Educational ecosystems for Information Science: the case of the University of Pisa

Vittore Casarosa[a,b], Salvatore Ruggieri[a], Enrica Salvatori[a], Maria Simi[a], Simona Turbanti[a]

(a) University of Pisa, Pisa, Italy
(b) ISTI-CNR, Pisa, Italy

Corresponding author: Salvatore Ruggieri, Department of Computer Science, University of Pisa, Largo B. Pontecorvo, 3, I-56127 Pisa, Italy. Email: salvatore.ruggieri@unipi.it

Abstract

Interdisciplinarity is becoming increasingly important in education. With the rapidly evolving job market, an interdisciplinary education can prepare students for the flexibility and broad knowledge base required to adapt. At the University of Pisa, we recognized the value of an interdisciplinary educational environment during our participation in the European project EINFOSE, where we harmonized the entry requirements for master programs in Information Science. Prior to this project, we had been building study programs in Digital Humanities and Data Science, whose intersection organically nurtured a diverse learning space. Through this lens, we will reflect on the obstacles constituted by disciplinary barriers and stress the importance of a flexible and open 'ecosystem' for education. These conclusions will be supported by data analysis on the careers of our students over the last eight years.

Keywords

Information Science, Digital Humanities, Data Science, Educational ecosystem.

1. Introduction

The need for flexibility is imperative in a fast-changing world. In promoting computational thinking, Mike Resnick, MIT professor and one of the creators of Scratch[1], warned, "Roughly two-thirds of grade school students will end up doing work that hasn't been invented yet" (Resnick, 2017). There are important signals towards the importance of interdisciplinary education in providing the ability to cope with or even manage evolution. Thus, there is an increasing success and appeal of interdisciplinary studies, including Digital Humanities (DH), Data Science (DS), and Information Sciences (IS) among them. Data science is now considered "one of the sexiest jobs on the market" (Davenport and Patil, 2012). There are more employment opportunities for students from a DH background than their peers coming from humanities alone. For example, recent statistics on salary variation in Italy show that there has been a remarkable increase of 38% for Digital Humanities graduates, when compared to inflation. Library studies are gradually evolving into Information Science (IS) (see for example the iSchool movement). Important Computer Science Departments (like Carnegie Mellon University, or Georgia Tech) took the challenge to evolve into colleges or schools of Computing 'without walls', a trend documented in a white paper by the Computing Research Association (Brodley et al. 2016). Recent concerns about the successes of AI have compelled computer scientist to call for responsibility towards society in the Vienna manifesto on Digital Humanism[2], where, among other things, they state that "a vision is needed for new educational curricula, combining knowledge from the humanities, the social sciences, and engineering studies". Finally, the first university without disciplinary barriers (The London Interdisciplinary School) will open in London in 2020[3].

Participation in a European project to harmonize entry requirements in IS master programs (EINFOSE) made us aware of the wide area of Information Science and its different declinations across Europe. This urged us to look retrospectively at the value of the educational environment that was created around the University of Pisa, Italy, over the years, thanks to interdisciplinary study programs. Through this lens, we will reflect on the obstacles constituted by disciplinary barriers and stress the importance of a flexible and open "ecosystem" for education.

[1] https://scratch.mit.edu/
[2] https://www.informatik.tuwien.ac.at/dighum/manifesto/
[3] https://www.londoninterdisciplinaryschool.org/

The paper is organized into six sections. In section 2 we present our current view of the relations among the various fields related to Information Sciences: Digital Humanities, Data Science, Computer Science and Information Systems. Following an introduction to an education ecosystem in section 3, we will describe our experience within the EINFOSE project in section 4 and describe the IS ecosystem at the University of Pisa in section 5. Section 6 will be dedicated to present the results of a data analysis on the careers of our students, which will be helpful to support our conclusions.

2. Digital Humanities, Information Science and other related fields

In this section we will present our understanding of the relationships among the different fields neighbouring or contributing to Information Science. Disciplinary aspects of these interactions have been thoroughly investigated and reported in the literature, yet no consensus seems to emerge. Furthermore, the focus and definitions of the different disciplines seem to be rapidly evolving and reflect local cultural and organizational differences.

Within the scope of this paper, we use a broad reference definition of Information Science, "the discipline that studies the whole communication chain of recorded information", including all aspects of the creation, organization, management, and dissemination (Bawden & Robinson, 2015).

Library Sciences and Information Science

The concept of Library Science was first introduced in the manual of the German librarian Martin Schrettinger in 1834[4]; the first Library School was opened by Melvil Dewey in the United States in 1887 (School of Library Economy). The term Library Science appeared in 1931 in Ranganathan's *The five laws of Library Science*[5].

Library Science, especially in countries with Anglo-American tradition, has been most of the time 'embedded' into IS, under the acronym LIS (Library and Information Science).

To understand the Library and information science field it is important to consider that LIS is an academic broad discipline with a theoretical basis which supports practical activity. Within

[4] Martin Wilibald Schrettinger (1834). *Handbuch der Bibliothek-Wissenschaft, besonders zum Gebrauche für Nicht-Bibliothekare, welche ihre Privat-Büchersammlungen selbst einrichten wollen*. Wien: F. Beck. Complete digitalization is available at https://reader.digitale-sammlungen.de/de/fs1/object/display/bsb10858302_00005.html

[5] S. R. Ranganathan (1931). *The five laws of library science,* with a foreword by P. S. Sivaswami Aiyer and an introduction by W. C. Berwick Sayers. Madras: Madras Library Association; London: Edward Goldston.

it, historical subjects are included – such as bibliology, history of books, history of libraries, history of printing - as well as more technical subjects (library science, library management, theory and techniques of cataloguing and classification, etc.).

Library and information sciences have undoubtedly an interdisciplinary nature and the capacity of reconceptualizing the traditional knowledge and skills thanks to the application of new technologies.

Digital information contexts increase questions and doubts about the identity of the discipline and the profession and, consequently, about the appropriateness of LIS curricula.

Starting from Andrew Abbott's Chaos of disciplines theory[6] the "interstitial nature" of LIS has been theorized. Like other disciplines, LIS tends to occupy spaces between other scientific fields: "LIS is therefore in perpetual conflict with other disciplinary 'spaces', such as information technology, information systems, and computer science, and also within itself" (Raju, 2017). Furthermore, using new technologies LIS reconceptualizes old ideas and traditional knowledges in new languages and under different forms (tendency for "fractal distinctions in time"). In this way the "inherent nature of the LIS discipline presents epistemological opportunities to reposition the LIS discipline in a broadened or extended disciplinary space" and this may be an opportunity to strengthen the sector (Raju, 2017).

Several studies compare LIS and DH and argue that "both therefore still have a tension between their status as an academic discipline in their own right and as a support function for research in other disciplines" (Robinson, Priego & Baden, 2015).

As already mentioned, "it seems that the field of LIS constantly displays some form of conflict within itself over its purpose and its future. Crisis, so to speak, is LIS' natural state" (Dillon, 2007).

Other scholars have identified relations among Philosophy of information (PI), Library and information science and Social epistemology (SE) (Floridi, 2002) - a further evidence of the interdisciplinary nature of LIS.

In our country, the Italian ministerial framing of the discipline in the context of history holds together the historical and technical component of Library and information science, but it does not facilitate the recognition of the field.

[6] Andrew Delano Abbott (2001). *Chaos of disciplines*. Chicago; London: The University of Chicago Press.
The Chaos of disciplines theory was born to prove the evolution of disciplines within social science; it has been applied to research in LIS (Raju, 2017).

The risk faced by the scientific sector is to be considered subordinated to historical disciplines with a lack of academic weight and a stigma of 'inferiority'. This weakness is also reflected in the profession. A strong position of the discipline and of the educators is required to train serious library professionals both in the discipline's nomenclature – librarianship, library studies, library and information science, information science, information studies – and in the different scientific collocation of the LIS field within the university systems of the various countries.

Digital Humanities and Information Science

Several aspects of the relationships between the disciplines of LIS and Digital Humanities (DH) are examined in Robinson, Priego & Bawden (2015). They define DH as "the field at the intersection of computational technology and traditional humanities disciplines". They see a potential for merging the two areas for the fact that they have a similar vocational role of servicing other disciplines (for documentation and computing services respectively), they share context (humanities departments, close collaboration with libraries, archives, museums), they have a number of shared research areas with a focus on academic use of recorded information. In a similar vein, Chris Alen Sula (Sula 2013) presents a data analysis attesting a strong and growing presence of scholarly publications from DH in Information Science journals and takes this trend as an evidence that the LIS community is ready to join DH: "Given this significant overlap in interests, competencies, and institutional structures, we are left to wonder not whether but how libraries can join in the work of digital humanities" (Sula 2013). Sula also provides an interesting conceptual model for this integration, providing a taxonomy of the different kinds of tasks related to cultural contents: the first dimension is related to the distinction between first order contents (books, articles, images, audio recordings, 3D models) and their representations or data about them. i.e. second order contents; the other dimension refers to the amount of automation required for a task, going from tasks completely performed by humans to tasks completely delegated to machines.

While integration is an avenue that can be pursued and possibly prove beneficial for the success or even survival of both LIS and DH, we still can see important distinctions in the approach and concerns of the two disciplines.

Digital Humanities were born 'digital': they evolved from "Humanities Computing", a term stressing the application of computational tools to humanistic research, but the field is nowadays stretching to cover any form of digital culture, not only preservation, organization, management and communication of cultural assets but also in-depth analysis of digital

contents, production of novel contents and resources, and critical assessment of technology. This broader mission may be controversial and not universally shared, but it is certainly the one that inspired us since the degrees in "Informatica Umanistica" started in Pisa in 2002. Information organization, classification standards, preservation, information retrieval and communication, core topics in LIS, are naturally part of the picture, but DH is essentially about bringing computational tools in the analysis of contents (old and new) to discover or produce new analysis, services and cultural contents. Computational linguistics and Natural Language Processing, now blooming fields with important industrial applications, are clear examples of what was made possible by combining computational methods and linguistics. Another important field born out of the DH's is the Digital Public History, which deeply changes the approach to history-making and the role of historians. With respect to traditional humanities in fact, DH's introduce novel research practices. Computational methods were already mentioned, but DH introduce also interdisciplinary and collaborative teamwork, the value of open access publications and open data, compliance to standards, shared tasks and challenges. We may say that DH's are about the past but also about the present and the future: in order to anticipate and govern the evolution of culture you must deeply understand the digital world we live in.

Data science, Computer Science and Information Science

Data Science (DS) aims at making sense from data (Han et al., 2012) through a combination of theory and practice from Computer Science, Statistics, Domain Knowledge and Information Science. Before the wide spreading of the term, still with a restricted scope, it was known as business intelligence, data mining, knowledge discovery, and big data. Data Science tackles problems, in virtually any application domain, that can be solved through the data analysis lifecycle: data collection and storage; data querying and processing; data summarization and exploration; pattern extraction; inference of statistical and machine learning models; interpretation and validation of the extracted models; storytelling; and deployment in computing systems. Curricula of Data Science have been proposed at graduate level (see the European Data Science Academy Project[7]), at undergraduate level (De Veaux, 2017), and at primary and secondary levels (Pittard, 2018).

The relationship between Data Science and Information Science has been recently investigated in many papers. For example, (Marchionini, 2017) argues that, while Information Science deals

[7] http://edsa-project.eu/resources/curriculum/

with genesis, flow, use and preservation of information, Data Science shares with Computer Science the concern with algorithms and techniques for computational processes. Data Science comes into play as a fourth paradigm in science (after the empirical, theoretical and computational): data exploration in many different domains can lead to better decision making and to a new form of scientific discovery. Data exploration is however dependent on the ability to collect, organize, and analyse data streams. In particular IS, looking at the entire lifecycle of data, could bring to Data Science two fundamental contributions: 'data curation', to ensure the quality of data collections (data cleaning, the use of appropriate meta-data for preservation, evaluation and reuse), and the concern for the socio-cultural issues connected with data collection and use, such as for example informed consent, privacy, legal regulations. The conclusion is that core competencies in IS are essential to education in Data Science and that information specialists should have a place in this interdisciplinary endeavour.

Similar arguments in favour of 'twinning' Data Science with Information Science in LIS schools come from (Jafar et. al, 2017). They are based on the observation that the two disciplines have a consistent mission and greatly overlap, but they also complement each other. Data Science focuses on the data-to-information process, while IS focuses on the information and knowledge management process. In this sense, IS can contribute to the development of Data Science. For instance, the notion of data and data quality is an objective notion from a Data Science perspective, while for IS it is influenced by culture and social contexts, and then, as such full of bias[8]. As a second point, IS principles, theories, expertise and skills can be valuable in managing data throughout the Data Science lifecycle – a new subdiscipline called data librarianship. And finally, (Jafar et. al, 2017) propose that document theory (Buckland, 2018) should be introduced in Data Science to bridge its scientific/engineering orientations with the humanistic orientations.

3. Ecosystems for Information Science

An 'ecosystem' can be described as a "community network of interactions between organisms and their environment" (Mueller & Toutain, 2015). We will take the concept of ecosystem as a metaphor to describe the different actors of an educational system, the relationships among them and its evolution (conscious or spontaneous). We will clarify what we mean by educational ecosystem, before explaining the specific characteristics of the one we are

[8] Ethical issues in Data Science, such as bias and discrimination, have been raised only recently (Barocas and Selbst, 2016).

immersed in at the University of Pisa. In so doing, we will keep a special emphasis on Information Science.

"Academia is an ecosystem composed of several stakeholders including graduate and undergraduate students, faculty, staff, institutions, scientific societies, and funders, each with a role to play". According to some scholars, "the academic ecosystem has fluctuated gently within the slowly changing parameters of societal norms and expectations" and "stakeholders of academia must redefine our ecosystem in search of a new equilibrium" (Hagan 2019).

The environment

The environment is constituted by the town hosting the university, by the local institutions and services (transportation, housing, welfare, etc.), by the companies and research centres nearby, by the university organization and facilities (departments, research labs, lecture rooms, laboratories, libraries …).

The students

A clear mission attracts motivated students and builds a sense of belonging; it makes students feel that there is a community behind them and makes them willing to cope with challenges. For example, the London Interdisciplinary School tagline: "*For those who want to shape the world, not just fit in*" is a clear call to a specific type of student: ambitious, proactive, at ease with technology and social media, with an entrepreneurial mindset. This is especially important in new interdisciplinary fields of study, which are difficult to characterize.

The faculty

Faculty members provide bridges to other research institutions and to the job market. They should be willing to work together with colleagues from other disciplines and departments. Public-private partnerships should be developed to connect to the job market. Departments as disciplinary silos are an obstacle; shared places for interdisciplinary projects are necessary.

The curriculum

Students entering an interdisciplinary master level degree usually come from different bachelor's degrees and bring with them different backgrounds and personal attitudes. Entry requirements must by necessity be low and, therefore, flexibility is required in the study programs. It may be useful to trace and analyse the flows of activities within the system as

student select their subjects, thus tracing educational pathways, and the jobs they end up doing. New professional profiles may emerge spontaneously.

Delivery methods

Delivery methods are related to the degree of innovation in teaching. Students give their best when they are involved. Traditional ex-cathedra lectures are becoming more and more inadequate to provide the kind of stimulus students need. Students love to see the connection of what they are learning with their personal goals and learn best when they are working at their own projects, alone or in team with fellow students and mentors.

4. The experience within the EINFOSE project

The EINFOSE project[9] was an opportunity to frame our experience in running interdisciplinary studies with respect to the international panorama of IS study programmes and to compare it with other international experiences.

EINFOSE (full name: *European Information Science Education: encouraging mobility and learning outcomes harmonization*) was a project funded under the EU Erasmus+ program, running from 2016 to 2018 and involving eight universities (Filozofski fakultet, Sveučilište u Osijeku, Croatia; Högskolan i Borås, Sweden; Stiftung Universität Hildesheim, Germany; Universität Graz, Austria; Univerza v Ljubljani, Slovenia; Universitá di Pisa, Italy; Universitat de Barcelona, Spain; Hacettepe Universitezi, Turkey).

The main goal of the project was to investigate what are the commonly accepted entry requirements for master programs in Information Science, and what are the expected Learning Outcomes of those courses, with the objective of promoting a common view of Information Science at European level and to facilitate students' mobility across European universities.

The project activities were articulated in five "Intellectual Outcomes": (i) a platform (based on Moodle) to support the activities of the project; (ii) a Didactic Framework to examine different teaching methods; (iii) an Evaluation Framework to compare different learning methods, (iv) (two editions of) a Summer School to fill the "knowledge gap" of students enrolling in a master degree in Information Science without previous studies in IS; (v) Final recommendations.

The Summer Schools have been successful and in 2019, even after the end of the project, a third edition was held, supported by the partner universities. The main motivation for this "unfunded effort" is clearly the possibility to attract to master programs in Information Science

[9] http://einfose.ffos.hr/

students with a background different from IS, enhancing in this way the multidisciplinary aspects of the educational system, and providing to the job market "multidisciplinary professionals", which is clearly the emerging trend in IS, DH, and DS.

As expected, the project confirmed that there are wide differences in Europe for what concerns education in Information Science, mostly due to historical, cultural, social and economic factors, as well as to educational traditions and epistemological frameworks. Differences are found not only in the content and learning outcomes of IS degrees, but also in the entry requirements to enrol in master degrees in IS.

As stated in the final recommendations document, "… the partners agreed that harmonization of study programmes, entry requirements and job market expectations is advisable but should be pursued with caution and tolerance, due to rather fundamental differences across Europe in terms of ideas and traditions regarding educational institutions and systems on the one hand, as well as employment market in various countries on the other…". At the same time, the Higher Education Institutions should promote the variety of study profiles and potential job profiles of Information Science graduates to the potential employers in different countries.

As stated before, the participation to EINFOSE has given us the opportunity to compare our approach with that of other universities. Given the intertwining of IS and DH, it has been interesting to note that while in Pisa courses related to DH-IS have appeared in an ecosystem mostly based on Computer Science, in other universities courses related to Computer Science have appeared in ecosystems already established mostly in Information Science and Digital Humanities domains.

5. Information Science at the University of Pisa

The term "Information science" in Italy is closely connected with the beginning of computer science curricula in Pisa (exactly 50 years ago). It was 1969, and the founders decided to use the name "Scienze dell'Informazione", literally "Information Sciences", as the name of the new discipline in recognition of the fact that it was meant to be concerned with all aspects of information processing and "not only about computers" and with an eye to the kind of information processing going on in the business practice.

Later, when the Department was established, it was called "Dipartimento di Informatica" (literally "Department of Informatics[10]"), which was however translated in English as

[10] We are aware that in other contexts the term "Informatics" is a synonym of Information Science.

“Department of Computer science”, when this term became used world-wide for the core discipline.

In parallel, within the field of Humanities there were attempts to develop curricula oriented to library management and archives as part of a study programme on Cultural heritage preservation. Initially the curriculum was organized in a five-year degree course in Library and information science; then, after the university reform in 1999, the course became a three-year bachelor degree and a two-year master degree.

Within the course of study, in addition to academic credits (ECTS) in Archival and library sciences, it was mandatory to obtain credits in historical disciplines, computer science, chemistry, and juridical, economic, sociological and philological disciplines. Internships of 150 and 250 hours were required in archives, libraries or LIS companies. Due to different priorities in academic policies, in 2009 the LIS curriculum at the University of Pisa was closed and only a few courses of the original LIS curriculum are currently available.

Interdisciplinary curricula in Informatica Umanistica (Humanities computing, later Digital Humanities) and Business Informatics (later Data science & Business Informatics) were established soon enough, testifying the original ambitions of the founders of Computer Science to be broad and encompassing.

Informatica Umanistica was born in 2002 as a shared initiative of the Faculty of Letters and Philosophy and the Faculty of Sciences, Computer Science in particular. In 2010 the Laboratory for Digital Culture was established, as an inter-departmental centre gathering staff members from 5 different University departments (our shared home).

Informatica Umanistica today is one of the study programs managed by the Department of Philology, Literature and Linguistics, with a strong involvement of the Department of Computer Science and some contributions from the Department of Civilization and Forms of Knowledge. We offer both an undergraduate curriculum and a master level curriculum in Digital Humanities, with specializations in “Graphics, interactivity and virtual environments”, “Language technologies”, “Digital publishing” and “Knowledge management”. This last curriculum, Knowledge Management, is the one with most overlapping with the master degrees offered by the Department of Computer Science and, specifically, with Data Science and Business Informatics.

The Business Informatics graduate degree was established in 2002 as a joint initiative of the Faculty of Science, Computer Science Department, and the Faculty of Economics and Management. The study program included specific training in Business Intelligence for decision support, and it was designed to prepare graduates to master information technologies

and at the same time to understand the needs of organisations from a business point of view. Surveys revealed already at that time a demand for graduates with interdisciplinary skills to enable data-driven support to decision making. Such a demand continued growing in 2000's (Davenport and Harris, 2017), despite the 2008 financial crisis, and persisted in the early 2010's with the Data Science boom (Davenport and Patil, 2012). Business Informatics has been renamed to Data science & Business Informatics in 2017 to account for a broader scope of the topics covered. The curriculum is differentiated based on students' bachelor's degree. Mandatory courses include data mining (12 ECTS), logistics (6 ECTS), business process modelling (6 ECTS), data warehousing (6 ECTS) and a laboratory of data science (6 ECTS). Elective courses can be taken from a large set of Data Science subjects (machine learning, big data analytics, social network analysis, web marketing, text analytics, information retrieval, legal issues in data science, etc.), Business Economics subjects (management, accounting, strategic and competitive intelligence, etc.), and Mathematics subjects (statistical methods for data science, operational research, financial models, etc.). Students without a bachelor's degree in Computer Science or in Computer Engineering are taught at the beginning basic subjects of Computer Science (programming, databases, algorithmics).

A recent and successful restructuring of the master degree programme in Computer Science in 2017 represents the latest contribution to the IS ecosystem of the University of Pisa. The change aimed at organizing the master program into more specialized curricula, moving away from a foundational and broad type of education in computer science that the students and the job market did not appreciate anymore. Among the four curricula introduced, two of them specifically contribute to the most advanced aspects of IS: a curriculum in Artificial Intelligence and a curriculum called "Data & Knowledge". A deeper understanding of the mathematical foundations, algorithms, data processing techniques and machine learning models is expected from the students of these curricula, at the level where they not only should be proficient in the use of existing software libraries, but they should be able also to propose innovative methods and solutions.

Table 1 illustrates several subjects offered at the University of Pisa in the area of IS. They are organized from left to right with different shades of blue according to the course degree where they are offered and the amount of mathematical and computer science competences they require. Students of DH have the flexibility of choosing selected subjects from Computer Science according to their interests and personal attitudes, making it possible for a few of them to even access PhD studies in Computer Science or Data Science.

In synthesis, Information Science in Pisa did not develop as such but rather as a spin-off of other interdisciplinary adventures in education. One reason may be that the name was already taken, another one was certainly the existence of disciplinary barriers that prevented the colleagues from the History department (where LIS was originally taught) to embrace new challenges and possibly even a low interest to pursue these new challenges.

Nevertheless, we can say that students today can find in Pisa an ecosystem where they can become information specialists, as is shown in the following section. The EINFOSE project, was for us an opportunity to re-discover this interdisciplinary field and to reflect on the relationship of our curricula and research environment with respect to IS.

The IS educational ecosystem in Pisa

Pisa is a small town in the centre of Italy hosting a medium size university: under 100,000 inhabitants, more than 40,000 students. In addition to the University, two élite schools with high reputation and ranking are located in Pisa, the "Scuola Normale Superiore", specializing in sciences and humanities, and the "Sant'Anna School of Advanced Studies", specializing in economics and engineering. A neighbouring town, Lucca, hosts the IMT School for Advanced Studies, offering PhD programs in cultural heritage, neurosciences, economics and engineering. Finally, Pisa hosts one of the largest research centres of CNR (the Italian National Council for Research), with 15 research institutes and over 1,000 researchers.

Given this unique setting, together with a nice climate, good food and the presence of an international airport, Pisa attracts students and researchers from all over the world. As a result, the area around Pisa is also a lively ground for small and medium size companies and university spin-offs.

The IS educational ecosystem greatly benefits from this environment, which is a combination of the University cultural tradition and a close cooperation with nearby research institutions and companies. The Digital Humanities and Data Science study programmes could not exist without substantial contributions from CNR institutes and other schools in Pisa, which provide valuable collaboration in terms of teaching (mostly innovative subjects) and related research opportunities.

Figure 1 illustrates the wide range of academic subjects which contribute to education in IS at the University of Pisa: these are offered mainly as part of Digital Humanities and Data Science, with significant overlapping among the two; important contributions also come from traditional humanities on the left side of the picture, and computer science on the right.

The connection with the industrial world is guaranteed by internships, usually in the frame of bachelor's or master thesis. Such opportunities are taken by most of our students and they are facilitated by the presence of professionals from private companies among the lecturers. In addition, seminars with representatives from SME companies (as well as larger companies) and representatives from other research institutions are regularly organized.

Students come from all over Italy. Thanks to a large internationalization effort by the University of Pisa, recent years have witnessed an increase in students from extra-EU countries. The data analysis in the following section accounts for the diversity of background and provenance for both DH and DS students. This is at the same time a challenge and an opportunity.

By observing the flow of activities of our students within the IS ecosystem and their placement in the job market after they leave University, we may discover interesting trends. This data analysis was performed with the goal of showing that we do form information specialists, even if no curricula was specifically established referring to the IS discipline. This was not anticipated. In fact, it came somewhat as a surprise the placement of the University of Pisa in the QS World University Ranking 2019 as the 50th university in the world in Library and Information Management[11], and the 2nd in Italy after Rome "La Sapienza".

6. Summary data

We present in this section a quantitative analysis of enrolments and transcript of records of students from the Digital Humanities (DH) and Data Science & Business Informatics (DS) master degrees. Data was collected by the statistics offices of the University of Pisa.

Figure 2 reports the numbers of new students enrolled from 2011 to 2018. They range from 30 to 50 units per year, with an increasing trend in the recent years, and, except for 2017, they are comparable between the two master degrees. The bachelor's degree of new students is, instead, rather specific to each master degree. For Digital Humanities, Figure 3 shows that 40% to 60% of new students are coming from a bachelor in Humanities (Literatures, Philosophy, Languages, Cultural Heritage). Over the 8-year period, they amount to 53% of the total. Another 38% comes from the bachelor's in Digital Humanities itself, and a 6% from Computer Science. Economics and other degrees have residual percentages.

For Data Science & Business Informatics, Figure 3 shows a clear trend: new students from Computer Science are decreasing in percentage from around 75% in 2011-2013 to 35% in

[11] https://www.topuniversities.com/

2017-2018. At the same time, students from Economics and other bachelor's degrees (Mathematics, Physics, Engineering) have been increasing, reaching about 60% in 2018. Such trend can be attributed to an increased attractiveness of the study program for students of Economics and other bachelors. In fact, the absolute numbers of new students from Computer Science remain stable over the years. Finally, there is a non-negligible flow of enrolments from the Digital Humanities bachelor, which is in the range 5%-10%.

Let us now focus on the interest of students in attending courses of the Information Science area. We have identified a set of 36 IS related courses over a total of 228 courses[12] offered by the two master degrees during the reference period. Such a set includes courses of library science, human language technologies, information retrieval, e-publishing, semantic web, data bases and mining, social network analysis, statistics for data science, visual analytics. Figure 4 shows the percentage of credits in IS related courses distinguished by master program. The top plot is for all students. It shows that IS related courses are more frequently selected by Digital Humanities students than by Data Science & Business Informatics students. The gap appears to be decreasing, moving from 30% in 2011-2013 to 15% in 2016-2017[13]. However, these conclusions may be affected by missing data on courses yet to be taken by students. The bottom plot is for students that are already graduated, and it corrects for such a problem. It turns out that IS related credits stably range between 50% and 60% for Digital Humanities students, and between 30% and 40% for Data Science & Business Informatics students. In the latter case, an increasing trend is clearly visible. It can be attributed to a revised offer of courses which, starting from 2014, increased the set of eligible courses in IS by reducing the number of mandatory courses in Economics.

Figure 5 shows further detail by distinguishing the percentage of IS related credits by the bachelor's degree of enrolled students. Regarding the Digital Humanities master, students with a Computer Science bachelor exhibit a larger variation over the years compared to those with a (Digital) Humanities bachelor. Such a difference in variability is not observable instead for students of Data Science & Business Informatics. However, in both cases, the differences among students of different bachelors are becoming less pronounced.

In summary, the data highlight that: (1) students are increasingly being attracted by master programs that complement their skills with multi-disciplinary competencies; (2) IS-related

[12] The total number includes free choice courses taken from other study programs at the University of Pisa.

[13] Notice that the 2018 enrolment year is missing because of incomplete data about passed exams at the time of writing.

courses represent the largest component of students' curriculum of DH and DS master programs; and (3) the weight of IS-related courses is higher for Digital Humanities compared to Data Science and Business Informatics, where mandatory courses in the areas of Mathematics, Computer Science and Business limit the set of elective subjects.

7. Conclusions: old walls and new barriers

Academics need to recognize that their impact on society and industry is valuable and of vital importance. This is especially difficult to grasp for traditional humanities, but it is becoming of paramount importance and not only for IS. We are living in a fast-changing world, in terms of competencies, disciplines and jobs. On the one hand digitalization and technological progress, made possible by the new wave of Artificial Intelligence, are destroying a lot of traditional jobs. Those jobs that do not require creativity and human responsibility (i.e. generic employees, white and blue collars) will be the first ones to disappear, while jobs related to research, artisanship, engineering, medicine and the like are expected to last longer. On the other hand, the new jobs required today by the market (several economists and sociologists think the trend will continue in the future) have few connections with the traditional educational framework of the disciplines and those jobs strongly call for an interdisciplinary approach, for a different gamut of competencies and for soft skills.

We, as Universities, are at a crucial turning point. If we are not able to offer a flexible educational program and different learning methods, we will be doomed to be deserted and substituted by other educational institutions and, more than this, we will be in part responsible for the global economic crisis. Instead, if we develop the ability to surf this wave, we will contribute to improve our future.

The experiences of study programs in Digital Humanities and in Data Science and Business Informatics at the University of Pisa are paradigmatic in this sense. They were conceived as multi-disciplinary programs since the beginning and designed to let students with different bachelor's degrees follow their own path. Courses with projects and internships in companies and institutions are definitely encouraged. Summary data reveal that flexibility in the study programs is highly appreciated by the students, and that IS-related subjects represent the largest component of students' curriculum. The lack of a complete IS study program is mainly due to historical reasons and is common to the Italian scenario. Graduates are highly sought after in the job market, and often they are assigned a responsibility role.

It's not all fun and games, though.

The rise of multi-disciplinary study programs is often (and it certainly was in Italy in early 2000's) slowed down by "walls" among disciplines. First, a rigid categorization of disciplines is ubiquitous in the organization of the Italian University system, since it governs the scope of Departments, the design of new study programmes, the evaluation of researchers' activities, the advancements in career and the assignment of research funds. Second, much time is spent in defining new barriers, i.e. what a discipline is not about, defining its focus, defining its research methods and shared vocabulary, defining its philosophical underpinnings. Although it is natural to try to define the boundaries of a discipline, and this need is understandable in terms of academic career and recognition, we think that this should not be the main objective. An educational ecosystem is made of communicating environments and collaborating partners and not made of separate 'pieces'. At the university, we need disciplinary experts but also explorers and pioneers, people building bridges across disciplines. It would be important if universities could come out of their 'education comfort zone' and adventure with greater courage into interdisciplinary grounds where different disciplines compare and integrate. As Italo Calvino wrote in a famous novel: "Se alzi un muro pensa a ciò che resta fuori" ("If you build a wall think of what you leave outside").

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Tables

Table 1. Three study programmes contributing to the IS ecosystem

Digital Humanities	Data Science & Business Informatics	Computer science
Curricula: *Digital publishing* *Knowledge Management*		*Curricula:* *Data & Knowledge* *Artificial Intelligence*
Topics: *Basic programming skills* *Databases* *Web design* *Human Computer Interaction* *Digital libraries* *Digital publishing* *Data journalism* *Knowledge management* *Text encoding* *Digital philology* *Natural language processing*	**Topics:** *Programming for data science* *Advanced databases* *Data warehousing* *Data mining* *Social network analysis* *Data visualization* *Web marketing* *Text analytics*	**Topics:** *Advanced programming* *Advanced databases* *Information retrieval* *Semantic web* *Artificial Intelligence* *Machine learning* *Human language technologies*

Competencies in math and computer science

Figures

Figure 1. An educational ecosystem for IS.

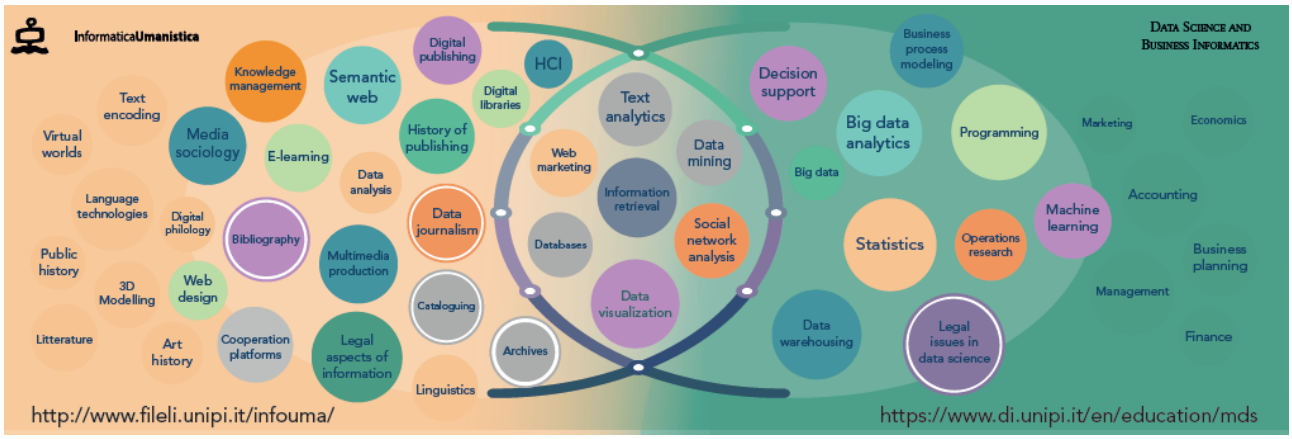

Figure 2. Number of students enrolled by year.

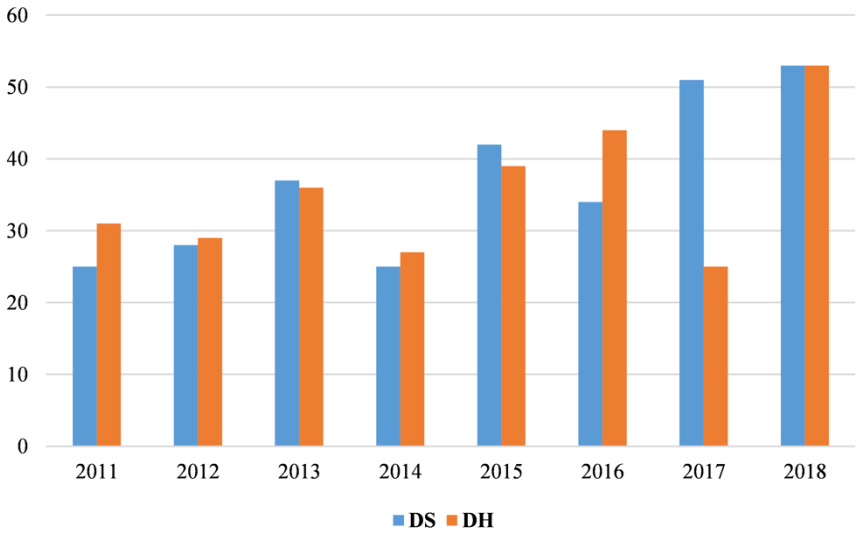

Figure 3. Student Bachelor's degree by year of enrolment. Legend: CS (Computer Science), DHB (Digital Humanities Bachelor), ECO (Economics), HUM (Humanities), OTH (Others).

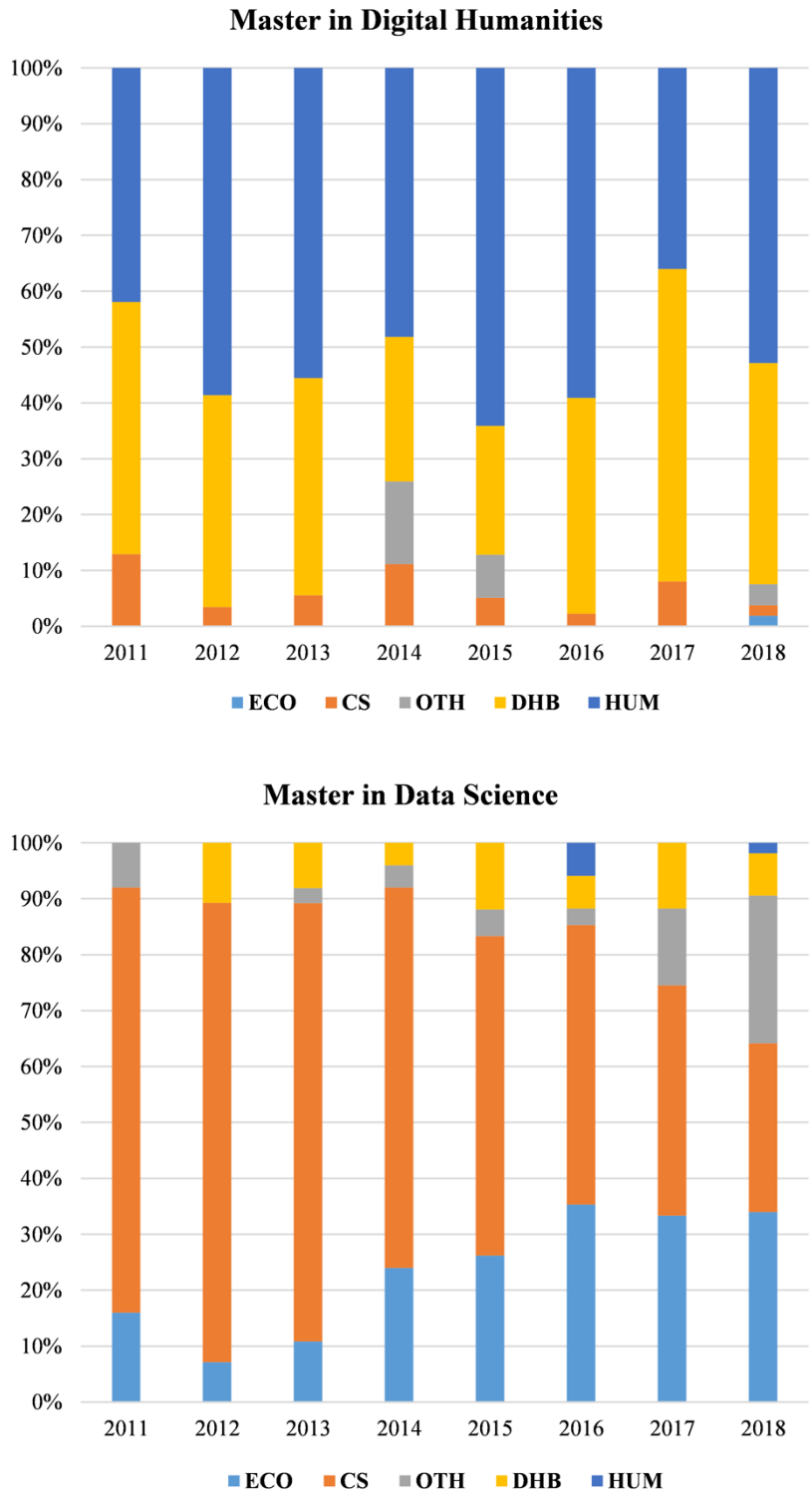

Figure 4. Percentage of IS related credits by year of enrolment.

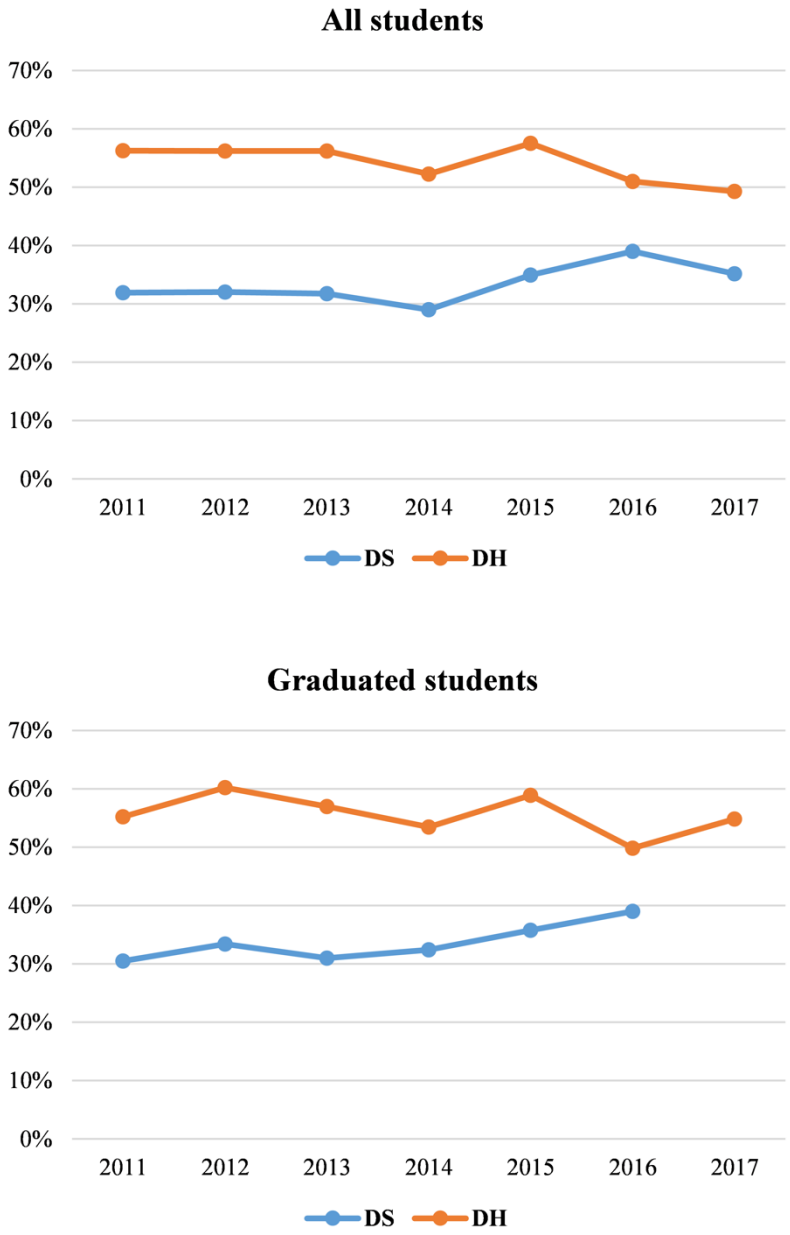

Figure 5. Percentage of IS related credits by year of enrolment and by Bachelor degree. Legend: CS (Computer Science), DHB (Digital Humanities Bachelor), ECO (Economics), HUM (Humanities).