend shows that accesses decrease across the academic years. It is evident, therefore, that students prefer to use video-lectures that are recorded when they follow the course.

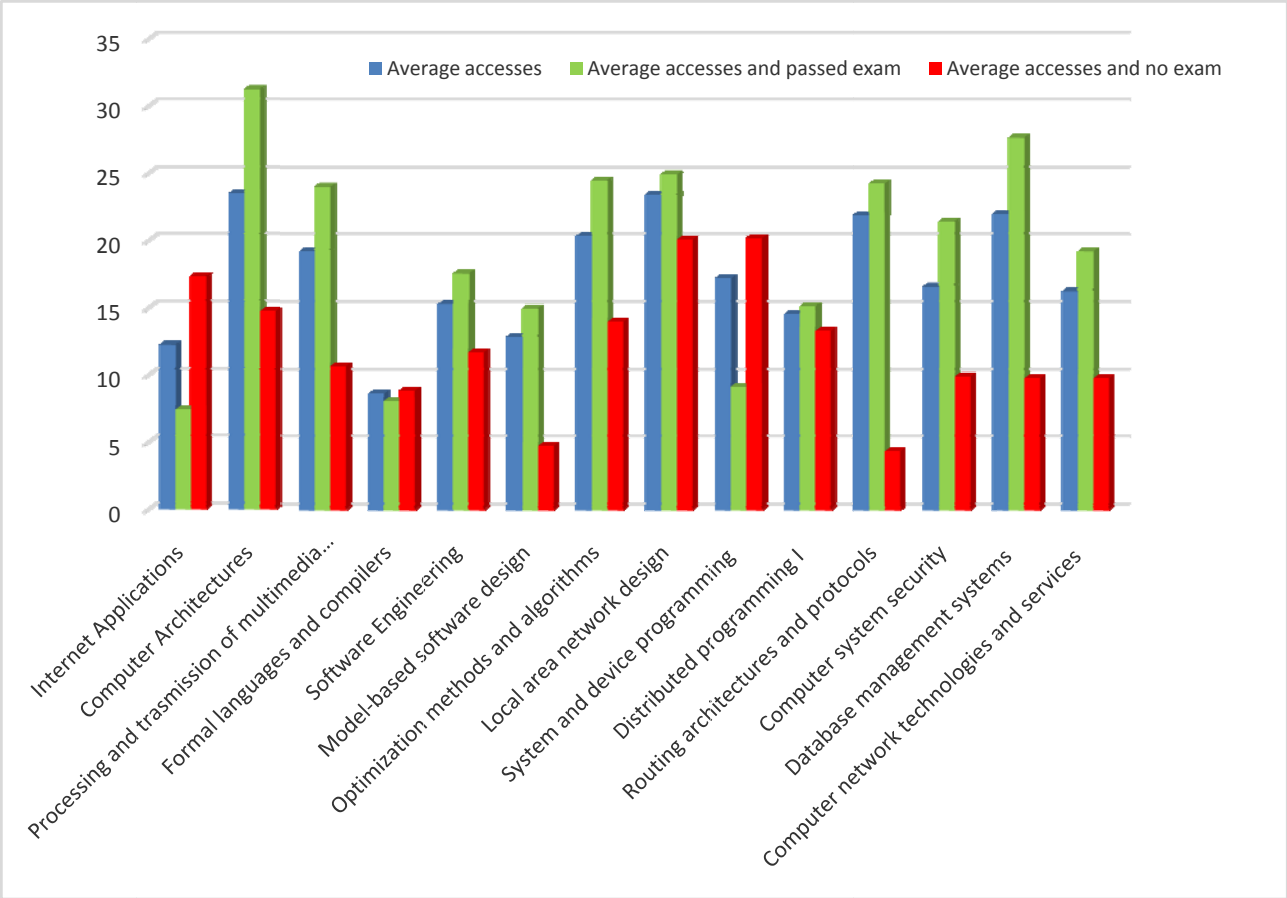

Figure 6 Video-lectures Average Access per Student — M.S. Curriculum in Computer Engineering, Academic Year 2013/14

The quality of the proposed blended model has also been assessed by analyzing the correlation between the use of video-lectures and the success in the study. This analysis is relative to the M.S. curriculum in Computer Engineering, where all courses are video-recorded every year, and students can access the video recordings of the same teacher in charge of the face-to-face course. For each course, Figure 6 shows the average accesses per student (blue bars), the average accesses of students that passed the exam (green bars) and the average accesses of the students that failed it (red bars). As an example, each student of the course Computer Architecture viewed in average 25.5 video-lectures, but the students that passed the exam viewed 31.25 video-lectures and students that failed it viewed only 14.7 ones.

The correlation between the use of video-lectures and the success in the exam is evident in Figure 6, thus demonstrating the positive effect of the adopted methodology. The anomalies in the graph are likely due to a misalignment between the course content and the assessment criteria (that unfortunately this sometimes happens).

3. From Desktop to Mobile Devices

In response to the change of students' preferences in accessing university services, Politecnico di Torino started to move in the direction of mobile Apps, preliminarily by designing responsive web sites, where services can be accessed by different devices and are optimized in terms of visualization for each kind of device (Castaldo et al., 2015).

With the web responsive paradigm, content is stored and managed in a single repository, but different styles of visualization are possible, depending on the dimensions and the graphic capabilities of the specific device; content and presentation can be generated both client-side and server-side. However, even though this paradigm is suitable for adapting web content for most of the mobile devices, data input, information access and navigation model are browser-based and designed for legacy devices such as PCs or laptops (Serrano et al., 2013).

Politecnico di Torino then moved toward the adoption of a "mobile web" model, that overcomes some of the limits of the web responsive model, by allowing mobile users to experience something similar to mobile Apps. This model requires to develop web application specific to mobile devices, and to design a new set of web services in addition to the traditional ones. By using APIs for connecting to existing web sites it is possible to design application servers for mobile web services that are not copies but "interpreters" of the same content that comes from the APIs (usually in JSON format); contents can be then distributed within a graphic and navigation framework that is typical of the mobile devices (Richardson et al. 2013).

The development of mobile applications for accessing university and territorial services has to rely on this approach, based on APIs and web services (Hussain, 2013). This mobile web model is able to cope with the rapid growth of mobile accesses in a better way that the other solutions: it is faster than the App approach and more effective than the web responsive paradigm.

The design of the Politecnico di Torino Educational Portal is web responsive: Figure 7 shows two screenshots, comparing the laptop version with the mobile one.

In addition, the mobile version of the Educational Portaloffers only the essential and the most frequently used services, so that the access is quick and "one-hand only": content is similar but the interface design is different (see the screenshots in Figure 8).

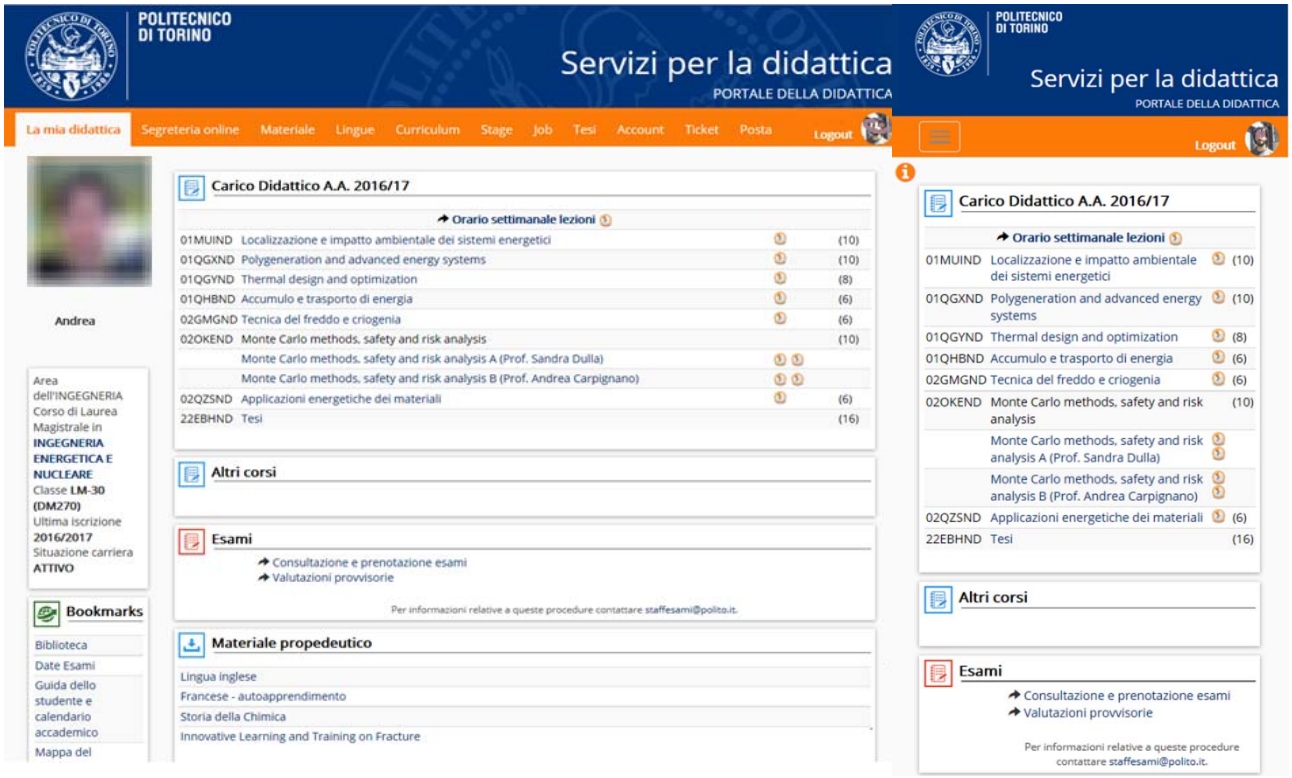

Figure 7 Screenshots of the Politecnico di Torino Educational Portal: Laptop Version (on the left) and Mobile Version (on the right)

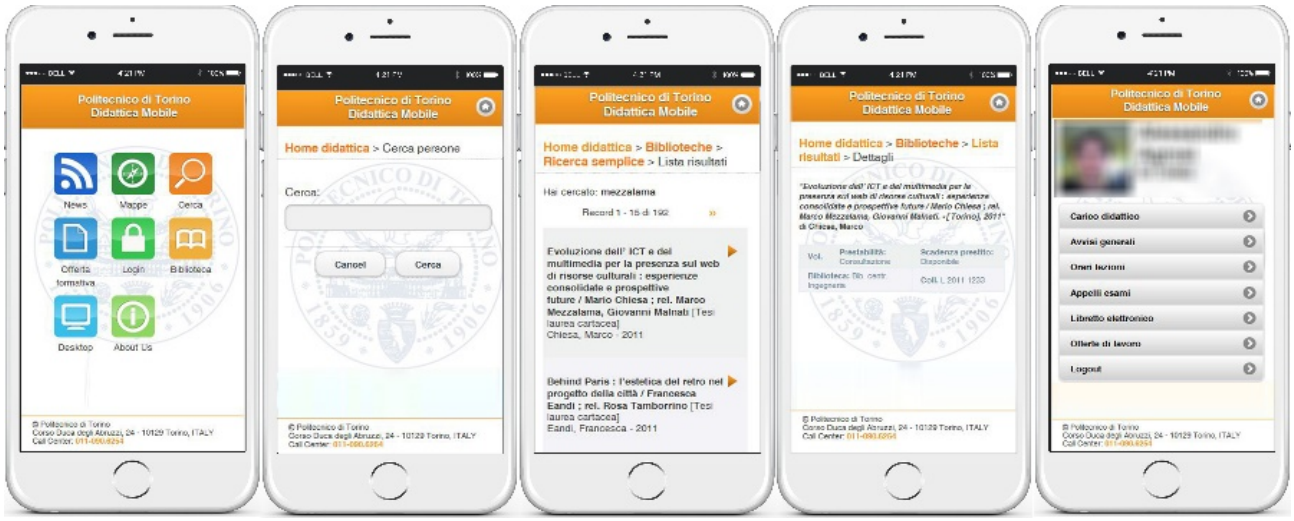

Figure 8 Screenshots of the Politecnico di Torino Educational Portal: Mobile Version

The limits of the mobile web approach emerged quite soon in response to the rapid growth of the mobile users interested in the university services (Sin et al., 2013): the need of re-designing the communication paradigm, in order to take full advantage of the native capabilities of the mobile devices (peripherals, sensors …) became evident. As an example, students would like to contact a teacher and call him or send her a message with just a few taps. The mobile web model is a good transition model, since it quickly allows the adaptation of existing web

content and services for a mobile platform, but cannot be considered as a permanent solution.

One of the main reasons to develop a mobile App in a context like Politecnico di Torino, where most of the services were available as mobile web or responsive web services, was the desire to use specific features that are not otherwise available, first of all notifications. The choice was to create an environment where students can receive real-time notifications: security warnings or general information, but also messages customized for specific groups or profiles.

4. The PoliTO App

PoliTO App is the first official App of Politecnico di Torino. The Android version was released on Google Play on February 26th, 2016; the iOS version was released on AppStore one month later and finally the Windows 10 version was released in early September, 2016. Today it is installed on about 20,000 Android devices and 10,000 iOS ones. The Windows 10 version (that runs both on mobile devices with Windows 10 and on laptops/desktops) has currently 1,500 users.

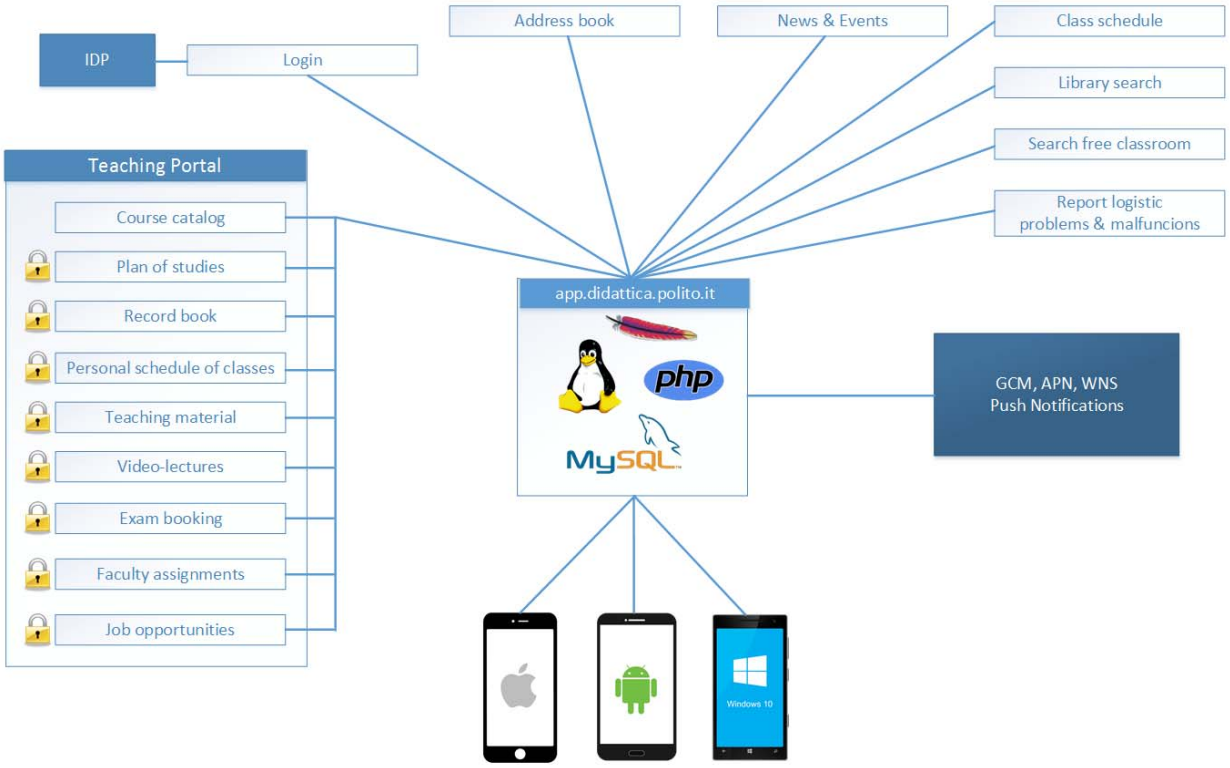

Figure 9 The PoliTO App general Architecture

The users' score of the PoliTO App is very good: 4.3 stars on Google Play (with more than 400 reviewers), 4 stars on AppStore and 4.8 stars on Microsoft Store.

From the architectural point of view, the PoliTO App has been designed and developed to follow as much as possible the Open Source philosophy that is valued in our university: it is based on a stack of open source components and software. The architecture builds around a central node that hosts a database and an application server, which is responsible for all the communication with the university and territorial information services, and

with all the mobile devices that run the App (Castaldo et al., 2016). Figure 9 outlines the PoliTO App architecture.

4.1 The Server-side Architecture

The central node, which is the hearth of the App, is based on the LAMP architecture (Linux, Apache, MySQL, PHP) and it hosts the application server. Its role is to deploy all services and information to the mobile devices that run the App, and it is where all the APIs reside. APIs are written in PHP and they are directly called by the App. The APIs allow for a transparent connection to the university or territorial information systems, and they manage, transform, aggregate and send in a packet all the data required by the App (Venturini et al. 2015).

The central node also hosts the database that stores all the information about the mobile devices that downloaded the App, to use them for authentication and notification purposes.

4.2 Authentication

The application server performs the authentication on the Politecnico di Torino IdP (Identity Provider), with the same credentials that students use for accessing the traditional web services and the e-mail account. In case of authentication success, the App receives a token that will be included in any successive data exchange with the application server. In this way the PoliTO App is always connected and authenticated, even after the logout of the current session or the reboot of the mobile device.

Authenticated users can access customized services, for example lecture schedule, exam booking, curriculum, and educational content including video-lectures.

4.3 The Client-side Architecture

The PoliTO App is a hybrid App developed using the Apache Cordova framework; this framework allows for the reuse of the same source code for a variety of mobile devices (based on iOS, Android and Windows). The client-side application is written in HTML5, CSS and JavaScript using the ONSEN and Angular frameworks (PhucHuy et al., 2012). The App has been designed to work in offline mode for some of the services, in order to reduce the number of requests to the server and consequently the network bandwidth. Specifically, content to be displayed is searched first in the local storage, and asked to the server only if necessary. Some of the services, of course, are real-time and available only in on-line mode, for example the classrooms accessible for study reasons or the public transportation timetable.

When a device runs the PoliTO App for the first time, all the information of the device and the downloaded App (operating system ad version, App version, unique registration ID, …) is recorded in the central database. After that, a public data package (that contains for example the contacts and the course catalog) is sent to the device to be stored in the local storage for later off-line usage. As soon as the user logs in, some more data is sent to the device to be stored in the local storage, including the information about his or her university career. A check for available updates is done every time the App is active and there is network connectivity. The PoliTO App, finally, can accept and manage notifications.

Figure 10 shows the requests made by the PoliTO App to the APIs, day by day. The number of requests is very high (up to 1,200,000 request per day), despite the fact that the App has been designed to limit the network traffic: students use it frequently, especially during the exam sessions (e.g., in July and October).

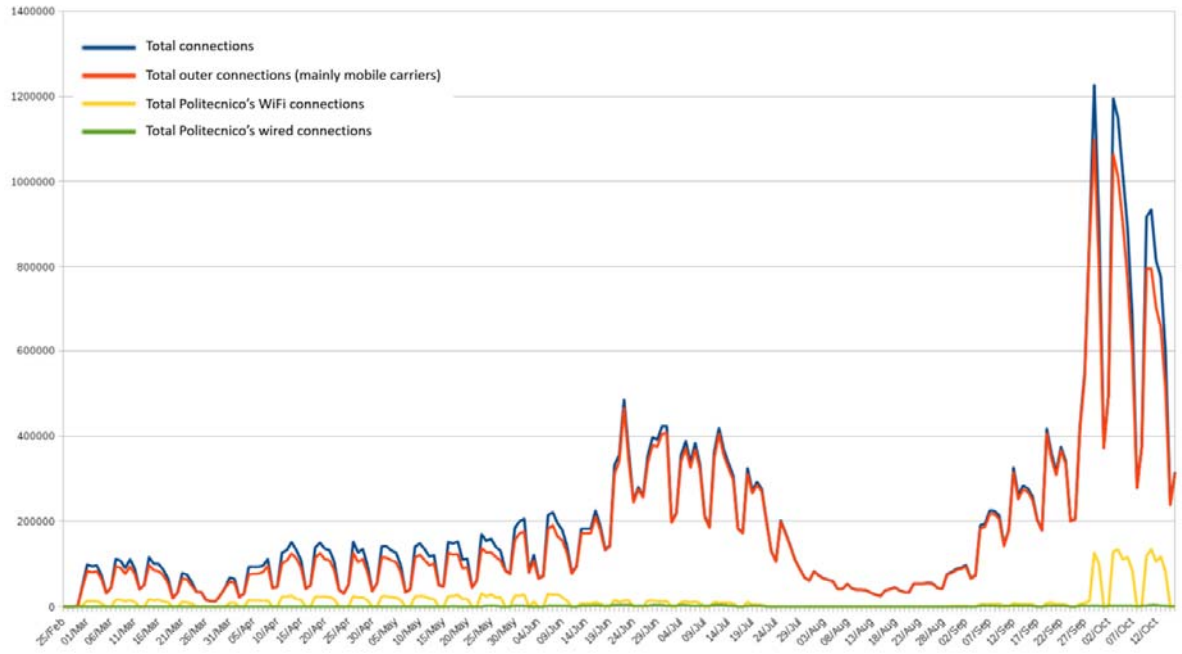

Figure 10 The PoliTO App PHP APIs Requests, Day by Day

4.4 The PoliTO App services

The design of the PoliTO App services and functionalities used data coming from the students' interviews, from the observation of the students' interactions in mobile App contexts, and from surveys in cooperation with institutions that are expert on the phenomenon of mobile interaction.

The PoliTO App is designed to offer information and personalized services to students, faculty and university staff. A non-exhaustive list of services includes: news and events, educational and job opportunities, real-time information on public transportation, class and exam schedules, library searches, access to the personal career, exam booking, signaling of problems or malfunctioning, access to personal e-mail, feedback on course quality, notifications, access to educational content including the video-lectures. Figure 11 shows a number of sample screenshots.

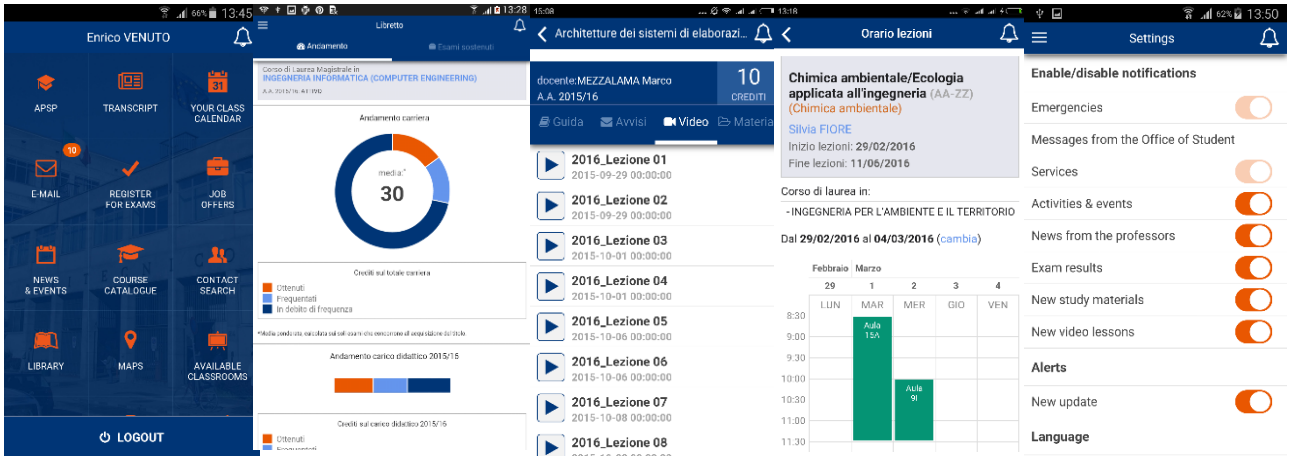

Figure 11 Some PoliTO Screenshots: Main Menu, Career Current Situation, Lectures' Schedule, Notifications' Settings

4.5 Notifications

One of the true added value of the App model, with respect to the responsive web and mobile web models, is the possibility to deliver notifications: together with the persistence of authentication, notifications implement the "always logged-on and on-line" paradigm. The "push model", where information is sent to the user as soon as it is available and without his or her direct intervention, overcomes the "pull model", where users always have to look for information. App notifications are divided in public and private, and each user can choose which kind of notifications he or she wants to receive (some of them, i.e., emergency warnings or important messages from the administrative staff are always enabled). Warning notifications are a really precious tool for emergency management, as they are able to reach in real time a very large number of users.

Everybody can receive notifications about news and events, but authenticated users can receive also notifications about their exam results, or about new educational content available. Figure 12 shows the notifications sent daily to the Android devices.

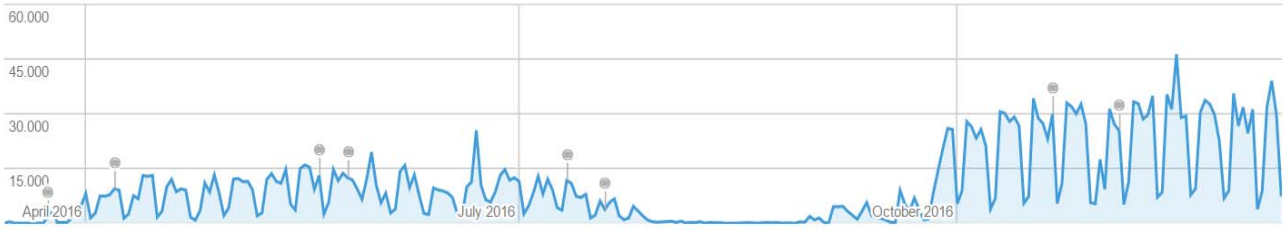

Figure 12 Daily Notifications (to Android Mobile Devices)

5. Conclusion

The paper describes the last six years of experience of Politecnico di Torino in the direction of a collaborative environment for deploying and exchanging educational content, with the specific case of video-lectures.

The adopted methodologies can be considered massive, since they involve a very large number of students, and since they are broadly adopted. These methodologies have been designed both to acknowledge the change of the educational processes and paradigms and to follow the fast evolution of the users' devices: increasingly powerful, media enabled, smaller and mobile.

The paper describes also the design and the development of the first official App of Politecnico di Torino, a hybrid App to deliver content and services mainly for educational purposes. This App is the last step of a process that started with traditional web sites and e-learning services to evolve first in a responsive web environment and then in a mobile web one. The choice of a hybrid App, with respect to a native App, has the advantage to exploit all the know-how acquired during the previous phases of the process. The success of the initiative is demonstrated by the numbers: in the first six months 26,000 students (out of a population 33,000) have been permanently connected. Besides, more than 5,000 users are people outside the Politecnico di Torino community that are interested in accessing public services (e.g., transportation timetable).

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