

A systematic literature review on technology in online doctoral education

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Abstract. Alongside the growing demand for doctoral degrees, there has been an increasing number of online doctoral programmes and online doctoral students enrolled across the globe. While the importance of mediating roles that communication technology plays in online doctoral education has been extensively documented, a comprehensive account of how and for what purpose online doctoral students use different technological tools has been lacking in the literature. To address the gap, the present authors have conducted a systematic literature review on doctoral students' use of technology in distance programmes. The review results suggest that the range of technology used by online doctoral students is limited—asynchronous and synchronous communication technology for discussing and community building being predominantly top. Arguably more advanced technology was rarely discussed in the reviewed literature. How online doctoral students learn and use other information technology to support their research activities was largely unknown. Based on the results, the directions of future research efforts have been suggested.

Keywords. Online doctoral education; online doctoral programme; professional doctorate; systematic literature review; technology

1. Introduction

Alongside the growing demand for doctoral degrees both in academic and industrial contexts, there has been an increasing number of online doctoral programmes (ODPs) and doctoral students enrolled in those programmes across the globe (Park, 2007; Mirick & Wladknowski, 2020). Unlike traditional doctoral studies, directly shaped around on-campus interactions between students and their academic advisors, online doctoral studies are usually structured and programmed, facilitated by technology-mediated interactions among the programme participants geographically dispersed (Perkins & Lowenthal, 2014; Provident et al., 2015). Such characteristics enable "mid-career adult learners" (Williams et al., 2019) with established social and professional responsibilities to pursue their doctorate without travelling and relocating to the campus. Compared to traditional doctoral students on campus, online doctoral students are often reported as under-prepared, under-resourced, or time- and resource-pressured (Berg, 2016; Williams et al., 2019). Therefore, although the accessibility and flexibility of ODPs allow adult learners to begin their doctoral studies in the first place, it is not necessarily easy to meet the programme's expectations while managing other responsibilities (Lee, 2020).

Recently, there has been a rapid increase in the number of technological tools made available and used to support diverse aspects of online doctoral studies and research practice. However, a comprehensive account of how and for what purpose students use different technological tools throughout their online doctoral studies is absent in the literature. Given the essential roles that technology plays in mediating distance learning activities as well as supporting research activities in ODPs, it can be even more beneficial for online doctoral educators to understand how their students

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use different technological tools for their studies. It is also important to develop a balanced perspective on the impact of technology in online doctoral education, embracing not only the benefits but the challenges that technology and technology-mediated interactions may bring into different areas of online doctoral studies. Such in-depth knowledge will enable ODPs to better serve their students by facilitating the more effective use of technology in online doctoral studies, making online doctoral education more authentically accessible to adult learners (Lee, 2017).

To address the gap in the literature, the present authors have conducted a systematic literature review on doctoral students' online learning activities in distance or blended learning programmes with a specific focus on how those activities are mediated by different technology. Considering the rapid change in technological tools in today's digitalised education context, this review focuses on specific mediating functions that different technological tools offer to online doctoral studies (e.g., asynchronous communication tools, learning management systems, social networking tools; see Table 4). Although some of the specific technological tools (i.e., products) mentioned in this article may disappear in a few years, such mediating functions will remain relevant to online doctoral students and educators for many years, if not permanently.

The following three questions have guided this review project:

What technological tools, and for what kind of learning activities, do doctoral students use in ODPs?

What are the intended outcomes of doctoral students' engagement with those online learning activities?

What are the associated challenges with those online learning activities that doctoral students experience?

Before reporting our review methods and findings, the next section will provide a brief overview of the historical development of online doctoral education and the general characteristics of online doctoral students and their learning experiences previously discussed in the literature.

2. Research background

The active participation of full-time professionals in doctoral studies is identified as a main driving force in developing ODPs and emerging information and communication technology as an enabler for universities to serve the non-traditional doctoral student group (Perkins & Lowenthal, 2014).

Subsequently, both researchers and practitioners have stressed the value of technology in increasing the accessibility and quality of online doctoral studies. For example, two decades ago, Sunderland (2002) documented the affective functions of email technology (a considerably new communication medium back in 2002) on a distance doctoral programme in which physical contact between Romanian students and UK tutors was restricted to periodic residentials. The study reported that email communications effectively reduced the psychological distance experienced by the students, created by their physical and cultural distance from academic advisors and institutions. Sunderland concluded that computer-mediated communication has "particular value for professionals studying part-time on distance programmes" (p. 233).

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A growing number of ODPs provide those students with an increased range of academic choices and reduced disruption to their personal and professional lives, including less travel and more learning time (Provident et al., 2015). From the mid-2000s, the higher education sector witnessed the rapid emergence of ODPs that proactively utilise and embrace pedagogical affordances of communication technology. Combe (2005) introduced one of the UK's first ODPs and emphasised the benefit of utilising "e-learning technologies" for both students and universities in the internationalised higher education contexts—removing geographical barriers to accessing each other. Crossman (2005) similarly argued that doctoral programmes in Australian universities enable Thai doctoral students to pursue their doctorate while working at higher education institutions in Thailand, where doctoral education options are limited. More recently, Kumar (2014) also highlighted that an ODP in Florida serves a cohort of in-service educators whose professional practice is situated across the USA.

Many ODPs utilise cohort-based admission and structured courses and further offer these students a unique and effective social support mechanism (Berry, 2017a; Byrd, 2016; Holmes, 2020). Even though technology-mediated social interactions, facilitated by the cohort-based structure, contribute to developing a sense of community among online doctoral students, there have been ongoing concerns over social isolation among online doctoral students (Berg, 2016; Roumell & Bolliger, 2017). It is worth noting that a sense of isolation is not a novel problem that exclusively exists in ODPs but a long-existing challenge faced by many doctoral students regardless of their educational medium—mainly due to the independent nature of doctoral studies (see Berry, 2017b). Nevertheless, a lack of face-to-face contact between students and advisors has been continuously raised as a drawback of online doctoral education. Subsequently, online doctoral educators have actively utilised both asynchronous and synchronous educational media to increase a sense of social presence in their programmes and ultimately improve student success (Hogan & Devi, 2019; Myers et al., 2019).

Literature on online doctoral studies has also discussed the characteristics (both affordances and limitations) of asynchronous and synchronous communication. For example, Warr and Sampson (2020) have found that the flexibility in asynchronous discussions often inhibits online doctoral students' organic and authentic engagement with critical dialogues. On the other hand, despite the useful features of synchronous communication, online doctoral students have reported associated problems such that synchronous approaches reduce the flexibility of online doctoral studies and their ability to remain focused while increasing online fatigue (Myers et al., 2019). Furthermore, many doctoral students do not feel comfortable, both technologically and culturally, with technology-mediated communications. Researchers also suggest that online doctoral students have limited opportunities for "informal conversations that happen in the hallways" (Myers et al., 2019, p. 334) or "serendipitous discussions with faculty and to observe what their advisor do" (Roumell & Bolliger, 2017, p. 88)—which is not easily replicated online.

Online doctoral educators have also stressed the great potential of advanced information technology for improving doctoral students' research practice by providing various tools and mechanisms to search, collect, organise, and present information (Tuñón & Ramirez, 2010). However, the literature seems to present a somewhat conflicting picture. Students enter the programme with varying degrees of information literacy skills (and, subsequently, needs) based on their previous experiences using library resources and databases (Kumar & Dawson, 2012). While some students enjoy the accessibility of online information and the variety of research-aid tools, some may feel rather lost or overwhelmed by the immensity of the information and the complexity of the tools (Brahme &

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Walters, 2010). Bolliger and Halupa (2012) also argue that online doctoral students experience different levels of technological anxiety (i.e., computer, Internet, and online course anxiety), negatively correlated to their learning satisfaction.

Online doctoral students, in general, also express much less confidence in their research skills than residential students, and they tend to seek more help from librarians and advisors (while residential students tend to solve issues and exchange support among themselves, see Brahme & Walters, 2010). Thus, researchers suggest that universities need to provide more proactive, personalised, and developmental support to online doctoral students (Kumar & Dawson, 2012; Tuñón & Ramirez, 2010). Other researchers (Rockinson-Szapkiw et al., 2014) report the significant differences among online doctoral students in terms of their use of social networking technologies to interact with peers outside the official learning space, which is positively correlated to their perceived sense of community in their online programme. In addition, students generally find thesis writing is one of the most challenging parts of their programmes, during which they feel particularly isolated from their peers and advisors (Brahme & Walters, 2010).

Online doctoral education is a complex phenomenon influenced by multiple factors—both technological and non-technological—and student experiences in ODPs are shaped by the dynamic combination of distinct characteristics of adult learners, doctoral studies, and online distance education (Lee, 2020). Online doctoral studies are both *individualistic* in nature as independent research and one-on-one mentoring are core activities, and *social*, where students often suffer from a sense of isolation and lack of face-to-face interactions.

3. Method and sample

3.1 Overview of the study

A systematic review is conducted to explore the tools, activities, and focus of online learning activities of doctoral students. Systematic reviews differ from more traditional literature reviews in that it is grounded on pre-defined criteria that are methodologically, justifiably, and consistently implemented, and it enables researchers to synthesise the results of previous studies and produce evidence-based statements (Gough et al., 2017; Zawacki-Richter et al., 2020). This paper synthesises a corpus of 67 studies on online doctoral education, attained after several steps of identification carried out systematically. To achieve a systematic and reproducible approach to attaining the reviewed studies, we have followed the below step—modified from Gough (2007, p. 218-219):

- determining the review question and protocols
- setting inclusion and exclusion criteria
- articulating the search strategy and choosing information sources
- screening the articles based on the inclusion/exclusion criteria
- mapping the results of the search strategy in a flowchart
- extracting relevant descriptive data from included studies
- appraising the quality and the relevance of main findings and arguments
- synthesising all collected evidence that answers the review questions

3.2 Search strategy and selection procedure

The search string (see Table 1) and criteria (see Table 2) for this systematic review were formed to retrieve articles concerning online doctoral students and their learning experiences, indexed in three international databases: Education Source, Scopus, and Web of Science. As the first ODPs started proliferating and becoming a subject of academic discussions in the early 2000s (e.g., Combe, 2005), the search is limited to the years between 2000 and 2020 up to the date the search was conducted. The original search string was formulated as broad as possible to hook all the related studies on doctoral students engaged with programmed and pre-designed online learning activities—either at a distance or in blended delivery mode. Those studies concerning residential students' online learning engagement at a personal and informal level were excluded. In a similar vein, articles documenting residential doctoral students' online learning experiences of somewhat unplanned and unstructured nature during the recent COVID-19 pandemic would not be relevant to this review. Nevertheless, while revising the present journal, following recommendations from anonymous reviewers in July 2022, the authors briefly reviewed articles published since 2021 and added some relevant research outcomes as supporting references to our review results.

As a result of the initial search on the above-mentioned databases covering titles, abstracts, and keywords conducted in November 2020, 2134 records (see Table 3) were obtained in total.

Table 1 Search string

Topic	Search string
Education level	(doctoral OR phd OR ph.d.) NEAR/2 (stud* OR program* OR course* OR degree*)
AND	
Intervention	(online* OR distance* OR blend* OR mobile OR technology-enhanced*) NEAR/2 (learn* OR teach* OR study* OR studie* OR degree)

Table 2 Final inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication year	2000 – 2020	Before 2000
Language	In English	Not in English
Education level	Doctoral-level students/candidates	Not at doctoral level
Methodology	Empirical, primary research	Non-empirical research, reviews, commentaries
Publication type	Academic journal articles indexed in Education Source, Scopus, or Web of Science	Not a journal article (e.g., editorial notes, book reviews, book chapters)

Mode of delivery	Online, distance, or blended learning	No learning setting in online, distance, or blended learning
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Table 3

Database searched	Date of search	Number of articles retrieved
Education Source	09.11.2020	1792
Scopus	02.11.2020	203
Web of Science	02.11.2020	139

All of the 2134 articles were imported to a reference management software, and after removing 230 duplicates, the first two authors of this paper screened the titles and abstracts based on the inclusion and exclusion criteria given in Table 2. For this first step of the selection process, sensitivity rather than specificity was adopted, which means including rather than excluding (Zawacki-Richter et al., 2020). For example, if the information provided in the titles and abstracts was insufficient to fully identify the mode of delivery of the concerned doctoral education in the articles being reviewed, the authors included the article for the next step of the selection process: full-text screening.

To evaluate the coding decisions of the two coders, inter-rater reliability using Cohen's kappa (κ) (Cohen, 1960) was used, which is a coefficient for the degree of consistency among raters based on the number of codings in the coding scheme (Neumann, 2007, p. 326). Twenty articles in one run, 60 articles in total across the three runs, were randomly selected, blindly screened, coded, compared, and discussed to reach a common understanding of the inclusion and exclusion criteria. Kappa values of .40 to .60 are characterized as fair, .60 to .75 as good, and over .75 as excellent (Fleiss, 1981; Bakeman & Gottman, 1997). Coding consistency for inclusion or exclusion between the two raters was $\kappa = .77$. Therefore, inter-rater reliability can be considered excellent for the coding of inclusion and exclusion criteria.

As can be seen on the flow chart in Figure 1, after the title and abstract screening of 1910 articles, 193 papers were selected for full-text screening, and after the second round of inclusion and exclusion exercise, 67 papers were finally selected for the present systematic review.

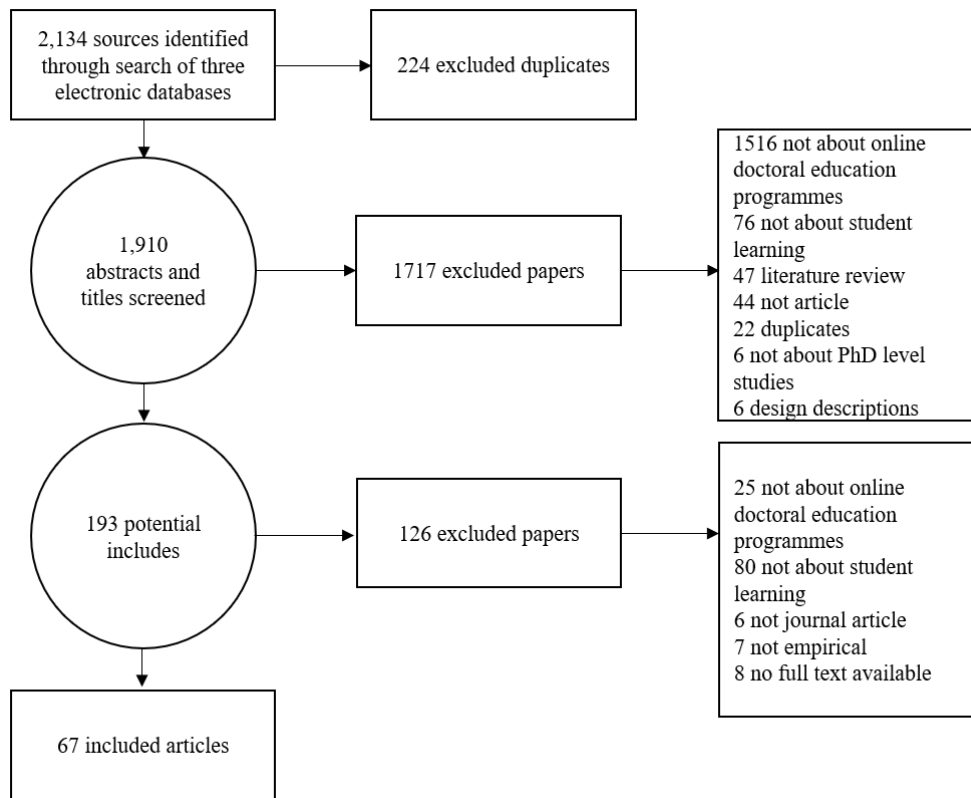


Figure 1. Systematic review flow chart

3.3 Data extraction and coding process

Full-text screening and coding were carried out using a systematic review software, the EPPI-Reviewer Web (see <http://eppi.ioe.ac.uk>). To establish a holistic view of the research landscape of online doctoral education, the main coding exercise included some fundamental aspects of online doctoral studies as described in the reviewed articles as follows: i) characteristics of online doctoral education research, including geographical characteristics (country of institutions of researchers, country of institutions of programmes) and research methodology (qualitative, quantitative, or mixed methodology), and ii) characteristics of online doctoral studies, including programme characteristics (mode of delivery, subject of doctoral study, stage of doctoral study) and the use of learning tools in the programmes (type of learning tools, the purpose of using tools, and type of learning activities). For the coding of technological tools, a slightly modified version of Bower's (2016) typology of learning tools was employed. Most articles were coded multiple times and assigned more than one code since most reviewed articles discuss the online doctoral students' usage of more than one tool.

Below, we will present a brief summary of our coding results of the geographical and methodological characteristics of the corpus and the general characteristics of online doctoral studies discussed in the corpus. The use of learning tools in the programmes is the primary concern of the present systematic review, as reflected in our review questions, which will be fully answered in the Results and discussion section.

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3.4 Study characteristics

Geographical and methodological characteristics of the corpus

Taking the country of the first authors into consideration, the previous studies have predominantly originated from the USA (71.6%, n = 48), followed by the UK (9.0%, n = 6), and Australia (7.5%, n = 5). Other studies are undertaken in Ghana, the Netherlands, Portugal, New Zealand, Sweden, South Africa, Saudi Arabia, and Spain, each sharing an equal number of contributions (n = 1).

In parallel with these results, across the 67 articles, the reviewed ODPs are largely offered in the USA (71.6%, n = 48). Whilst three studies do not mention the country of the programme, the list has UK (n = 5), Australia (n = 4), Ghana (n = 1), New Zealand (n = 1), Portugal (n = 1), South Korea (n = 1), Sweden (n = 1), South Africa (n = 1), and Fiji (n = 1).

A total of 41.8% of the studies (n = 28) are qualitative in nature, followed by mixed research methodology (29.9%, n = 20) and quantitative research (20.9%, n = 14). Descriptive research composes only 7.5% (n = 5) of the corpus.

Programme characteristics

In more than half of the studies (61.2%, n = 41), doctoral programmes are described that are delivered fully online at a distance. Considering that even a short campus visit may have a different pedagogical effect, fully online learning settings with brief residential programmes are coded separately. Taking these settings as a part of the fully online programmes adds 10.4% (n = 7) to the fully online mode of delivery. The remaining studies (n = 19) form the blended learning setting, accounting for 28.4%.

Regarding the codes of concerned subject areas of the ODPs, the population of the research corpus is composed of 37 (54.4%) studies in Education, 12 (17.6%) studies in Health & Welfare, four studies in Arts & Humanities (5.8%), two studies (2.9%) in Natural Science, Mathematics & Statistics, two studies (2.9%) in Social Sciences, Journalism & Information, and one study (1.5%) in each study field of Engineering, Manufacturing & Construction, Information & Communication Technologies, and Interdisciplinary. One study (see Almusharraf et al., 2020), due to its dual focus, is coded for both Engineering, Manufacturing & Construction and Natural Science, Mathematics & Statistics. Eight studies (11.9%) were coded as "not specified".

4. Results and discussion

In the present section, we will first present a brief summary of coding results and then provide an in-depth discussion, answering each research question.

4.1 What technological tools, and for what kind of learning activities, do doctoral students use in ODPs?

Across the 67 included studies in the corpus, doctoral students use a wide range of educational media and tools in ODPs. Not surprisingly, most studies in the corpus used asynchronous communication tools (58.2%) and synchronous collaboration tools (53.7%) to facilitate interaction in online learning (see Table 4). The tools are closely linked to the learning activities of doctoral students.

Therefore, media usage is described below along with the learning activities (i.e., discussing, networking and community building, collaborating, taking supervision, writing, presenting, evaluating and peer assessment, analysing data, and organising and self-management) (see Table 5). It is important to note that the learning activities were not specified in just over half of the included studies (53.7%) since the tools and media were merely a prerequisite for taking part in online courses and programmes.

Table 6 provides a cross-tabulation of online learning activities and the tools used for these activities. The tools often appear in combination. For example, a plethora of 12 different tool types (i.e., all available tool types except for data analysis tools) was used in studies focusing on student engagement with online discussions in doctoral courses. Similarly, 11 tool types (except for information retrieval tools and games) were used in studies on collaborative learning activities among doctoral students.

Table 4: Use of educational media and tools across studies (N = 67)

Technological tools mediate online learning	n	%
Asynchronous communication tools (ACT)	39	58.2
Synchronous communication tools (SCT)	36	53.7
Text-based tools (TBT)	33	49.3
Learning management systems (LMS)	24	35.8
Audio-visual media (AV)	15	22.4
Social networking tools (SNT)	9	13.4
Assessment tools (AT)	6	9.0
Website creation tools (WCT)	5	7.5
Knowledge organisation and sharing tools (KOS)	4	6.0
Virtual worlds (VW)	3	4.5
Data analysis tools (DAT)	3	4.5
Information retrieval tools (IRT)	3	4.5
Games (GAM)	2	3.0

Table 5: Learning activities in online doctoral courses across studies (N = 67)

Online learning activities	n	%
discussing	26	38.8
community building and networking	23	34.3

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collaborating	15	22.4
supervision / mentoring	14	20.9
writing	8	11.9
presenting	5	7.5
evaluating / peer assessment	4	6.0
analysing data	4	6.0
organising and self-management	2	3.0
not specified, taking a course	36	53.7

Table 6: Co-occurrence of doctoral learning activities and tools

Activity / Tools*	ACT	SCT	TBT	LMS	AV	SNT	AT	WCT	KOS	VW	DAT	IRT	GAM	Sum
writing	4	4	6		2	2		1		1	1		1	23
organising and self-management	1	1	1	2	1				1					7
community building and networking	14	15	4	10	5	8	1	1	2	1				61
discussing	20	14	12	8	7	2	2	4	2	2		1	1	75
collaborating	11	8	9	6	2	3	2	2	2	2	1			48
analysing data	2	3	2			1	1				1			10
presenting	5	1	4	2	1	2		1	1	1		1		19
evaluating and peer assessment	1		4	2	2		2							11
general learning (taking a course)	22	18	19	16	13	5	5	4	3	3	3	1	1	113
general learning (supervision)	10	11	8	4	2	1			1	1	1	2		41
Sum (Tool)	90	75	69	50	35	24	13	13	12	11	7	5	3	

*acronyms: ACT = asynchronous communication tools, SCT = synchronous communication tools, TBT = text-based tools, LMS = learning management system, AV = audio-visual media, SNT = social networking tools, AT = assessment tools, WCT = website creation tools, KOS = knowledge organisation and sharing tools, VW = virtual worlds, DAT = data analysis tools, IRT = information retrieval tools, GAM = Games

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Discussing

In the majority of studies (n = 26, 38.8%) about online doctoral education, digital media and tools are used to facilitate discussions in online courses. Asynchronous communication tools and synchronous communication tools are the top two types of tools that are implemented in ODPs (Table 4). These communication tools play by far the most important role in supporting discussions, but they are also used in general for collaboration, community building, and networking (see below). In the following section, therefore, the focus is placed on studies that explicitly apply synchronous and asynchronous communication tools for the purpose of discussion and discourse in ODPs.

Asynchronous interaction allows maximum flexibility and independence from time and space in distance learning programmes (e.g., Feast & Anderson, 2003; Keopuhiwa, Srivastava, Oonge & Maundu, 2012). Agee and Uzuner Smith (2011) investigate how doctoral students use asynchronous online discussions in a blended learning course on research methods. The qualitative and quantitative analysis of three rounds of discussions reveals that the course participants are engaged in deep learning processes in the text-based asynchronous environment: "The interactions in the selected discussions demonstrated that asynchronous online discussions can be helpful in providing students at this level with increased opportunities for a collaborative dialogue where they can reflect on and make sense of research with support and assistance from peers" (p. 315). The authors conclude that providing opportunities for asynchronous discussions adds value for students on this level of study in terms of exploring and understanding complex ideas that go beyond the limited time of face-to-face meetings.

Asamoah and Mackin (2016) report on an online educational technology course for first-year PhD students at the University of Ghana in the sub-Saharan African context, where students are frequently faced with poor internet connectivity, low bandwidth at high costs, and power fluctuations. Despite these challenges, the authors conclude that the online learning activities contributed to "a better learning outcome than face-face-teaching and learning" (p. 44). The students rated the asynchronous forum higher than all other tools like an integrated massive open online course, a quiz or the class website. Due to the high bandwidth required, the use of synchronous communication technologies would not be feasible in this context.

Where internet access is not a problem, synchronous video conferencing can be used for direct interaction (e.g., Andrew, 2012; Enger & Lajimodiere, 2011). Warr and Sampson (2020) found that doctoral students in a programme at Arizona State University rated synchronous video chat as most engaging and supportive of critical discourse, whereas the asynchronous discussion activities were rated least enjoyable.

Community building and networking, and collaborating

Numerous studies concern particular instructional designs, interventions and services to support community building and networking (n = 23, 34.3%) and collaboration (n = 15, 22.4%). Since these activities are closely linked with each other, they are synthesised together here.

In these studies, learning and knowledge sharing communities are established and sustained via a range of synchronous and asynchronous communication tools, both standalone or within an LMS

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(e.g., Kumar & Coe, 2017; Lai, 2015; Sivula, 2011). A number of ODPs provide opportunities for direct interaction via video-conferencing, often in combination with asynchronous communication tools. For example, Berry (2017b) explores in a qualitative study based on multiple data sets, including video footages of synchronous interactions, text messages in asynchronous discussion forums and interviews, how first and second-year students in an ODP in the USA create a learning community. Berry identified four subgroups in the courses (i.e., the cohort, class groups, smaller peer groups, and study groups) that helped develop a sense of community among students, who reported that they drew academic, social, and emotional support from their interactions.

In addition to simple tools for communication, knowledge organisation and sharing tools and devices play a special role in the studies that deal with collaboration between students in the courses. For example, Cotter et al. (2015) evaluated the benefits of mobile learning devices (e.g., e-book readers, tablets) to support learning and collaboration in a blended learning programme in a School of Allied Health Professions.

On the other end of the spectrum, in some doctoral programmes, more advanced virtual environments are used to support community building, collaboration, and learning. Deutschmann and Panichi (2009) investigated interaction patterns in an English course for international doctoral students in a Swedish programme using the multi-user virtual environment *Second Life*. In a more recent study, Giddens et al. (2020) described the development of a virtual community platform for a collaborative learning purpose at the High Tide University School of Nursing and Health Professions. The authors, after reviewing the pre-existing virtual platforms such as *Second Life* and *The Neighborhood* (i.e., a commercial tool with stories, case studies and activities in a virtual world), developed a web-based platform, which is easily accessible to learners, simple to navigate, and flexible in design to support a variety of learning activities. This virtual community platform, with other multimedia tools (e.g., *VoiceThread*), was integrated into the programme's LMS: *Blackboard*. They found that the platform enabled online doctoral students to create shared knowledge and develop emotional connections with each other.

Snelson et al. (2017) describe a research methods course at Boise State University (USA), in which students proceed through various exercises in a massively multiplayer online game (*World of Warcraft*) and collaboratively write an article to submit to an academic journal in the final course unit. However, these examples are rather exotic in contrast to the vast majority of standard information and communication technology applied in the corpus of the studies.

Other studies are investigating the use of social networking tools for community building and networking beyond the course or programme level with the wider community of doctoral students, early career researchers, as well as practitioners and professional networks in their field. Myers et al. (2015) conclude that it is possible to create a community of scholars using simple forms of technology to connect and collaborate, such as a group on *Facebook*. Otherwise, "it is possible that students can become overwhelmed with the variety of formats for interactive teaching, course delivery, and professional socialization" (p. 651). Berry (2019) also explored the extracurricular interactions of doctoral students and found that they can have a thriving network outside the classroom. The students interacted by checking in via texting and calling, through social media (e.g., *Facebook*) and mobile apps (e.g., *Whatsapp*, *GroupMe*) and occasional in-person meetings that were not only academic and

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formal but social and casual in nature (e.g., some students organised a trip to a football game on campus). Overall, the media used for the scholarly community and identity building among the online doctoral student group (and academic and social networking more broadly) have been constituted with relatively simple and accessible technological tools.

Academic writing and presenting

Eight studies (11.9%) dealt with issues related to tools for academic writing. Kirkpatrick (2019) reports on a qualitative study about discussion boards in a doctoral-level course on writing for scholarly publication in which students were asked to reflect on their writing process. The asynchronous communication tool was also used to provide feedback by the instructor. Computer-mediated feedback on academic writing also plays a vital role in the qualitative study by Odo and Yi (2014) with international doctoral students in a TESOL programme (Teaching English to Speakers of Other Languages). Feedback sessions were facilitated via *Skype*, a synchronous communication tool. The authors conclude that such synchronous mentoring practice has "the potential to facilitate the scaffolding of academic writing" (p. 129). Sloan et al. (2014) describe an e-learning tool, *The dissertation game*, to support international post-graduate students in preparing their dissertations. The course participants are guided through the generic content of the dissertation (e.g., introduction, literature review, research methodology) by engaging with a series of quizzes and exercises. The tool received positive responses from participant students and faculty members as a source of feedback and support.

Meyer (2010) evaluated and compared a range of so-called Web 2.0 tools (see Beldarrain, 2006) for creating texts in wikis, blogs, and discussion boards in an online doctoral course on higher education finance. The wikis generated objections from students who did not appreciate group work, whilst others found it a good tool for collaborative writing. The blogs received more positive comments as they were easy to use and set up, and students could take ownership over their content. Students experienced discussion boards as a safe place to express ideas: the asynchronous text-based nature of this tool allows students to prepare their contributions and challenges carefully in advance. Despite the differences among the tools, Meyer (2010) concludes that "the level of learning achieved may have less to do with the tools chosen than with the nature of the assignment" (p. 231).

Although presenting research results in class or at an academic conference is an important experience and skill for doctoral candidates and early career scholars, only a few studies have addressed this aspect of doctoral learning (n = 5, 7.5%). The software tools and media used for presentations in those five studies are surprisingly conventional: students are expected to prepare PowerPoint presentations (Feast & Anderson, 2003) or to engage in an audio- and voice-based conference (Arduser et al., 2011).

Evaluating and peer-assessment, analysing data, self-management and organising

Other online learning activities pursued by the doctoral students are evaluating and peer-assessment (n = 4, 6.0%), analysing data (n = 4, 6.0%), and self-management and organising (n = 2, 3.0%). In a study by Loureiro et al. (2012), students in a Spanish doctoral programme on Multimedia in Education used a wiki-based online tool for peer-assessment to give each other feedback about a group work assignment. The peer-assessment activity also helped to increase interaction among the different student groups. Atkinson (2020) describes the development and evaluation of a pilot library

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course on metaliteracy and information literacy in an online Doctor of Education (Ed.D) programme using the LMS, *Canvas*, and videos, and Jiang et al. (2019) report on an online statistics course in an educational leadership programme, in which participants used *SPSS* for assignments.

Finally, Rockinson-Szapkiw (2012a) investigated the use of a cloud computing workspace and content management server (*Microsoft SharePoint™*) for managing and organising dissertation processes in an Ed.D. programme in the USA. Students enrolled in this programme can access a collaborative workspace called *The Dissertation Portal*. Through this portal, students could manage and organise their dissertation writing process using a calendar function, manuscript templates, tutorials, discussion forums, as well as document management and sharing features. The study (Rockinson-Szapkiw, 2012a) revealed that doctoral students "who use the Dissertation Portal extensively have significantly higher student-to-student connectedness and student-to-faculty connectedness than both doctoral students who use it moderately and on a limited basis" (p. 277).

Supervision and mentoring

Digital tools are not only used in ODPs for offering and taking courses and formal instruction but also for supervising and mentoring doctoral students (n = 14; 20.9%). Providing guidance and supervision for doctoral students is a demanding and time-consuming endeavour, especially in distance learning programmes.

Erichsen et al. (2014) investigated students' perceptions of supervision by conducting a survey sent to 295 doctoral students enrolled at three universities in the USA. The students were well aware of the critical role the research supervision plays in their successful completion of the degree by providing guidance, support, structure, feedback, and encouragement. Nevertheless, the prevalent tools used to communicate and interact with their supervisors are rather basic and simple: many students reported they communicated using the telephone and e-mail (36.8%) or e-mail only (30.8%). Surprisingly, the participants at two universities indicated that they never used a discussion forum in the university's LMS. Sunderland (2002) analysed e-mail messages exchanged among students and between students and supervisors during their coursework in a distance PhD programme at the University of Lancaster (UK). The students wrote messages "asking for" advice, extensions, a favour, confirmation or permission, "telling about" coursework, feelings, family, leisure, health or professional experiences, and "other" topics like offering help, expressing good wishes, thanking and apologizing. Even by this simple channel for communication, the participants "*broadened* (sic) [...] identities as academics working in a global academic community" (p. 245).

Other studies evaluated online mentoring programmes (e.g., Arslan-Ari et al., 2018). Welch (2017) used a qualitative approach to explore the lived experiences of doctoral nursing students who participated in a "Virtual Mentoring Program[me]" that was developed utilizing *Google+®* and *Google Hangout®*. Some students struggled with this new platform that was different from the LMS with which they were already familiar. Harris et al. (2016) administered a survey using the Ideal Mentor Scale in a Doctor of Nursing Practice (DNP) programme. In the "e-Mentoring" programme, different modes of communication via e-mail, text messages, telephone and Skype calls, and discussion forums in the university's LMS were applied. The authors conclude that the "use of e-mentoring within distance DNP programmes may be an effective way to support doctoral students who are actively willing to engage in the process" (p. 461).

4.2 What are the intended outcomes of doctoral students' engagement with those online learning activities?

Across the 67 articles, more than half (n = 39, 58.2%) concern doctoral students' use of technology during the coursework stage of ODPs, the period when students participate in pre-designed and structured online learning activities in a course (see Table 7). A relatively smaller number of the reviewed studies (n = 13, 19.4%) deal with students' online learning activities during the thesis work stage, where individual students work on their thesis rather independently with some supervisory support. Only 7.5% (n = 5) of the studies cover both coursework and dissertation writing stages, although ten studies (14.9%) do not specify any particular study stage.

Table 7. Stage of doctoral studies focused in the literature (N = 67)

Stage of doctoral studies	n	%
coursework (module)	39	58.2
thesis work (research)	13	19.4
both	5	7.5
not specified	10	14.9

The intended outcome of online learning activities (i.e., learning objectives) discussed in the literature is as follows (see Table 8). With slightly more than one-fourth of the corpus (26.9%, n = 18), the most frequently mentioned learning objective is the acquisition of research methodology (or a range of research skills). It is closely followed by 23.9% (n = 16) of the reviewed studies that mention acquiring other skills (e.g. self-directed learning skills) necessary for completing doctoral studies and by 20.9% (n = 14) of the studies focusing on learning subject knowledge in the specific field of doctoral studies. There are also ten articles (14.9%) that exclusively discuss adopting certain online learning activities and tools in the concerned doctoral programmes as a mechanism to provide supervision and establish an effective supervisory relationship. Generally, these studies in which supervision is the central focus of student learning activities do not specify the specific objective of the activities; however, it can be assumed that the focus of supervision practices is multifocal and more comprehensive—beyond learning particular knowledge and skills.

Table 8. The central focus of learning activities in ODPs (N = 67)

The focus of online learning activities	n	%
research methodology	18	26.9
subject knowledge	14	20.9
other skills	16	23.9
thesis supervision	10	14.9
critical perspectives	2	2.9

not specified	15	22.4
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Learning research methodology

The majority of the studies in the corpus (n = 18, 26.9%) focus on online learning activities in a research methodology course (e.g., Brahme & Walters, 2010; Feast & Anderson, 2003; Agee & Uzun Smith, 2011). As developing advanced research skills is a core objective of all doctoral studies, taking a research methodology course tends to be a prerequisite for thesis work—a compulsory part of the coursework stage in most PhD programmes (Card et al., 2016). Concerning the abstractness of teaching how to research in university settings, many studies focus on developing and implementing new pedagogical approaches and instructional designs to expand doctoral students' research knowledge (e.g., Snelson et al., 2017; Feast & Anderson, 2003; Rockinson-Szapkiw, 2012b).

To address the challenging nature of research methodology courses, Snelson et al. (2017) employ a novel instructional approach using *World of Warcraft* to simultaneously enhance online doctoral students' research knowledge and practice. The article presents the outcomes of a duoethnography in which three doctoral students and an instructor explored their learning and teaching experiences in the online course. A student described his positive experience of learning new research methods and skills in the particular game-based learning setting as follows:

Well, it's like this game, it's uh, I don't feel like I've made the achievement yet or the grade, well of course because there isn't one, but I know that I've been growing. The types of research that I understand, or the methods that we use, or even the articles that I've read have been a little more relevant and I'm understanding them more now that I'm immersed in doing this. (p. 1452)

Apart from those studies looking into innovative instructional approaches to design and teach research methodology courses, there has been some research interest in the roles of student engagement with other research support activities available outside the pre-designed course and programme structure. For example, Brahme and Walters (2010) investigated online doctoral students' research habits regarding their usage of different information sources (e.g., librarians, search tools) for their research projects. In their qualitative case study, employing a grounded theory methodology, the authors carried out semi-structured interviews with 20 doctoral students, half of whom were registered in ODPs. Contradictory to some earlier predictions made by other researchers (e.g., Barrett, 2005; Campbell, 2006) who anticipated the replacement of human librarians and physical library facilities with advanced information technology in the near future, Brahme and Walters (2010) argue that "both distance and residential doctoral student researchers continue to rely heavily on librarians' assistance in locating literature, choosing and using research tools" (p. 497).

Bolliger and Halupa (2012) also conducted their study within a research methodology course; however, their study did not focus on the research skills development of online doctoral students but on the impact of students' technological anxiety on course satisfaction. They concluded that technological anxiety (or computer anxiety) is one of the key factors determining online doctoral students' successful completion of their programme. Such conclusions further imply the high relevance of information technology to today's research practice.

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Learning subject knowledge

Many articles concerning online doctoral students' acquisition of subject knowledge (n = 14, 20.9%) correspond to those examining the coursework stage of online doctoral studies (e.g., Kumar, 2014; Pittenger & Olson-Kellogg, 2012; Warr & Sampson, 2020).

An early example of those articles (Schoech, 2000) includes a description of one of the first fully online doctoral courses entitled "Technology Supported Practice", where doctoral students learn relevant theories and scholarships underpinning technology-mediated social practice. Whilst confirming the pedagogical benefit of the wide range of tools the Internet offers for doctoral students' subject knowledge learning, Schoech (2000) particularly underlines the critical need for communication and, subsequently, the effective use of chat tools to enable and facilitate communication in ODPs.

In their mixed-method research, Pittenger and Olson-Kellogg (2012) implemented collaborative digital writing activities in an online pharmacotherapy course for physical therapy doctoral students. In this case, with the help of technological tools (*wikis*), an authentic and collaborative learning environment was created to develop online doctoral students' subject knowledge and disciplinary competency. In addition, a scenario-based assessment using hypertext documents was utilised. The study reported the positive impact of the learning activities on raising online doctoral students' awareness of the importance of effective communication with patients, mutual understanding within the professional group, and critical thinking in physical therapy practice. More importantly, collaborative writing activities and scenario-based assessment in the course enhance the professional identity of the participant doctoral students since they "take on the role of physical therapist in addressing the entire patient, both in designing physical therapy recommendations within a pharmacotherapy context, but also communicating with multiple audiences as the physical therapist" (p. 73).

In parallel to the effectiveness of authentic learning opportunities and the need for collaborative learning communities for online doctoral students' subject knowledge acquisition, Berry (2017a) also emphasises the critical role of instructors in creating an authentic and collaborative learning community in a virtual environment. Based on the author's qualitative case study, Berry (2017a) concludes that if instructors adopt multiple strategies that increase their social and teacher presence in online courses, this "helps increase first-year students' sense of community" (p. 12), which is suggested as a prerequisite for their effective learning of subject knowledge in ODPs.

Learning other skills

Almost one-fourth of the studies (n = 16, 23.9%) concern a set of other skills developed as a result of doctoral students' engagement with different online learning activities such as collaborative note-taking activities (e.g., Almusharraf et al., 2020), self-regulated learning activities (e.g., Marshall et al., 2019), problem-based learning activities (e.g., Candela et al., 2009) and community building activities (e.g., Berry, 2017a). Although some of those activities are already discussed above, the coded articles include a particular emphasis on the deliberate pedagogical efforts put into practice to develop 'other' skills than research methodology and subject knowledge (e.g., writing skills, self-regulated learning skills, problem-solving skills), which are also necessary for the successful completion of online doctoral students.

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With a small sample group, Marshall et al. (2019) piloted the implementation of online writing centres in ODPs and investigated their effect on students' self-regulation behaviours for research writing. The writing centres offered embedded tutoring (with live sessions) to doctoral students, through which students received timely feedback on their writings and writing tips. The students who participated in the pilot study reported positive results in developing not only writing skills but also self-regulated learning skills for continuing independent writing practice—in fact, thesis writing is one of the most challenging aspects of online doctoral studies. Participant students wrote in their "Writing Self-Regulation Inventory" (see Marshall et al., 2019 for details) as:

I am able to learn from my mistakes with clear feedback,

I seek out resources for improvement, and

I learn from my mistakes from one draft to the next. (p. 94)

Based on a sample of 149 post-graduate students from a South Korean university, Almusharraf et al. (2020) investigated the causal relationship between student knowledge acquisition about academic writing practices and their collaborative note-taking behaviours, aiming to create a quality group summary of video lectures on academic writing skills. Although there was no strong correlation between individual students' quiz scores and their group note qualities, the study demonstrated the effectiveness of collaborative note-taking activities in increasing meaningful learner interaction in online courses. Students, as a result, acquired collaborative and communicative (social learning) skills.

Berry (2017b) explored how social network structures were formed in ODPs over time and how those differed from network structures more frequently observed in residential programmes. Based on her observations, she conceptualised the social communities that emerged in ODPs as 'nested communities' to capture the diversity of their formations—in terms of their sizes, purposes, participants and durations. Despite the diversity, most of those communities in ODPs are more peer-dependent and detached from formal institutional and academic support. While the vital roles that social communities play in online doctoral studies have already been discussed above in 4.1, it is worthwhile to note that the peer-dependent and detached nature of those communities emphasises the importance of acquiring social and online communication skills. Only with those skills, online students will be able to create and participate in different online communities that accommodate their needs at different points of their doctoral studies.

A very small number of studies have focused on non-academic skills development. For example, Lenihan et al. (2015) describe an online leadership development programme that the University of Illinois Chicago has offered to its doctoral students. The programme, adopting the evidence-based practice, is found to be successful, and "students are demonstrating through their action learning projects that key action learning principles are being learned and applied, in 80% of the cases to address a real leadership issue at a student's practice site" (p. 57). Therefore, the intended outcomes of online learning activities that doctoral students engage with throughout the programme are leadership development, which supports their professional growth.

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Thesis supervision

Ten studies (14.9%) deal with online learning activities associated with thesis supervision practices in ODPs. These studies tend to conceptualize the supervision practice as collaborative knowledge creation or collaborative learning activities. A more democratic and collaborative mentoring relationship (instead of a supervisor-centred and top-down supervision relationship) is sought in ODPs where most students themselves are mature adults and experienced professionals who are expected to be active in their learning (e.g., Harris et al., 2016; Lai, 2015; Odo & Yi, 2014). In this sense, the intended outcome of supervision practice in ODPs is more holistic and fundamental than the simple acquisition of new knowledge and skills.

Lai (2015) investigated supervision both from the perspective of providing feedback and collaborative knowledge construction. In the study, supervision practice is mediated and facilitated by doctoral student engagement with online discussion activities, aiming to develop their thesis proposals collaboratively and exchange peer and tutor feedback. Unlike the private nature of supervisor-and-supervisee interactions in face-to-face doctoral education contexts, ODPs tend to expand such one-to-one supervisory relationships to community-based group interactions. Both online discussion threads and interview texts with doctoral students and supervisors suggest the value of constructive feedback in students' thesis work. Welch (2017) also highlights that doctoral students feel academically and personally supported not only by their supervisors but by other members of their learning communities; at the same time, they are very aware of the importance of self-regulation and time-management skills for their academic success.

Kumar and Coe (2017) describe their phenomenological research project, which explored the roles of mentors, the challenges of mentees, and the need for mentor support in ODPs. Among the wide range of mentor support, the article highlights the importance of timely feedback from mentors for students' academic success and further demonstrates the effectiveness of virtual small group meetings with a mentor and other mentees. Although "dissertation mentoring, whether in on-campus or distance education setting, is perceived to be dependent solely on the mentor and the mentee" (p. 13), the authors also argue that it is fundamentally critical to supplement supervision with institutional and programme-level support to assure the progress of online doctoral students on their dissertation projects.

Schulze (2016) explored the academic socialisation processes and outcomes of post-graduate students who successfully completed their online programmes and similarly concluded the extended supervision practice beyond the one-to-one interactions. The qualitative interview data collected from 11 participants, support the conceptualisation of the supervision practices as part of online collaborative learning activities. Although in ODPs, students are often expected to self-regulate and self-motivate their studies at a distance from their supervisors, the data demonstrated the crucial roles supervisors play in student learning. For example, students reported that supervisors' timely and quality feedback are closely linked to their ability to self-regulate their studies. Harris et al. (2016) also argue that effective virtual mentoring programmes could increase student attrition rates, as evident in reviewed literature (from 12% to 25% in life sciences).

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Critical perspectives

There are two additional papers in the corpus that use online learning activities specifically to develop doctoral students' critical perspectives. Enger and Lajimodiere (2011) report on an online diversity course, through which the doctoral candidates have experienced a perspective transformation and developed a critical recognition and awareness of ethnical diversity in their online learning community. The phenomenological study that analysed the student journal entries revealed that students enhanced their understanding of existing social and educational inequality within the community and beyond. They became more conscious of the impact of economic and cultural differences on each doctoral student's academic progress. Students also problematised the Euro-centric perspective towards races and developed a more positive and constructive attitude to diversity.

Warr and Sampson (2020) tried to facilitate a critical (Freirean) dialogue in an ODP. They report that when dealing with sensitive and political topics, doctoral "students preferred asynchronous video to asynchronous text, and synchronous video to asynchronous video" (p. 865). One of the students, in particular, expressed her hesitation to use asynchronous communication tools for such sensitive and subtle subjects as the input would be recorded and would remain on the cloud. It is also suggested that building trust among participants is the key to success in such an effort, which can be achieved through having synchronous communications frequently.

4.3 What are the associated challenges with those online learning activities that doctoral students experience?

Online learning not only provides mature adult learners (often less privileged than residential students) with expanded opportunities for participation in doctoral studies but presents several associated challenges. 22 papers in the corpus deal with issues related to such challenges as follows: the feeling of isolation and not being in direct contact with the community of peers or scholars (e.g., Andrew, 2012; Brahme & Walter, 2010; Crosta et al., 2016; Erichsen, 2014, Fuller et al., 2014); the poor technical infrastructure of households, cities, or universities and the lack of access to technology (e.g., Asamoah & Mackin, 2016; Gibbons-Kunka, 2017; Hogan & Devi, 2019); the lack of time (time limitations to interact with peers) and the need to juggle between work, study and personal life (e.g., Berry, 2017b; Erichsen, 2014); the lack of or need for faculty support (e.g., Brahme & Walter, 2010; Erichsen, 2014); and the lack of training on technology and digital literacies (e.g., Dooley et al., 2003; Kawulich & D'Alba, 2019).

Isolation is one of the strongest predictors of attrition in doctoral education (Nettles & Millet, 2006), which is even more critical for online doctoral students (Brahme & Walters, 2010; Byrd, 2016), and building community can be preventive to this problem (Rovai, 2003). Even within well-developed and well-structured ODPs, learners expressed their strong need and desire to belong to a community where they can contact and support each other informally and frequently (e.g., Crosta et al., 2016). Community support is not limited to facilitating students' academic development but extends to addressing the pressing needs of online doctoral students to share and overcome their stress, anxiety, and concerns with their peers (e.g., Kirkpatrick, 2019; Kumar & Coe, 2017; McKenna, 2018). With the online push of the pandemic, recent studies also contend the crucial need for learning communities for online doctoral education (e.g. Cullinane, 2022; Graham et al., 2022; Webber et al., 2022).

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As discussed in 4.1, the previous studies have confirmed that many online doctoral students use communication technology to network, collaborate, and build learning communities in ODPs. Nevertheless, it is important to remember that building a strong learning community among distance learners is not always an easy task. That said, it may be useful to discuss the unique characteristics of learning communities in ODPs. Despite being unpredictable due to its organic form (Berry, 2019), some studies in the corpus (n = 26) reveal important characteristics of online learning communities. For example, Berry (2017b) argues that "online doctoral communities vary considerably from their face-to-face counterparts in that they are smaller, more insular, and lack central institutional figures such as faculty" (p. 45). In a follow-up study, Berry (2019) brings out how online doctoral communities are student-driven, naturally formed and not subject to a single space and single function as these communities develop in diverse shapes—from small studying groups to large socialisation groups—on different occasions.

However, McKenna (2018) and Myers et al. (2019) emphasise the critical roles that an instructor may play in initiating contact, developing a sense of community, and building a strong community, especially at the beginning of the programme. In some cases, even Q&A sessions organised by instructors using synchronous communication tools are suggested as an alternative to learning communities when urgently needed (e.g., Jiang et al., 2019; Mei et al., 2019).

5. Conclusion and Implications

Doctoral education is a complex entity encompassing a comprehensive set of requirements. Completing a doctoral study, whether online or face-to-face, is a challenging process, through which doctoral students need to engage with various types of learning activities to acquire multi-dimensional knowledge and skills. When it comes to online doctoral studies specifically, there is an additional layer of complexity due to the technology-mediated nature of online interactions and communications. As there has been a rapid growth in ODPs, more and more adult learners with other social and professional commitments choose to pursue a doctorate at a distance from their institutions and supervisors.

Since the early 2000s, there has also been a growing number of research efforts to investigate the unique characteristics of online doctoral students and their experiences and explore pedagogical strategies to better support their distance learning processes and outcomes. The present paper is one of the first scholarly attempts to synthesise those research endeavours. Given the central roles technology plays in online doctoral studies, the authors have strategically focused on doctoral students' use of technology throughout their participation in ODPs. We have also aimed to address a significant gap in the existing literature where a comprehensive account of diverse learning activities students engage in ODPs is lacking. The previous section presented and discussed the authors' main observations drawn from systematically searching, selecting, and reviewing 67 articles on online doctoral studies. Here, we will highlight some of the critical gaps and imbalances further identified by our review results, which offer a useful direction for future research endeavours in the field.

Across the 67 articles, there was a strong emphasis on the importance of mediating roles that technology plays in online doctoral studies; however, the range of technological tools used by doctoral students was surprisingly limited. 'Asynchronous and synchronous communication tools' are the two of the most predominantly used technology in ODPs (or at least, the most frequently

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discussed technology in the literature on the focused area). On the other hand, arguably more advanced and complex technology (e.g., virtual worlds, games) was only discussed in a minimal number of the reviewed articles, with newly emerging technology (e.g., artificial intelligence applications or 3D printing) never mentioned. Given the prevalence of such technology in some fields (e.g., engineering, computer sciences), this phenomenon may be explained by the fact that a majority of ODPs are in Social Sciences (with Education being the top subject matter).

A similar inference can be drawn from the outcome that 'discussing' and 'community building' are the two most common online learning activities mentioned in the reviewed articles. That is, the knowledge advancement process in Social Sciences often involves a community of researchers sharing and discussing their opinions and perspectives and creating new ideas and understandings. Another possible explanation is that there has been excessive research and pedagogical interest in reducing a sense of isolation among distance learners in those programmes, as it is the central theme of one of the first articles published on the topic (Sunderland, 2002). Nevertheless, it is somewhat counter-intuitive that other relevant tools such as 'social networking tools' and 'knowledge organisation and sharing tools' have not attracted much research interest despite the great affordances of those more sophisticated tools for communication and collaboration. In fact, although social networking tools are mentioned in nine articles, only one article has them as the main subject of study.

Another problematic imbalance in the review result is a lack of research interest in examining student engagement with more research-relevant learning activities. While 39 studies exclusively focus on the coursework period of ODPs, only 13 studies investigate student experiences during the thesis work period. In total, 15 articles mention technological tools used for supervision and mentoring, but only ten refer to specific learning activities associated with supervision and mentoring practices in online doctoral studies. Even those ten articles tend to be overlapped with the articles that more fundamentally discuss community building and networking activities—in fact, supervision and mentoring activities are often rather abstractedly and broadly conceptualised as part of community building and networking efforts in ODPs. Thus, these articles have no meaningful bearing on our understanding of supervision practices in online doctoral studies.

The same pattern was found in the research input into the student use of technology as there has been a minimal effort to look into the use of research-aid tools, including 'data analysis tools', 'assessment tools' and 'information retrieval tools'. There are no article concerns about student use of data analysis tools or their acquisition of data analysis skills—considering the critical roles that those tools play in any scholarly context, such absence was rather disappointing. Similarly, while 'discussing' and 'networking' are exclusively stressed in the reviewed article, more serious academic 'writing' and rigorous peer 'evaluating' activities have not been thoroughly studied. Knowing both that online doctoral students overall find it difficult to maintain a sense of connection with their peers and institutions after the coursework period (Lee, 2020) and writing a thesis is one of the most challenging activities in online doctoral studies (Brahme & Walters, 2010), this is particularly worrying to us.

On the related point, except for two articles focused explicitly on doctoral students' use of library supports (i.e., Brahme & Walters, 2010) and students' level of information literacy (i.e., Bolliger & Halupa, 2012), we could not find an in-depth discussion on this aspect of doctoral studies. Even those two articles appeared to be limiting as Brahme and Walters (2010) took a comparative perspective on

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the difference between face-to-face and online doctoral students' uses of library supports, which they did not deepen their discussion further on online doctoral studies. Bolliger and Halupa (2012) also discussed online students' information literacy (and its importance) in the context of reporting the impact of students' technological anxiety on their academic success, in which they did not yet draw any pedagogical implications for online doctoral studies.

To conclude, since 2002, when the first article reviewed in this project was published, the field of online doctoral education has made remarkable progress in advancing its research knowledge and pedagogical practice. Notably, the field has established a solid foundation for developing a supportive learning community in ODPs through effectively facilitating technology-mediated interactions between students and tutors and among students. The next step can be to explore the potential of more advanced technologies to accelerate both technological and pedagogical innovation in online doctoral studies. Future research can also look into the effective mechanisms to sustain a sense of community, successfully developed through structured course activities and pre-planned tutor supports, until the end of the thesis writing stage of the programmes. In addition, the creative use of social networking tools can be helpful to expand and connect the in-house programme networks to the outside world, by doing so, help online doctoral students develop their scholarly identities and memberships in their chosen field.

Despite the laudable success through a relatively short history of its development, the scholarship of online doctoral education will greatly benefit from learning more about students' use of technology for online learning activities more directly related to their doctoral research. That is, a series of research questions can be asked: 'what are the available technological tools that may be useful (or necessary) for online doctoral student research development and practice?', 'how do students find, choose, use those research-aid tools in ODPs?', and 'how can online courses and tutors help doctoral students learn and utilize those research-aid tools more effectively?' In the same vein, similar questions can be asked regarding a wide range of technology that supports writing, peer-reviewing, mentoring activities, and all other learning activities essential for the successful completion of online doctoral studies.

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