

GEE Paper

143

Março de 2018



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Gabinete de Estratégia e Estudos

Digital innovation in higher education: A questionnaire to Portuguese universities and polytechnic institutes

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Abstract

Over the past decade, the societal impact of digital transformation, with the prospects of a Fourth Industrial revolution, has led to an innovation imperative in European policymaking regarding Higher Education Institutions (HEIs). This article examines Portuguese universities and polytechnic institutes, the two components of the national higher education system, in order to (1) characterize digital infrastructure, networks and equipment availability (hardware and software), (2) describe the self-reported digital practices among Portuguese HEIs' faculty members, and (3) verify the alignment between faculty members' digital practices, teaching environment and European recommendations for digital education. The study, descriptive in nature, conducts the most comprehensive online questionnaire available to date on digital innovation in Portuguese HEIs (N=547). The main constraints to digital innovation in Portuguese higher education teaching are the limited infrastructure and resources, a conservative academic culture, a lack of funding opportunities, insufficient technological resources and technical support.

JEL Classification: I23

Keywords: Digital innovation; Higher education; Infrastructure; Faculty; Digital practices

Note: This article is sole responsibility of the authors and do not necessarily reflect the positions of GEE or the Portuguese Ministry of Economy. This paper was one of the winners of the Call for Papers about R&D and Innovation in Digital Economy (GEE and ANI)

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1. Introduction

Over the past decade, digitization and innovation became keywords in European policymaking. The European Commission and several other international organizations propose a greater and deeper level of integration of digital technologies across sectors, including Higher Education Institutions (HEIs) (European Commission, 2018; OECD, 2019). This European push towards innovative uses of emerging and existing technologies in educational settings is a response to the global processes of the digital transformation of societies and the prospects of a Fourth Industrial revolution. Growing concerns in the European policy agenda are both an innovation gap, the proposition that HEIs need to reinforce their contribution to the economy, and a digital skills gap, the lack of essential digital skills among European citizens.

Portugal has been active in following European recommendations for the digitization of Education, but efforts often emanate from individual HEIs rather than from policymaking (Dias & Gomes, 2018). The call to implement a “Bologna Digital” (Rampelt, Suter, Orr, Hijden & Röwert, 2018) and a Digital Education Action Plan (European Commission, 2018) pressures HEIs to focus on different action lines, such as digital teaching and learning, internationalization and mobility or quality assurance. Further pressures stem from the structural deficit on skills and the mismatches between expected skills and current needs of the labour market (DGES, 2018; Figueiredo, Biscaia, Rocha & Teixeira, 2017).

A comprehensive study regarding the digitization of HEIs, in terms of infrastructure, teaching practices and knowledge of the actions and priorities, is lacking. As such, the main objectives of this study are to (1) characterize digital infrastructure, networks and equipment availability (hardware and software), (2) describe the self-reported digital practices among Portuguese HEIs’ faculty members, and (3) verify the alignment between faculty members’ digital practices, teaching environment and European recommendations for digital education.

2. Innovation, digital technologies and education

Innovation in education systems can be understood “as the adoption of new services, technologies, competences by education organizations”, which “can help to improve learning outcomes, enhance equity and improve efficiency” (European Commission, 2018, p.2). In this regard, the Digital Education Action Plan (European Commission, 2018) expresses three key political priorities: (1) making better use of digital technology for teaching and learning, (2) developing relevant digital competences and skills for the digital transformation, and (3) improving education through better data analysis and foresight. In addition, it sets out measures to support EU Member States address explicit challenges, such as providing tools to help teachers make better use of technology, including better infrastructure and internet connectivity, develop relevant digital competences or improve education via better evidence and analysis.

Digital technologies can have a profound impact on economies and societies (Graham & Dutton, 2019) and their potential to innovate teaching and learning processes, and foster mobility is widely recommended and documented (European Commission, 2018; Serdyukov, 2017; Veletsianos, 2016). Education is clearly pointed as critical for the development of skills that nurture new ideas, technologies, employability and competitiveness (OECD, 2019; United Nations, 2017). However, despite efforts to modernize teaching, learning and assessment processes with the support of digital technologies, education systems continue to fail in maximizing their potential to innovate and equip students with the necessary skills to operate in a changing digital society (Price & Kirkwood, 2014; Selwyn, 2016).

Based on evidence collected across ten European universities, a recent study on the barriers and drivers of innovation in higher education found three major cluster of hurdles: external macro-level barriers of innovation, internal barriers acting within the participants’ organizational environment, and barriers on the individual level. In summary, the main issues are: disparities between needs of HEIs and regulatory framework, tensions in academia business-cooperation, inconsistent technological developments, blocked management, rigid human resource management operation, and unprepared academic staff (Lašáková, Bajžíková & Dedze, 2017). One of the cited issues of unpreparedness relates with the insufficient ICT-related skills found among participating teachers. Teachers’ self-confidence and belief in the pedagogical value of digital technologies is known to be an important driver for innovative pedagogical approaches (Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017).

There are few studies on the use of digital technologies in Portuguese Higher Education as a whole, i.e. comprising universities and polytechnic institutes from public and private spheres. A different number of studies are available but reflecting individual cases and embracing different foci of analysis, such as specific technologies or students and teachers’ perceptions regarding different tools (Torres et al., 2013; Costa, Alvelos & Teixeira, 2016; Ferreira, Silva & Valente, 2018; Maia, Borges, Reis, Martins & Barroso, 2018).

A study carried out between 2011 and 2014 (Almeida et al., 2014) concluded that digital technologies were mainly used in an instrumental way and functioned as a resource repository rather than as a driver for learning mediation and innovative teaching practices. The study aimed at identifying the communication technologies that were being used in Portuguese Public Higher Education (PPHE), analysing the purpose of their use in educational contexts and examining their impact on teaching and learning processes. Researchers questioned nine PPHE and 185 teachers and interviewed 11 teachers from the different participating PPHE. They found that, in general, PPHE provided the necessary technological infrastructure to enable teachers using digital technologies in their practices but did not provide technical support to help

them design or develop pedagogical strategies for their effective use. The predominant technologies used by teachers were the institutional Learning Management Systems (LMS) and email, mainly to share content and resources. The use of these and other tools for collaborative or assessment practices was little evident. Concerns put forward regarding the use of digital technologies in the future included budget to modernize, update and maintain available equipment and infrastructure and teacher training.

Another study (Mesquita, Peres & Moreira, 2018) questioned 109 teachers and 337 students regarding digital technologies used in the classroom, as well as the purposes of use. Triangulation between teachers and students' responses revealed that the most used technologies were the laptop and the data projector to visualize presentations, and the Moodle platform to make material in digital format available. Teachers referred they used technology to facilitate the creation and storage of files, to communicate with the students and to allow the implementation of more efficient collaboration and assessment methodologies. On the contrary, students' responses suggested they used technology mostly to download content and perform study-related tasks. Their responses also showed they would like technology to be used to promote project-based learning and transform assessment strategies. Authors concluded that the majority of teachers were not prepared to select, and plan technology use to support and enhance teaching and learning strategies. Reasons put forward include the lack of training to explore the pedagogical potential of technology, lack of time to plan and implement technology-based activities and teachers' lack of confidence to teach with technology.

The innovative capacity of digital technology is highly dependent on the level of digital competence of teachers. They are key to use it creatively, efficiently and with good pedagogical judgement (Krumsvik, 2014). This includes being able to use digital technologies for their individual professional development, for identifying and fitting resources to their learning objectives and learner group, orchestrating digital teaching strategies or analyses and interpreting digital evidence to inform teaching and learning (European Commission, 2018; Redecker, 2017). This digitization of education poses significant challenges to teachers, especially to those who may have never been taught how to use digital technologies during their own teacher education (in cases where HEIs teachers have received teacher training - cf. Santana, 2016) or have not received training on such use as part of their professional development. Possibly for these reasons, the level of HEIs teachers' digital competence, not only among Portuguese HEIs faculty members, is reported to be insufficient (Silva et al., 2014; Jääskelä, Häkkinen & Rasku-Puttonen, 2017; Koskinen, 2015; Watty, McKay & Ngo, 2016).

3. Research methods

3.1. The online questionnaire: sampling and data collection

There are 34.227 higher education teachers officially registered in Portugal (PORDATA, 2018). The target participants for our study were faculty members engaged in teaching in Portuguese HEIs, distributed by a dual system composed of universities and polytechnic Institutes, across the public and the private sectors, in all scientific domains and Portuguese regions. No previously published study developed such a comprehensive inquiry on digital innovation in Portuguese HEIs. In order to contribute with a substantial and updated groundwork for a more nuanced discussion and policymaking, we adopted an exploratory research framework aimed at generating unprecedented empirical data that can conduct to a clearer problem formulation, as well as to research design improvements. We departed for this study by composing a maximum variation/heterogeneous purposive sample based on the fundamental inclusion condition of being publicly identified as a faculty member on the institutional web page (e.g. department, college, school) of a Portuguese HEI, covering all officially registered universities and polytechnic institutes, across the public and the private sectors, in all scientific domains and Portuguese regions. Using this exploratory sampling criteria, a database with 8563 entries was composed. No statistical representativeness is claimed.

Quantitative research is adequate to collect the attitudes of the respondents based on structured questionnaires. As such, our exploratory inquiry has found in the social survey a useful methodological approach. Particularly, the online questionnaire allowed researchers to cover a large sample and produce general descriptive and analytical statements. Despite its unavoidable usefulness as a means to allow weighted generalizations through a self-completion questionnaire in a relatively short time for reduced costs, the online questionnaire comes with the epistemological peril of subsuming distinct cultural settings under the quantitative umbrella: besides not looking directly to subjects' behavior but rather to what subjects say they do, it leaves significantly obscured the "why" and the "how", indispensable for the study of social phenomena (e.g. Buckingham & Saunders, 2004; Dillman, 2007; Iarossi, 2006).

For data collection, an online questionnaire was designed using the Qualtrics Survey web-based platform, containing seven sections: (i) socio-demographic composition, (ii) infrastructure and digital networks, (iii) digital skills for teaching, (iv) mobility and professional experience, (v) teaching environment, (vi) knowledge of the European digital innovation agenda, and (vii) constraints to innovation. These sections comprised 37 questions mapped directly on to the research objectives articulated above and summarized in Table 1.

Table 1 - Relation of research objectives

Research objectives		Questionnaire section	Questions
#1	To characterize digital infrastructure, networks and equipment availability (hardware and software) in relation to faculty members self-reported practices;	(ii) infrastructure and digital networks;	Q9-Q11
#2	To characterize the self-reported digital practices among Portuguese HEIs' faculty members;	(i) socio-demographic composition; (iii) digital skills for teaching;	Q1-Q8 Q12-Q22
#3	To verify the alignment between faculty members' digital practices, teaching environment and European recommendations for digital education;	(iv) mobility and professional experience (v) teaching environment; (vi) knowledge of the European digital innovation agenda; (vii) constraints to innovation;	Q23-Q24 Q25-Q29 Q30-Q36 Q37

The questionnaire principal aim was to establish background information about the respondents (Q1-Q8), their self-evaluation regarding the quality of Internet connection, hardware and software as available in their specific teaching context (Q9-Q11), their self-assessment on their own digital educational practices (Q12-Q22), their activity in national and/or international networks as well as international teaching experience (Q23-Q24), their level of autonomy, collaboration and/or competition among peers and administration/managerial tasks (Q25-Q29), their acquaintance regarding the topics of digital transformation, innovation, contemporary societal questions, multidisciplinary, the Fourth Industrial revolution, knowledge transfer and entrepreneurship (Q30-Q36), and, finally, the most influential factors constraining innovation in their specific teaching contexts (Q37).

Except for the socio-demographic (Q1-Q8) and constraints to innovation (Q37) sections, which employed drill down and multiple-choice question types, all the other sections were based on matrix tables using a 5-point Likert scale. Analysis of the collected quantitative data included calculation of the percentages of responses and, in the case of Likert scales, calculation included mean averages and standard deviations of the sample.

The online questionnaire was pretested with a group of 11 HEIs' faculty members. This sample of potential respondents assessed needs for revision and improvement in survey design. The main objective was to check wording, technical jargon and conceptual clarity, spell checking and navigation structure.

According to the pilot's group feedback, minor adjustments were implemented in order to optimize instructions' comprehension and readability (e.g. normalization of expressions in Portuguese), as well as questionnaire digital user experience (e.g. introduction of a backspace button). After operationalizing these adjustments, the definite data collection instrument was created. Participants were individually contacted via the institutional email made publicly available on their educational institution website. Informed consent was obtained by explicitly explaining the research objectives, the intervenient researchers and their institutions and the terms of the applicable privacy and anonymity regulations both in the email body and in the questionnaire header. The online questionnaire was released on May 3, 2019, only accessible by direct link and distributed amongst the sample database. Individual reminders were sent weekly, in a total of three. The questionnaire was closed on 30 May 2019.

3.2. The respondents

A total of 642 responses were collected. Of these, 95 respondents (14.8%) did not supplied complete answers to all questions and/or dropout the online questionnaire. These were excluded in benefit of analysis consistence. Although considering the purposive sample database of 8563 entries the response rate is low (N=642, 7.5%), the present study, descriptive in nature, conducts the most comprehensive online questionnaire available to date on digital innovation in Portuguese HEIs (N=547).

Regarding the sample structure, respondents are female (52.3%), male (47.4%), and non-binary (0.3%), with a mean age of 40.2 years old (SD=9.2), working as faculty members at the university (49%), the polytechnic (45%) or in both (6%) systems, across the public (81%) and the private (19%) sectors, in all Portuguese regions: North (29.8%), Center (20.7%), Lisbon Metropolitan Area (26.5%), Alentejo (8%), Algarve (6.6%), Azores AR (5.5%) and Madeira AR (2.9%). Most respondents are included in the categories of Assistant Professor at the University (30.9%) and of Adjunct Professor at Polytechnic Institutes (29.1%), across all scientific domains: Social Sciences, Arts and Humanities (53.4%), Exact Sciences and Engineering (28.7%), Life and Health Sciences (11.9%) and Natural and Environmental Sciences (6%). Faculty professional experience fell within a range from 1 year to 48 years, with the mean professional experience being 18.9 years.

4. Results

4.1. Digital infrastructure, networks and resources

Our findings reveal that the main constraints to digital innovation in Portuguese higher education teaching are (#1) the limited infrastructure and resources, (#2 ex-aequo) a conservative academic culture and a lack of funding opportunities, (#4) lack of technological resources and of (#5) technical support. Respondents were asked to select the three most influential factors, allowing for multiple combinations in a sample of 547 respondents. An overview of the constraining factors for innovation in Portuguese HEIs is available in Table 2.

Table 2 - Main constraints to digital innovation in Portuguese HEIs

	Factor	Percentage	N
#1	Limited infrastructure and resources	14.9%	245
#2	Conservative academic culture	11.5%	189
	Lack of funding opportunities	11.5%	189
#4	Lack of technological resources	11.4%	187
#5	Lack of technical support	10.7%	176
#6	Lack of leadership and vision	6.9%	114
#7	Centralized management model of the institution	6.7%	110
#8	Lack of collaboration among peers	6.6%	108
#9	Unsatisfactory remuneration	6.2%	101
#10	Aged faculty	5.8%	95
#11	Inadequate administrative organization	4.8%	78
#12	Rigid and inflexible norms	3%	49

An aggregate of 82.9% respondents working in polytechnic institutes claim to totally (38.6%) and partially (44.3%) agree that the quality of the available Internet connection in their HEIs is adequate. Their peers in the university express greater discontent, with an aggregate of 72% stating that it is totally (33.2%) and partially (38.8%) adequate to teaching/learning activities. On the other hand, HEIs' location

appears as a factor of asymmetry in the national territory: while an aggregate of 97.3% (N=36) of faculty members working in Algarve are the most satisfied with the network connection, followed by colleagues based in the Madeira AR (81.3%, N=16), an aggregate of 70% of faculty members working in the Azores AR (N=30) are the ones claiming that the available Internet connection in their institutions is inadequate. These findings suggest that national asymmetries prevail regarding the connection to the global computing network not only between regions (NUTS), but particularly between the two Atlantic autonomous regions.

In both Portuguese higher education contexts, comparing with the infrastructural conditions, the overall levels of perceived adequacy fall when faculty members evaluate the available digital resources (hardware and software): an aggregate of 65% in polytechnic institutes and of 60.1% in universities. Once more, HEIs location appears as relevant: while an aggregate of 83.4% (N=36) of faculty members working in Algarve are the most satisfied with hardware and software at disposal, followed by colleagues based in the North (65%, N=163), an aggregate of 76.7% (N=30) of faculty members working in the Azores AR are again the ones claiming that the available digital resources in their institutions is inadequate.

Most Portuguese HEIs' faculty members, an aggregate of 67.7% (N=370), state that the digital strategies they implement are highly dependent on the availability of students' digital resources. Respondents from the Madeira AR deviate from this overall tendency with an aggregate of 43.8% partially (37.5%) and totally (6.3%) disagreeing. Complementary, faculty working in the Natural and Environmental Sciences are, by scientific domain, the ones who express a different opinion, with an aggregate of 30.3% stating that their digital strategies are not dependent on the availability of students' digital resources.

Analysing a second layer of constraints to innovation in Portuguese HEIs, faculty working in the Azores AR stand out as those for whom a centralized management model of the institution in which they work (12.2%) is a barrier to innovative teaching practices, compared to a national mean of 6.7%. On the other hand, respondents working in the Madeira AR are by far the ones less satisfied with the lack of funding opportunities (22.9%), compared with a national mean of 11.5%. Full Professors at universities are the ones most signalling aged faculty as a barrier to innovation (27.3%), compared with a national mean of 5.8%, as well as a lack of leadership and vision (15.2%), compared with a national mean of 6.9%. Portuguese faculty members working in the private sector tend to see more financial remuneration as a constraint to innovation (11.9%) than their colleagues in the public sector (4.8%). Particularly, faculty working in the North are the ones most signalling an unsatisfactory remuneration as an obstacle to innovation (10.2%), compared with a national mean of 6.2%.

4.2. Digital practices among Portuguese HEIs' faculty members

One of the key competence teachers need is to effectively identify and create resources that best fit their learning objectives and support their teaching. With regards to this, 92.5% of Portuguese HEIs' faculty members declare to use different internet sites and search strategies to find and select a range of different digital resources for their teaching. Most refer to do it frequently (57.2%), while less admit doing it occasionally (18.8%) and always (16.5%). In line with this, 81.7% recognize they create their own digital resources and modify existing ones to adapt them to their needs: 43.3% claim to do it frequently, 23.0% occasionally and 15.4% always. Within the different professional categories, the percentage of respondents claiming to never create and modify resources correspond to Assistant Professors (45.5%). Curiously, Assistant Professors are also the ones who report to always do it (41.7%).

Another key competence is to design new ways of promoting collaborative learning activities. Again, respondents claim to use digital technologies to experiment with new formats of collaborative learning occasionally (41.5%), frequently (30.5%) and always (5.5%). This claim is more notorious among teachers from the polytechnic institutes (80.9%) than among teachers from universities (73.8%). Those who state to perform such experiences more often (sum of options always and frequently) are in the Madeira AR (43.8%) in contrast with those from the Alentejo (29.5%). Again, Assistant Professors' responses are more expressive at the extremes of the answer options: never (51.2%) and always (40.0%). Interestingly, the percentage of teachers monitoring their students' activities and interactions in the collaborative online environments they use is lower in all options expressing frequent use, namely always, frequently and occasionally (67.6%). An aggregate of 32.6% admits to rarely (22.7%) or never (9.9%) do it. In contrast, the combined percentage of 83.0% refers to frequently (45.5%), occasionally (23.6%) and always (13.9%) use digital technologies to provide students with timely and effective feedback on a frequent basis. Responses from teachers located in the Madeira AR are null to what the options never and rarely are regarded. As such, these teachers are the ones who most implement this practice, followed by those from the Azores, who report an absence of the never option and only 10% in the rarely option. Teachers located in the Centre are the ones who least implement this practice, stating to never (4.4%) and rarely (15.9%) doing it.

As stressed by the EU Digital Education Action Plan “personalized teaching can result in increased motivation by focusing on individual learners” (p. 2). In line with this assumption, results suggest that, overall (74.0%), HEIs' faculty members use digital technologies to offer students personalized learning opportunities. Still, 17.2% admit using them rarely and 7.9% to never use them for such purposes. Also, less teachers (63.5%) make use of digital technologies to allow their students to reflect on and self-evaluate their learning process. A higher percentage refers to use them occasionally (33.5%), rather than frequently (25.2%) or always (4.8%), and this practice is more evident among polytechnic teachers (68.7%) than university teachers (56.7%). Digital technologies can furthermore be used to shift the focus of the teaching process from teacher-led to student-centred processes, enabling students to actively engage in classes. Teachers from both higher education contexts claim to use digital technologies for students to actively participate in class. An aggregate of 74.9% claim to use them occasionally (35.8%), frequently (32.0%) and always (7.1%). However, almost half of the respondents do not take full use of digital technologies to monitor their students' progress (44.9%), nor take advantage of the data generated in digital environments/tools to inform their teaching practices (43.0%).

As to the use of digital technologies to participate in online training opportunities (e.g. MOOCs, webinars, virtual conferences), an aggregate of 60.1% claim to participate occasionally (43.5%), frequently (14.6%) and always (2.0%). Again, the percentage of teachers admitting to rarely or never participate in such opportunities is higher among teachers from universities (46.3%) than from the polytechnic institutes (32.9%). HEIs' faculty members from the Azores AR are the ones who participate more occasionally (53.3%), but contrastingly more rarely (36.7%). Those from the Algarve are the ones who participate more frequently (22.2%) followed by those from the Madeira AR (18.8%). Assistant professors from universities (36.4%) and Adjunct professors, as well as Coordinator professors (18.2%) are the ones who claim to always participate in such opportunities.

4.3. Perspectives on academic environment, international mobility and entrepreneurship

4.3.1. Academic environment: autonomy and management tasks

Considering, as stated by the European Commission Digital Education Action Plan, that “to bring innovation and technology to the classroom, educators need the right environment, infrastructure, devices and leadership support” (p.5), it is noteworthy that most Portuguese HEIs’ faculty members (65%) claim having the necessary autonomy to implement a digital teaching/learning environment. Most respondents (74.3%) declares that collaboration among peers is a priority in their specific teaching context.

Although, most respondents point out that administrative and management tasks do not allow them the proper time to conduct original research (66.1%). Particularly, Adjunct Professors (73.5%), at polytechnic institutes, and Assistant Professors (72.8%), at universities, are the ones who most claim to be harmed in their research activities by the accumulation of management tasks. Most respondents who totally agree work in the Social Sciences, Arts and Humanities domain (38.4%). At the same time, most respondents also admit that administrative and management tasks do not allow them the proper time to prepare their classes (52.5%). Among those who totally agree, 23.6% (N=58) work in polytechnic institutes, compared with 12.7% (34%) working in the university. Associate Professors at the university are the ones who most state the constraint generated to their classes by managerial tasks (75%). The variation across scientific domain is not statistically significant.

4.3.2. International mobility

Our findings reveal a clear split of activity by Portuguese HEIs’ faculty in digital education networks, with an aggregate of 50.8% not being fully active: when asked if they were active in one or more national or international digital education networks, 34.7% totally disagreed and 16.1% partially disagreed. Regarding HEIs’ context, 40.7% of university faculty members claim to be totally inactive, compared with 29.7% in polytechnic institutes. Looking at the professional category, the most active in digital education networks are university Associate Professors (21.4%) compared to a national mean of 8.4%.

Faculty members in universities declare having more teaching experience in international contexts (54.1%) than their peers in polytechnic institutes (35.8%). By professional category, university Associate Professors, with an aggregate of 89.3%, are the ones leading in international teaching experience. On the other side of the spectrum, a total of 76.4% of polytechnic institutes’ Assistant Professors claim to have no international experience (63.2%) or only residual (13.2%). Teaching staff based in Azores AR are the ones with less international experience (53.3%), being the national mean 42.9%. Considering scientific domains, more than half (52.2%) of faculty members teaching in the field of Exact Sciences and Engineering declare not having international experience teaching, followed by their colleagues in the domain of Life and Health Sciences (46.1%). Natural and Environmental Sciences faculty champion international educational experience (66.7%).

4.3.3. Digital transformation and entrepreneurship education

The relationship between universities, regional economic impact and national pro-democratic attitudes has also been stated (Valero & Reenen, 2019) and the Digital Education Action Plan stresses that “innovative and entrepreneurial spirit in education and training should be fostered and supported with clear political willingness and effort to make innovation work for everybody” (p.3). Most Portuguese HEIs faculty

members (78.9%) consider that a digital transformation of teaching is partially (42.2%) and totally (36.7%) a strategic priority. Most respondents who totally agree work in the Exact Sciences and Engineering (40.8%) and in the Social Sciences, Arts and Humanities (36.6%) domains. Based on location, faculty members working in the Azores AR (50%) stand out from the national mean (36.7%).

In Portuguese HEIs, most faculty members (73.1%) claim that entrepreneurship-related skills in the curricula are partially (37.1%) and totally (36%) a priority. Among these, most are Invited Assistant Professors in universities (84.2%, N=48) and Adjunct Professors working in polytechnic institutes (81.8%, N=122). The variation across gender, HEIs' context and sector, location and scientific domain is not statistically significant.

5. Discussion

Our findings are consistent with the study of Lašáková et al. (2017), having found that the main constraints to digital innovation in Portuguese higher education teaching are (#1) the limited infrastructure and resources, (#2 ex-aequo) a conservative academic culture and a lack of funding opportunities, (#4) lack of technological resources and of (#5) technical support.

It is striking to notice that infrastructure, technological resources and technical support are amongst the top barriers to digital innovation in the Portuguese universities and polytechnic institutes. From our perspective, this fact cannot be detached from the reported dependence on the availability of students' digital resources faced by faculty members working in Portuguese HEIs and underlines the significant divide, also stressed by the European Commission Digital Education Action Plan, still in place between and within EU Member States, regarding digital infrastructure, which hinders inclusive growth. Furthermore, if "a key part of digital education is ensuring equity and quality of access and infrastructure" (European Commission, 2018, p.5), an inadequate and asymmetric availability of digital infrastructure and resources is hindering the innovative potential of digitization of teaching/learning activities and methodologies in the Portuguese context.

Such barriers play a key role regarding the adoption and use of digital technologies by teachers and may partially explain the low level of implementation of digital teaching practices. This can be further explained by teachers' digital competence, which may not be enough for an effective and critical use of technologies for teaching (Jääskelä et al., 2017; Krumsvik, 2014; Silva et al., 2014; Watty et al., 2016). Although our study did not focus on directly measuring this aspect, results suggest the need for improving competences at different digital pedagogical levels. While respondents seem to be comfortable with the use of digital technologies to find, select, create and adapt digital resources to support their teaching, the translation of these into concrete activities that can foster collaboration or enable students to plan, monitor and reflect on their own learning is still lacking. This is in line with results put forward by previous studies on Portuguese HEIs, which point at the instrumental use of digital technologies to maintain teacher-centered practices (Almeida et al., 2014; Mesquita et al., 2018). Such notions are further reinforced by results regarding the monitoring of students' activities to inform teaching and learning. Different studies stress the importance of analysing and interpreting data generated by students in digital spaces complemented by the analysis of conventional evidence on learner behavior - as extremely important to help make (pedagogical) decisions and benefit students' learning (Ifenthaler, 2017; O'Farrell, 2017).

Additionally, the inclusion of self-assessment and peer-assessment strategies, enabled by digital means, are central to develop critical, self-awareness and overall confidence (Harris & Brown, 2018; Winsor, 2017). Such practices do not seem to be regular among Portuguese HEIs' faculty members and may suggest a prevalence of traditional assessment practices (exam/test-based assessments). In accordance with Lašáková et al. (2017), these may constitute barriers to digital innovation, as they inhibit teachers to step outside their comfort zone and experiment innovative approaches, which can give students a more active and responsible role in their learning. The results also point out the need for continuous professional development. New technologies often require user training. It is essential that institutions offer techno-pedagogical support to its faculty members on how to innovate pedagogy using digital technologies to create learner-centered courses. Institutions also need to encourage the use of

technologies to benefit from free-of-charge content and courses, MOOCs or open access research, so that faculty members can update and advance personal knowledge and individual digital competence. Previous research has proven such strategies to have a positive impact on both teachers' teaching practices and disposition to experiment, as well as students' learning and competence development (Bond, Marín, Dolch, Bedenlier & Zawacki-Richter, 2018).

The weight of managerial tasking by faculty members cannot be underestimated. In the international context it has been approached from multidimensional perspectives (e.g. Briggs, 2005; Menzies & Newson, 2007; Mudrak et al., 2017). Our findings represent an explicit call to action to HEIs executive boards and to governmental policymaking towards effective technical and administrative support to faculty members and for accounting the effective work time dedicated to academic administration when evaluating professional career progressions.

Research has shown the existence of a positive and significant effect of business, public and higher education Research and Development (R&D) on innovation in the European Union (Pegkas, Staikouras, & Tsamadias, 2019) and, particularly, that science-based and knowledge-intensive business services are active collaborators with universities for innovation (Lee & Miozzo, 2019). Furthermore, the interconnectedness of academic research and universities economic activity has been suggested as benefiting both "old" and "new" higher education institutions (Degl'Innocenti, Matousek, & Tzeremes, 2019) and three key themes in the digital transformation of innovation and entrepreneurship have been proposed: (1) openness, the sharing and flow of knowledge and technological assets across organizational boundaries, (2) affordances, how innovation tools and infrastructure facilitate the innovation process in specific use contexts, and (3) generativity, the ability to combine skills and blend concepts (Nambisana, Wright, & Feldman, 2019).

In view of these results, future studies need to appreciate if access to and the use of digital technologies is effectively helping to reduce the learning gap between students from high and low socioeconomic backgrounds. In addition, the role of students – and Portuguese families – supporting effective teaching in Portuguese HEIs, and particularly the teacher/student dynamics in place in order to surpass institutional material limitations, can only be adequately assessed by new and deep qualitative inquiries involving interviews and ethnographic fieldwork. On the other hand, considering the reported relationship between HEIs and regional economic impact (Valero Reenen, 2019), a line of studies also needs to address the real contribution of regionally based policy making on digital innovation and assess its efficiency on closing the asymmetries between high and low, coast and interior regional economies across Portugal. Complementarily, both from a research and a scientific policy-making perspective, a study on the drivers and barriers to collaboration between Portuguese universities and polytechnic institutes are lacking. In particular, the flow level of shared knowledge, technical expertise and technological infrastructure need to be evaluated, towards the possible creation of HEIs joint ventures and regional R&D clusters.

6. Conclusion

Our study structured digital innovation in HEIs around three axes: (1) digital infrastructure, networks and equipment availability, (2) educational digital practices among faculty members and their self-assessment of academic environment and priorities. The exploratory nature of the study led us to conduct a quantitative research design operationalized through an online questionnaire aimed at covering both Portuguese universities and polytechnic institutes, across the public and the private sectors, in all scientific domains and regions.

One last word should be addressed to the limitations of our study. Although conducting the most comprehensive online questionnaire on digital innovation in Portuguese HEIs (N=547) to date, no statistical representativeness is claimed. This implies that a generalization of the results across socio-demographic variables must be appreciated with epistemological moderation and considered in future developments, since sampling, due to its exploratory design, may affect generalizability and, particularly, underrepresentation. Also, quantitative data generated by our online questionnaire were analysed descriptively, asking for further cross-variate analysis work. Finally, we consider that without a complementary qualitative research approach (e.g. semi-structured interviews) the reading of the data generated by us will remain incomplete.

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