

6-18-2022

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Recommended Citation

Han, Shengnan; Nikou, Shahrokh; Ayele, Workneh Yilma; Balasuriya, Balasuriya Lekamalage Prasanna; and Svee, Eric-Oluf, "DIGITAL PROCTORING IN HIGHER EDUCATION: A SYSTEMATIC LITERATURE REVIEW" (2022). *ECIS 2022 Research Papers*. 57.
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DIGITAL PROCTORING IN HIGHER EDUCATION: A SYSTEMATIC LITERATURE REVIEW

Research Paper

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Abstract

To improve the academic integrity of online examination, digital proctoring systems have been implemented in higher education worldwide, particularly during the COVID-19 pandemic. In this paper, we conducted a literature review of the research on digital proctoring in higher education. We found 115 relevant publications in nine databases. We applied topic modeling methods to analyze the corpus which resulted in eight topics. The review shows that the previous studies focus largely on the systems' development, adoption of the systems, the effects of proctored online exams on students' performance, and the legal, ethical, security, and privacy issues of digital proctoring. The annual topic trends indicate future research concerns, such as systems' development, online programs (MOOCs) and proctoring, along with various issues of using digital proctoring. The results of the review provide useful insights as well as implications for future research on digital proctoring, a crucial process for digitalizing higher education.

Keywords: Digital proctoring, literature review, topic modeling, digitalization of higher education.

1 Introduction

Digitalization of higher education has been strengthened as the Internet and personal computers have become more and more available to people across the globe (Siemens et al. 2015). Higher education institutions have transformed their teaching and learning practices to deliver courses online using learning management systems (LMS) (Muzaffar et al. 2021). This has created a solid foundation for higher education to deliver quality education to more students, thus freeing them of geographical constraints, institutional boundaries or temporal differences, via, for example, the development of MOOCs (Mass Open Online Courses) (Peters and Jandrić, 2018). Whereas higher education is moving quickly towards the digital future, several critical problems are frequently experienced: *How can we maintain and assure academic integrity and security?* as well as *How do we prevent dishonesty and cheating behavior in distance online examinations* (Pavlou et al. 2008)? To address these problems, more and more digital proctoring systems are being developed and adopted by higher education institutions (Nigam et al. 2021). The emergency crisis of the COVID-19 pandemic has also disrupted both campus-based and online education, and particularly the practice of examinations. Thus, higher education institutions need new approaches to handle the urgent situation of remote assessment and examination. This has resulted in dramatically increased usage of digital proctoring systems (e.g., Raman et al. 2021). In this paper, digital proctoring is defined as the use of digital tools and technologies

to ensure that the students (exam-takers) are “*taking examinations and other forms of assessment follow the prescribed guideline and policy*” (Alessio et al. 2017; Udechukwu, 2020).

Our intention in writing this paper is to provide a state-of-the-art literature review on digital proctoring as practiced in higher education. The knowledge and insights provided through this research will serve to introduce academics, policymakers, and students to the development and use of digital proctoring with particular emphasis on the impacts of the systems on digitalizing examinations in higher education. This knowledge will also serve as a departure point to discuss the continuous use of the systems and their long-term influences on digitalizing higher education. To fulfill this aim, we formulated the research questions: *What is the current research of digital proctoring in higher education?* and *How has this phenomenon been studied in the literature?*

We answer the research questions through a systematic literature review. Nine databases were searched for peer-reviewed scientific publications (e.g., journal articles and conference papers) on digital proctoring, including ACM, ERIC, IEEE, ProQuest Social Science, PsycINFO, PubMed, Scopus, Web of Science, and Google Scholar. We used topic modeling methods to analyze the final dataset, comprising 115 studies. The current research of digital proctoring in higher education is presented in eight topics (areas). The studies focus largely on the systems’ development, adoption of the systems, the effects of proctored online exams on students’ performance, as well as the legal, ethical, security, and privacy issues of digital proctoring. The annual topic proportion trends indicate future research concerns, such as systems’ development, online programs (MOOCs) and proctoring, as well as the issues of using digital proctoring. The review provides useful insights about the implications for the research of digital proctoring, which is a crucial process for digitalizing higher education. We also discuss the implications for information systems (IS) education and research.

2 Digital Proctoring

Digital proctoring, also known as e-proctoring, virtual proctoring, remote proctoring or online proctoring, is defined as “*the process of using digital tools and technology to ensure that candidates taking examinations and other forms of assessment follow the prescribed guideline and policy*” (Udechukwu 2020, p. 6262). A proctored test is a mechanism which ensures the authenticity and authorship of the exam takers. The mechanism is used to prevent and detect the exam takers’ unacceptable and unauthorized activities and behaviors during the online exam (Udechukwu, 2020). González-González et al. (2020) emphasize that digital proctoring allows the examination process to be implemented remotely without requiring the physical presence of the exam takers on site. This new practice is a trend favored globally among the MOOCs and open education.

Digital proctoring can be classified into three categories (Arnò et al. 2021, Hussein et al. 2020, Nigam et al. 2021). These are live proctoring programs (LP), recorded proctoring programs (RP), and automated proctoring programs (AP). The technical features of these three categories are different: (1) live proctoring programs (LP) require a human invigilator to authenticate the exam takers and observe their activities to prevent and detect any form of misconduct through the use of a screen monitor. One invigilator can supervise 10-12 persons in one screen. If there are large numbers of exam takers, then more human invigilators are needed. (2) Recorded proctoring programs (RP) do not utilize a human invigilator, but instead, student behavior is recorded during the examinations. A human invigilator must review the recorded videos and check for possible warning flags that signal an alert of an exam taker’s behavior. However, a human invigilator may spend a lot of time reviewing the recorded videos and making decisions about the suspicious behaviors. The students may not agree with the decisions which can cause numerous complaints that cannot be easily solved. (3) Automated proctoring (AP) are currently the most advanced available programs. Exam takers’ behaviors are recorded during the test, and an automated system then reviews the feed through advanced audio-video analysis functions to detect any cheating behaviors in near real time. The AP uses Artificial Intelligence (AI) technology to monitor students during exams. In this process, the proctoring system can pause or terminate the student’s exam if cheating behaviors are detected. The AP programs can be used for both live (LP) or recorded proctoring (RP).

Arnò et al. (2021) present state-of-the-art research based on a review of 29 proctoring systems available in the market and used in higher education. Nigam et al. (2021) also review AI-related features that are largely used in various digital proctoring systems. Technical advances have improved the accuracy of detecting misconduct during proctored online examinations to ensure academic integrity and security. The adoption of digital proctoring systems¹ has become a global phenomenon mostly due to the COVID-19 pandemic. The early adopters have been in the US and Europe. Proctoring systems used by universities in US are for example, Examity, ProctorU, Proctorio, Proctortrack etc. In Europe, universities in the Netherlands use Proctorio systems. ProctorU is used by universities from Ireland and Finland, and thus far, universities in Sweden and Norway are using the Inspira Exam Portal and Smart Proctoring. Universities in Australia and New Zealand were found to use the ProctorU and Inspira systems. A few cases were found in universities in Asian countries, such as those in Singapore, that were reported to use digital proctoring systems (e.g., Examsoft and RPNOW), during the COVID-19 pandemic¹.

3 Method

Literature reviews play an important role within scientific inquiry (vom Brocke et al. 2015) and on accumulating knowledge from the previous researches (Webster and Watson, 2002). With the aim to review all related peer-reviewed studies about digital proctoring across as many disciplines as possible, we retrieved data from nine databases, including: ACM, ERIC, IEEE, ProQuest Social Science, PsycINFO, PubMed, Scopus, Web of Science, and Google Scholar. The retrieval was started with three criteria ‘proctoring’, ‘education type’ and ‘type of exam’. Based on these three criteria we decided the final search keywords. Which are:

(“Digital Proctoring” OR “Online Proctoring” OR “Online Exam Supervision” OR “Remote Proctoring” OR “Automated Proctoring” OR “e-Proctoring” OR “Proctoring Systems”) AND (“Higher Education” OR “University” OR “College” OR “Institute”) AND (“e-Exam” OR “Digital Assessment” OR “e-Assessment” OR “Formal Assessment” OR “Exams” OR “Online Testing” OR “Assessment”)

Because Google Scholar allows only 256 characters of search keywords, the query was slightly modified for this purpose:

(“Digital Proctoring” OR “Online Proctoring” OR “Online Exam Supervision” OR “Automated Proctoring” OR e-Proctoring) AND (“Higher Education” OR University OR College OR Institute) AND (e-Exam OR “Digital Assessment” OR “Formal Assessment” OR “Exam”)

In the literature search process, we followed the guidelines of both vom Brocke et al. (2015) and the PRISMA process (Page et al. 2021) which supported a rigorous and systematic review. We completed the search in September 2021, with 801 papers found in total. After removing the duplicates (n=353), 448 papers remained. We followed the inclusion and exclusion criteria listed below to screen the relevance of the articles. The inclusion criteria are: (1) the article must study digital proctoring, e.g., online or remote proctoring, automated proctor; (2) the article must study digital proctoring within higher education, either in universities or colleges; and (3) the proctoring system is used for online examination or assessment purposes. We excluded those papers that are: (1) not written in English; (2) not peer-reviewed reports or workshop papers; and (3) those gray literature published in newspapers or magazines. However, papers that were published by ArXiv (Balash et al. 2021) and SSRN (Cleophas et al. 2021; Colanna, 2021) were included because of their high relevance to the review. We manually checked the abstract of these 448 articles, and finally 115 articles were considered as relevant to the literature review and included in the final analysis. The PRISMA diagram of the literature search and review process is shown in Figure 1.

¹ We performed a Google search in the Spring 2021, and there were around 90 universities worldwide that had reported their use of digital proctoring for online examinations on their official universities web pages, e.g. in US, [Columbia University](#), [Temple University](#). The technical report can be shared upon request.

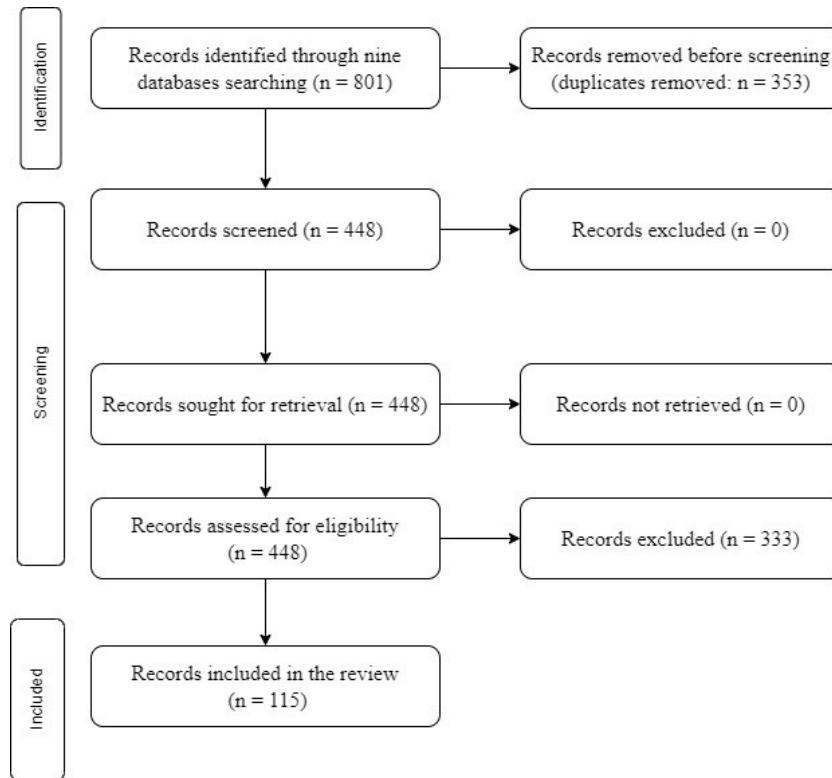


Figure 1 PRISMA diagram of the literature search

using 2-grams to produce strings, for example, to create “COVIDand19” as one word, which is “covid19”. We removed stop words such as ‘IEEE’, ‘ACM’ and ‘SPRINGER’ and ‘COPYRIGHT’, with “FIND” and “ALSO” also considered as stop words since they are the most frequently used words in an Abstract. Standard stop words, for instances, ‘remove HTML tags’ and ‘remove numbers’ were also selected. We selected ‘lemmatization’ for the analysis option because the same word may sometimes have multiple different forms, and with this selected, it considers the context and converts the word to its meaningful base form. However, we did not select the ‘stemming’ option to analyze the dataset since stemming removes the last few characters of a word. In addition to that ‘noun’, ‘verbs’,

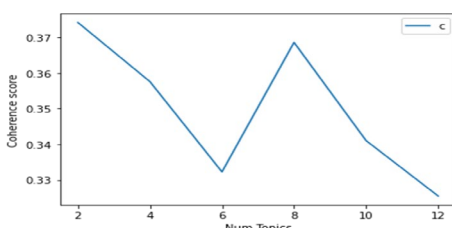


Figure 2 Optimum number of topics

‘adjectives’, and ‘adverbs’ were selected as the parts of speech filtering to ensure the text corpus only retained those parts of speech that are important to the topic models. Second, we computed the optimal numbers of topics by computing the coherence score based on the algorithm by Röder et al. (2015) using the Python Gensim library (see Figure 2). The coherence score—based on the semantic interpretability of the generated topics (O’Callaghan et al. 2015)—measures the internal coherence and validity of a given topic. Thus, a higher coherence score equates to more interpretable topics, and

therefore we used the highest coherence score to determine the number of topics. The results indicated the optimal number is eight. Next, we ran the topic modeling analysis with the eight topics using latent Dirichlet allocation (LDA) algorithm (Blei et al. 2013). To interpret the meanings of these eight topics, we qualitatively re-examined the words and documents that were highly related to each topic. We coded the meanings separately using the following criteria: (1) the most representative terms in each topic can build a meaningful topic together; and (2) the abstracts which have a high probability in each topic are tightly related to the given topic. Consensus was reached through team discussions. During the coding process, we paid particular attention to the relevance of the identified topics as well as the topics exclusivity. The labeling of topics

We applied topic modeling methods to detect the latent themes within the research of digital proctoring. Topic modeling methods are recommended for doing information systems research (Debortoli et al. 2015), as well for studying the intersections of computers and education (Chen et al. 2020).

The quantitative analysis of the 115 articles was done in three steps. First, we prepared and cleaned the data for topic modeling analysis by using minemytext.com, following the recommendations of by Schmiedel et al. (2019). We exported the bibliographic data from Zotero to a single .csv file which included “date” (publication year of the papers” and “text” (Abstract)).

We tokenized the documents by

was done by assigning descriptive names to topics in a way similar to that suggested by (Blei et al. 2003). We also counted on our domain knowledge and judgments in labelling the topics (Schmiedel et al. 2019). By completing these tasks, we ensured the reliability and validity of the qualitative analysis.

4 Results

Although we did not restrict the timelines for the literature search, the first study of digital proctoring was published in 2008 (Pavlou et al. 2008). Between 2008-2019, few articles were published each year: for example, no study was found in 2010. We witnessed a sharp increase in publications in both 2020 and 2021 (See Figure 3). The 115 articles were published in 63 outlets including journals, book chapters, and conference proceedings. The papers were published from various disciplines among natural sciences,

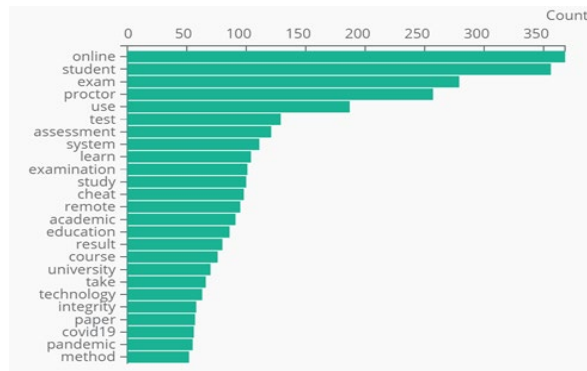


Figure 4 Word frequency

literature. We found 18 papers focused on LP programs (e.g., Rosen and Carr, 2013; Vazquez et al. 2021), eight articles reported the results of examining RP programs (e.g., Davis et al. 2016; Lewis 2020), whereas four investigated the AP programs (e.g., Miguet et al. 2018; Susithra et al. 2021). Most of the papers (n=50) studied the combined programs (e.g., Karim et al. 2014; Shirodkar et al. 2021) while 16 studies developed or examined AI features to advance digital proctoring systems (e.g., Amigud et al. 2018; Jia and He 2021). Other papers studied digital proctoring in general (e.g., Fask et al. 2014; Kharbat and Daabes, 2021)

4.1 Digital proctoring research: the eight topics

Table 1 shows the eight topics proportions throughout the entire corpus, their most frequently used words, and their references. The most studied topics are Topic 3 Adoption of digital proctoring (23.3%), and Topic 6: Compare proctored and un-proctored online exam on students' academic performance (20.6%). We further elaborate these eight topics below in Table 1.

Topic (T) labels (%)	Most frequent words	Example references
T1: Digital proctoring systems developments (14.8%)	Online, system, exam, propose, examination cheat, face, model, student, method	Ganidisastra and Bandung, 2021; Indi et al. 2021; Kamalov et al. 2021; Maniar et al. 2021; Özgen et al. 2021; Saba et al. 2021
T2: Digital proctoring as the emergency response to Covid-19 pandemic (11.1%)	Pandemic, remote, covid 19, university, assessment, method, program, transition	Arja et al. 2021; Camara, 2020; Cygan and Bejster, 2021; Du Plessis et al. 2021; Lei et al. 2020; Son et al. 2020

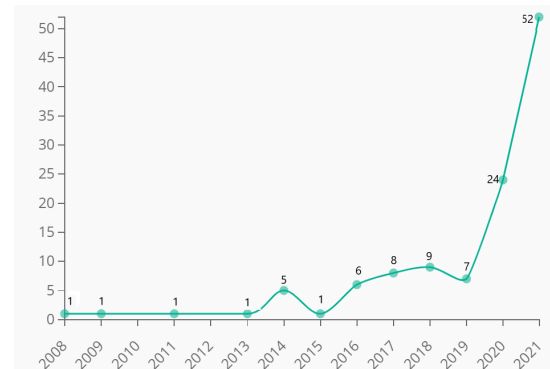


Figure 3 Publications timeline

medical sciences, social sciences, and humanities. The first among the 63 outlets—Education and Information Technologies—has published 3 articles (Kharbat and Abu Daabes, 2021; Nigam et al. 2021; Raman et al. 2021). Figure 4 shows the most frequently used words in the corpus, such as *online*, *student*, *exam*, *proctor*, *use*, *test*, and *assessments*.

The three digital proctoring programs, LP, RP and AP, or combined programs, such as LP+AP, or RP+AP or LP+AP+RP, were studied in the

T3: Adoption of digital proctoring (23.3%)	Online, student, assessment, learn, education, examination, academic, study, technology	Draaijer et al. 2018; Gudiño Paredes et al. 2021; Liapis et al. 2021; Muzaffar et al. 2021; Raman et al. 2021; Reedy et al. 2021; Selwyn et al. 2021
T4: Digital proctoring and educators' challenges (9.9 %)	Exam, student, proctor, online, paper, distance, problem	Cleophas et al. 2021; Chotikakamthorn and Tassanaprasert, 2020; Law et al. 2020; Li et al. 2021; Scarbecz et al. 2020; Smith 2021
T5: Digital proctoring and students' authentication and authorship (6.6%)	System, cheat, teacher, approach, assessment, authentication, student, check, teach, biometric	Bergmans et al. 2021; Marín García et al. 2021; Mellar et al. 2018; Peytcheva-Forsyth et al. 2019; Zhu and Cao, 2021; Vegendla and Sindre 2019
T6: Compare proctored and un-proctored online exam on students' academic performance (20.6%)	Proctor, student, online, exam, test, score, study, result, compare, academic	Alessio et al. 2018; Goedl and Malla, 2020; Hylton et al. (2016); Lee 2020; Reisenwitz 2020; Rios and Liu, 2017; van Halem et al. 2021; Wuthisatian 2020
T7: MOOCs, online program and digital proctoring (3.3%)	Candidate, framework, behavior, app, program, MOOCs, register	Li et al. 2015; Maas et al. 2014; Pavlou et al. 2008; Rodchua et al. 2011; Staubitz et al. 2016
T8: Issues of digital proctoring (legal, privacy, ethics, security) (10.6%)	Test, proctor, remote, technology, security, privacy, online, concern	Balash et al. 2021; Coghlan et al. 2021; Colonna 2021; Kharbat and Daabes, 2021; Stapleton and Blanchard, 2021

Table 1 Topics with their percentages in the corpus, most frequent words, and example references

Topic 1 (T1) discusses developing advanced technical features, especially AI features, of digital proctoring systems to make online distance examination more secure and reliable. For example, Indi et al. (2021) introduced a system to identify malpractice by categorizing the student's VFOA (visual focus of attention) data by capturing head pose estimates and eye gaze. This received an accuracy rating of 96.04% in classifying the Attention Matrix. Deep- and machine-learning techniques were used in the systems' development (Ganidisastra and Bandung, 2021; Kamalov et al. 2021; Maniar et al. 2021; Özgen et al. 2021; Saba et al. 2021). Other examples such as a biometric authentication and blockchain-based online examination scheme (Zhu and Cao, 2021), visual verification (Meraliyev et al. 2021), desktop robot for proctoring examinations in online/distance learning courses (Rosen and Carr, 2013), face recognition (Guillen-Gamez, 2017), and live video and audio streaming (Pandey et al. 2020) during an online exam were all discussed within this topic.

Moreover, Abisado et al. (2018) proposed gesture modeling to classify and identify student disengagement effect through the use of head poses as gesture during the online examination. It was reported as having a 78.77% accuracy level when classifying suspicious behaviors of the students while taking e-exam. Atoum et al. (2017) and Prathish et al. (2016) have used multimedia analytics system—an e-cheating intelligence agent—as a mechanism (Tiong and Lee, 2021), while keystroke dynamics-based authentication (KDA) (Senthil Kumer and Rahti, 2021), and fingerprints (EI Sayad et al. 2014) that perform automatic online exam proctoring were also studied. The authors in their proposed system used webcam, wearcam, and a microphone to monitor the visual and acoustic environment of the testing location and reported high accuracy, robustness, and efficiency.

Topic 2 (T2) discusses the use and challenges of digital proctoring systems as an emergency response to the education crisis caused by COVID-19 which demanded the transition from face-to-face teaching and learning to a virtual environment (Cygan and Bejster, 2021). After investigating changes implemented in education such as video-based remote proctoring, Arja et al. (2021) concluded that adaptations of medical education during this pandemic were highly dependent on technology. Daftary et al. (2020) argued that the use of online proctoring with AI during emergency remote learning can be a successful replacement of the traditional on-campus exam, and with software training, can ensure the integrity of assessments. Du Plessis et al. (2021) and Son et al. (2020) investigated the challenges of a rapid transition to distance-learning and stated that one of the main challenges was conducting web-

based assessments with reliable and secure proctoring systems (Camara, 2020). Finally, Lei et al. (2020) studied the optimization use of the testing facility as well as investigated the supporting programs developed to aid teaching staff when assessing the students learning during campus closure. The authors pointed out many challenges associated with such a transition. Examples include the sudden shift from classroom to online learning and exam proctoring (methods/strategies), as well as the adaptation and changing behavior on how to use such systems.

Topic 3 (T3) discusses the adoption of digital proctoring systems. Muzaffar et al. (2021) performed a systematic literature review on factors influencing the adoption and use of online exam proctoring and found that several factors impact the overall adoption of online exam systems, such as the network infrastructure, hardware requirements, implementation complexity, and training requirements. Moreover, Parfenov and Legashev (2020) argued that the lack of fully-fledged technical solutions is an objective factor influencing the provision of all forms of organizing the educational process in a distance format. The authors recommended developing online proctoring systems as well as mechanisms embedded in the electronic educational systems of universities to stimulate student motivation. Hussein et al. (2020) argued that the adoption of online exam proctoring solutions by educational institutions greatly depends on two important factors: the cost of the services and their technical requirements. Reedy et al. (2021) found that higher educational institutions need to redefine the characteristics of academic misconduct to account for changes in the execution of the examinations delivered digitally. The pandemic was also an important factor that influenced the uptakes of the proctoring systems (Bernardo and Bonta, 2020; Haus et al. 2020; Selwyn et al. 2021). Jefferies et al. (2017) argued that factors such as security, cheating prevention and deterrence, privacy, and data protection are the main issues for adopting such systems.

Several studies investigated the factors that influenced students' behaviors toward proctoring systems. For example, Raman et al. (2021) studied students' adoption behavior based on diffusion of innovation theory, while Sapawi et al. (2021) identified the factors influencing students' attitudes in implementing both alternative and online assessment in an outcome-based education (OBE) system. Moreover, it has been found that the adoption of remote proctored exams by students is seen as a sense of obligation with feelings of being watched, rather than internal motivation or a personal reflective process. This lack of privacy and the increased anxiety are influential factors experienced by the students (Gudiño Paredes et al. 2021). Also, Liapis et al. (2021) found that students were satisfied in general from the remote examination process and indicated that they would be willing to be examined remotely in the future. Cramp et al. (2019) concluded that, for successful implementation of online exam systems, students should be well-informed and equipped with the technical requirements, acquire digital skills, and be provided with accessible and responsive technical support. Draaijer et al. (2018) found that students may opt for an online exam for several different reasons, such as completing online distance learning programs anywhere in the world with internet access, or they live close to their local institutions but choose online assessment for its convenience, (e.g., employment or those who have children to care for at home).

Topic 4 (T4) discusses problems and challenges faced by the teachers and examiners when conducting an e-exam, in other words, the problem is proctoring off-campus exams (Chotikakamthorn and Tassanapraser, 2020), preventing students from cheating (Balderas and Caballero-Hernández, 2020; Shirodkar et al. 2021), and using several techniques to authenticate students taking the online exams (Senthil Kumar and Rathi, 2021). However, educators met serious challenges in preventing malpractice. Smith (2021) studied the experiences of educators' who developed online proctoring methodologies incorporating the direct use of students' smartphones and devices during online assessments. The study results showed that the evidence of academic dishonesty, its prevention, along with mistakes and best practices in creating a viable proctored academic environment, were the main challenges of online exams faced by the educators. Similarly, Cleophas et al. (2021) reported on e-exam proctoring challenges faced by educators and mentioned that even though a range of proctoring software providers offer to uphold students' academic integrity, precluding cheating is not easy when tech-savvy students take online exams at home and on their own devices. In another study, Lewis (2020) investigated the challenges of e-exam from the educators' perspective and their research showed strong correlations

between online exams and paper exams, alleviating concerns that widespread cheating may take place. In addition, educators found that, despite the measures taken to keep the online exam secure, repeating the same exam at a later date for students who missed the original exam was seen as potential problem. Li et al. (2021), in their attempt to identify the major challenges on e-exam proctoring as seen by educators, found that the main issue of concern was the online exam at individual homes invites students to cheat in various ways, especially collusion. Other educators' challenges were also discussed: for example, Scarbecz et al. (2020) argued that demand for proctors exceeds the supply, and often campus colleges reported unsatisfactory experiences as remote proctoring resources are limited. Also, Law et al. (2020) argued that providing course lectures and materials online may lead to employing surface learning strategies by students. This required integration of more proctored online exams to tackle the problem.

Topic 5 (T5) discusses the problems and solutions of students' authentication and preventing cheating behaviors when using digital proctoring. Rodchua et al. (2011) reported that the inability to control a student's environment while taking exams has been a major challenge for higher education and found that there is a clear correlation between an increase in the number of acts of dishonesty and the failure of institutions offering courses to monitor and enforce policies on cheating. Mellar et al. (2018) studied higher education teachers' perceptions of the prevalence and types of cheating in e-assessment, especially authentication of the students (Hussein et al. 2020), as well as to understand the differences in risk and possible mitigations (González-González et al. 2020; Vegendla and Sindre, 2019), along with the integrity of the assessment and the capacity of the students to adapt to this new assessment method (Marín García et al. 2021). In this regard, Amigud et al. (2018) argued that managing integrity of continuous and authentic assessments in an open and distance environment is a complex process. Therefore, there is a need to develop an institutional approach to academic integrity and the integration of technologies for student authentication (Peytcheva-Forsyth et al. 2019).

A few solutions are proposed to tackle the problems. Bergmans et al. (2021) used a dedicated system, which used an AI-based algorithm to automatically flag suspicious behavior, which can then be checked by a human agent. Özgen et al. (2021) developed an anti-cheating system and evaluated the usefulness of such system for mitigation. Also, Jie and He (2021) designed and implemented an intelligent online proctoring system (IOPS) by using AI technology to monitor online exams to prevent the learners from cheating. In this way, they guarantee the integrity and equality for all examinees as in traditional classroom exams. In addition, Zhu and Cao (2021) proposed to improve online examination schemes by using the protection of biometric features and fine-grained access control. Finally, Vegendla and Sindre (2019) suggested using biometrics as a key solution to improve students' authentication in online distance examinations.

Topic 6 (T6) mainly studies the impacts of proctored online exams on students' academic performance (e.g., study results or exam scores). The differences of the students' scores were found between proctored and unproctored exams. Goedl and Malla (2020) compared exam scores statistically alongside the time necessary to complete exams for proctored and un-proctored exams in two online courses, and found that proctored and un-proctored exams are not equivalent and suggested that instructors should approach online testing thoughtfully if the intention is to maintain grade equivalency with traditional proctored examinations. Wuthisatian (2020) also studied the impact of different proctored environments on student exam performance in online economics courses and showed a significant difference between the two proctored environments, with a higher average score for the final exam proctored onsite at testing centers. Alessio et al. (2018) investigated that students' performance taking online exam and found that the use of proctoring software resulted in lower average scores for students, implying greater compliance with academic integrity compared with when exams were taken without proctoring software. Davis et al. (2016) reported that the grades were significantly lower for students who were proctored using a remote service compared to students who were not proctored. Hylton et al. (2016), Reisenwitz (2020) and van Halem et al. (2021) also compared students' score on online and offline exams and did not find any significant difference between the scores of the two groups, although the non-proctored group had slightly higher scores.

Similarly, Alessio et al. (2017) found that students achieved, on average, lower scores and used significantly less time in online tests that utilized proctoring software versus those that were un-proctored. Prince et al. (2009) found significant differences in average test grade scores between tests taken electronically without a proctor as compared to those administered using a live or a remote proctor overall. The studies of Vazquez et al. (2021) and Daffin and Jones (2018) showed that students whose exams were not proctored scored higher on average than those whose exams were proctored. In another study, Fask et al. (2014) found that the difference in the testing environments disadvantaged students taking the online exam, which somewhat offsets the advantage that the un-proctored students gain from greater opportunities to cheat. Finally, Woldeab and Brothen (2019) studied students' performance and argued that online exam proctoring brings about lower exam scores and that this is especially true for those students with high technological anxiety of taking exams in an online proctored setting.

However, a few studies reported that proctoring systems did not influence students' performance. Lee (2020) and Rios and Liu (2017) examined students' performance on online exams and found that there is no difference in the mean scores of exams and, therefore, the exam proctoring environment is unlikely to be related to student performance even when students take their exams either in online- or offline proctoring environments. Teclehaimanot et al. (2018) explored the use of three testing tools to determine whether there are differences in test scores and student grades in distinct testing environments. The results showed that there is not significant difference in the mean score between three different (non-proctored recorded online, non-proctored lockdown online, and non-proctored online) testing environments. Finally, Karim et al. (2014) found that the use of remote proctoring was associated with more negative test-taker reactions and decreased cheating, whereas remote proctoring did not directly affect test performance.

Topic 7 (T7) discusses the integration of digital proctoring to handle certificate valuation in MOOCs and online programs. Maas et al. (2014) studied how Coursera, one of the biggest MOOCs providers, verified students' credentials as the record of their performance by using biometrics methods. Staubitz et al. (2016) compared online proctoring and the current practices of MOOC platforms and concluded that online proctoring seemed to be a suitable way to verify the students. Li et al. (2015) argued that the practice of MOOCs failed to provide an effective method to detect cheating on online exams. Thus, they proposed a Massive Open Online Proctoring (MOOP) framework consisted of three major components: Automatic Cheating Detector (ACD), Peer Cheating Detector (PCD), and Final Review Committee (FRC) to detect cheating behaviors. The proposed systems can detect misconduct with good accuracy and can reduce the overall human resources required to monitor students' MOOC exams. The "Telexetasis" system proposed by Pavlou et al. (2008) also discussed the problems that e-examination posed in open and distance learning, such as impersonation, collaboration, and cheating. The failure of higher education institutions to provide secure and reliable exams in distance education resulted in the slow development of online programs and MOOCs (Rodchua et al. 2011).

Topic 8 (T8) discusses the various issues associated with the implementation of digital proctoring, such as legal, security, privacy, and ethical issues. In a systematic literature review of existing AI and non-AI-based proctoring systems, Nigam et al. (2021) found that the major issues are security and privacy concerns, ethical concerns, and trust in AI-based technology, among others. Colonna (2021) was concerned about the legal implications of the use of AI-based remote proctoring to monitor online exams and to validate students' identities. The author studied and explored the use of AI-based remote proctoring technologies in higher education, both from the institutional perspective as well as from the student perspective. The results indicated that the use of AI-based remote proctoring technologies in higher education impacted the rights of students, with a focus on the fundamental rights to privacy, data protection, and non-discrimination.

El Sayad et al. (2014) stated that the online examination system is the most important component of e-education because of the security issues and stated that to be free of cheating is the main challenge that faces the online examination system versus traditional paper and pencil exams (Stapleton and Blanchard, 2021). Similarly, Langenfeld (2020) studied issues associated with securing the online exam environment and stated that vendors offer online assessment delivery systems designed to minimize unauthorized behaviors with varying security levels. Tucker and Cross (2016) argued that one of the

main problems associated with online proctoring is that the provider of the test must be certain that the student is displaying their capability and it is naive to think that students are not taking advantage of electronics or other methods to give them an unfair advantage in examination performance. As such, the authors stated that educational institutions must strive to find different approaches to secure their online exam environments. Turani et al. (2020) demonstrated that security is one of the major concerns in online exams and concluded that such systems must not only ensure the identity of a test-taker but also the overall test integrity and exam security. Purpura et al. (2021) argued that high-tech security software is instrumental in administering education during the pandemic.

Coghlan et al. (2021) stated that online exam proctoring technologies have alarmed some students who see them as a “Big Brother-like” threat to liberty and privacy, and as potentially unfair and discriminatory. They concluded that critical, ethical appraisals of online proctoring technologies must be provided by the educational institutions. Moreover, Cohney et al. (2021) argued that universities have been forced to rely on remote educational technologies to facilitate the rapid shift to online learning and concluded that introducing such systems pose new risks of security vulnerabilities and privacy violations. It has been found that the adoption of the remotely proctored exams by students is seen as a sense of obligation and contains a feeling of being watched, rather than fostering internal motivation or a personal reflective process. Additionally, the lack of privacy and anxiety are influential factors experienced by the students (Gudiño Paredes et al. 2021). Kharbat and Daabes (2021) investigated students experience with digital exam proctoring and reported that students are mainly concerned about their privacy and personal data protection. Finally, Balash et al. (2021) found that students are concerned about both the amount and the personal nature of the information shared with the exam proctoring providers.

4.2 Digital proctoring research trends

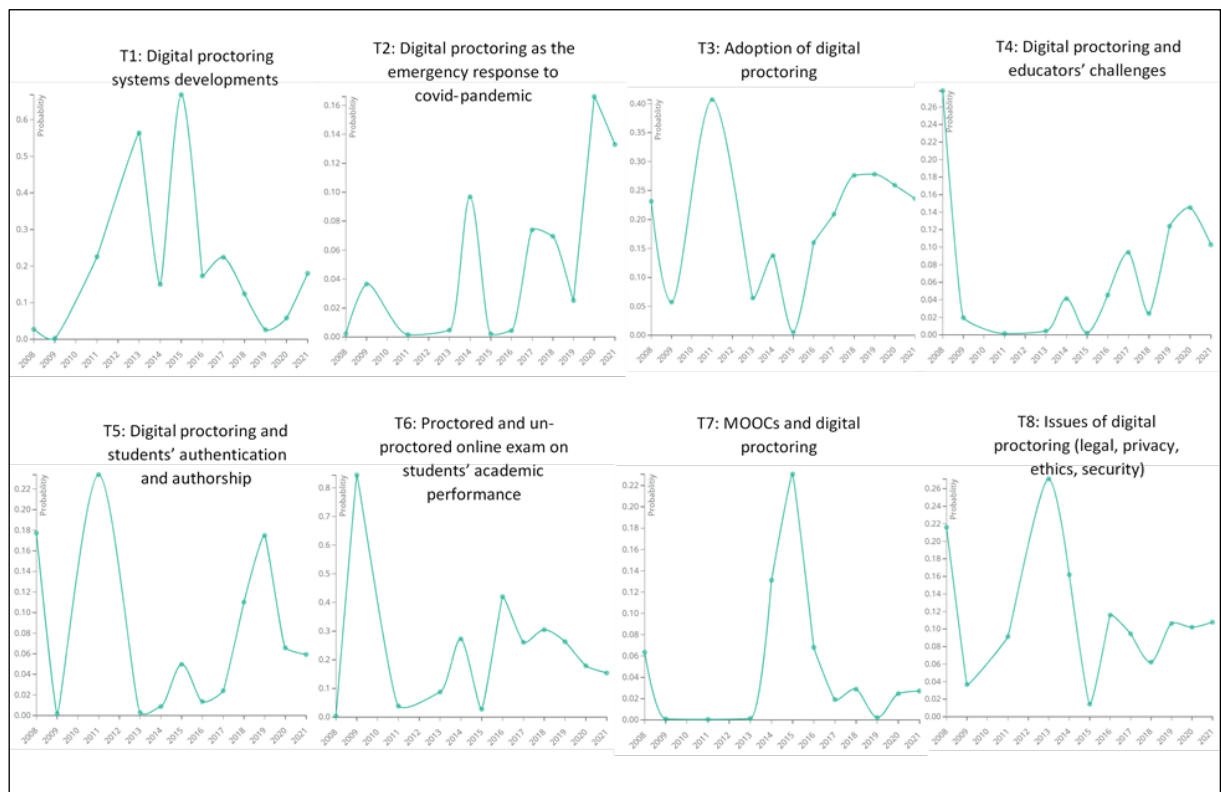


Figure 5 Annual topic proportion within the corpus for the eight topics

Figure 5 shows the research trends of the eight topics of the entire corpus. Topic 1: Digital proctoring systems developments has been studied mostly in the years between 2012 to 2015, and then declined.

The research on this topic rebounded after 2019. Obviously, Topic 2 has greatly increased after 2019 as the response to the COVID-19 driven problems. Topic 3 shows that research about adoption of digital proctoring reached its peak in 2011, to the bottom in 2015, and then steadily increased from 2016. Educators' challenges regarding the use of digital proctoring was an important topic (Topic 4) through the years, particularly from 2016 to 2021, although variations in the use of digital proctoring were found. The studies of how to use digital proctoring to detect cheating and to improve students' authentication in online exams (Topic 5) also varied over the years. This variation can also be found in the research of Topic 6: Effects of proctored exam on students' performance. The studies on Topic 7: MOOCs, online programs and proctoring reached the top in 2016. The issues related to digital proctoring have been discussed in the literature, with a slightly increasing trend in 2021. If we look closer at the research trends in 2021, we can see that the research on Topic 1, Topic 7, and Topic 8 have a positive trend. Other topics have tended slightly downwards.

5 Discussion

In this paper, we have presented a state-of-the-art literature survey regarding digital proctoring across various disciplines and we have identified how such research has been studied in the literature. This review differs from other literature reviews, for example, done by (Arnó et al. 2021; Nigam et al. 2021) as we had broader foci and an explicit agenda to search for the relevant literature. Additionally, we employed topic modeling analysis. We found eight topics and research trends through the completion of the review.

The findings demonstrate that the technical features of digital proctoring systems have improved, in tandem with both the innovations of education technology, as well as with advancements of AI technologies for detecting misconduct and malpractice in online examinations. The digital proctoring systems can, in general, provide a secure environment for online examination and can improve academic integrity with appropriate accuracy. The technological advancements of digital proctoring systems are necessary and critical to overcome the underlying challenges of online exam such as cheating. Nevertheless, no current proctoring systems can fully prevent and detect malpractices in online distance examination environments. More research should be conducted to improve the technical features of the systems as the research trend of Topic 1: Digital proctoring systems developments showed in Figure 5. Though there are numerous challenges for implementing the proctoring systems, higher education institutions have accumulated valuable knowledge and practices, especially during the pandemic time. This research suggests that higher education needs to develop an institutional approach for proctored online exams and define new principles for preventing and detecting misconduct. New examination practices supported by proctoring systems need to be advocated. Sufficient support and training for teachers and study administrators is needed. Students also need to be informed and prepared for the new examination practice. Supported by potential technical advances in proctoring systems, higher education institutions can enhance their control over the online distance examination environments, and thus improve the academic integrity of exams. This will be valuable for the institutions to develop and improve more online programs and MOOCs for disseminating knowledge to more people. Future research can focus more on the relationships between the use of digital proctoring systems and the effects on online program and MOOCs development.

The findings of this research showed that the exam-takers have generally positive attitudes towards the proctoring systems. The research showed evidence that the use of proctored online exam did significantly influence (e.g., Wuthisatian 2020) students' academic performance in comparison to in-person or non-proctored examinations, though insignificant results were also found (e.g., van Halem et al. 2021). This may largely be due to the fact that the students were first-time users of proctoring systems and this situation produced technostress and anxiety during the exam (e.g., Woldeab and Brothen, 2019). This can be mitigated after the students gain experience in having this type of proctoring for their examinations. However, future studies are necessary to provide better understanding of the effects of proctored exam on students' academic performances.

The review results also pointed out the legal, security, privacy, and ethical issues of using digital proctoring systems in higher education which need to be fully understood and addressed by all stakeholders and decision makers. Otherwise, the issues may limit and hinder the use of the systems, especially the legal issues (Slusky 2020). The literature review demonstrated that, such as those reviewed in Topic 1: Digital proctoring systems developments, more and more AI and deep learning techniques are used in developing and enhancing the technical features of the proctoring systems. However, the technological development of AI, such as face recognition, has posed threats to students' fundamental human rights (privacy, data prevention etc.), ethics and privacy (Coghlan et al. 2021). Greenstein (2021) argued that the development of AI-related laws and regulations is slower than the technological developments of AI, and is bounded by national borders. Nonetheless, we need to further explore whether the proctoring systems are necessary and lawful for transforming the examination practices in higher education from traditional physical locations to digital environments. This transformation has serious legal implications for students (Nigam et al. 2021). We should pay more attention to investigating the legal issues and implications of using proctoring systems, especially AI is an exam invigilator (Colonna 2021). The research trend of Topic 8 (see Figure 5) also indicates the importance of such requirements.

We argue that the implementation and use of digital proctoring systems for online examination is a crucial process for digitalizing higher education. The review results show the insights from the practices across all academic disciplines, though most of the usage of the digital proctoring systems were forced by the emergency disruption of tradition education due to COVID-19 pandemic. However, we argue that the practice during the pandemic is valuable and can serve as departure points to continue using proctoring systems to improve the academic integrity of online examinations even after the universities return back to normal "campus" education. Vermunt (2007) has strongly argued that the ultimate goal of higher education should be to help students to prepare for lifelong, self-regulated learning. This is also one of the United Nations sustainability development goals (SDG #4), which is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (UN, 2015). We also assert that such lifelong learning should not be restricted by spatial-temporal restrictions and institutional boundaries when the world population has increased the accessibility to Internet and personal computers. Digital proctoring systems have provided a new way of implementing final assessments and examination of online teaching and distance learning in higher education. Digitalizing examination with the support of digital proctoring systems should ideally continue in the future. We think this is crucial for higher education to provide equal access of knowledge to all humans across the globe, and this equality should not be limited or hindered by the challenges of online examinations in comparison with traditional physical examinations. We are positive that the technological advancements of digital proctoring systems will address the issues and challenges will also posing more demands and changes in digitalizing higher education.

The insights that this paper provides are also applicable to the IS education. Freeman and Taylor (2019) and the authors of the special issue titled "The Changing Landscape of IS Education" have provided rich evidence about how IS education was transformed by technology in the last 30 years. Although they did not specifically discuss the practice of digital proctoring within IS education, they claimed that "we do not know what the future will bring, but we believe the discipline is up to the challenge" (ibid, p. 215). Therefore, we encourage the IS community to continue the development of digital proctoring and thereby advance IS education to the next stage, (i.e. digitalizing IS education to a greater extent even after the pandemic).

The findings of this review paper allow us to suggest that Information Systems (IS) research, in close collaboration with researchers from other disciplines, (e.g., education assessment and pedagogy), can play a central role in promoting the diffusion and the use of digital proctoring systems, as well as in producing new knowledge by investigating the new digital proctoring practice in higher education. The IS research community has the unique ability and distinction to bridge different discipline boundaries to study and understand new technological phenomena through the sociotechnical axis of cohesion (Saker et al. 2019). Walsham's (2012) remarkably open-ended and future-oriented paper advocated that the aim of information and communication technologies (ICTs) should be directed at humane ends, that

is, at making this a better world. Whether it is reasonable to expect that new technologies can be used, apart from political and economic revolutionary initiatives, to liberate benefits to all equally, we suggest that IS research focus more on the ethical and legal issues related to the uptake of digital proctoring systems, in the cross disciplinary research between information systems, ethics, and law.

There are some theoretical and practical implications in the current paper. In terms of theoretical implications, the review findings show that there is a need for a theoretical framework to bridge the gap between the complexity of the academic integrity of online examinations and digital proctoring applications in higher education. In addition, the review of 115 studies show that the primary focus of these studies was on the technical aspects of digital proctoring tools and methods. We found few studies which discussed the theoretical underpinning of digital proctoring research such as Raman et al. (2021), who used Diffusion of Innovation (DoI) to examine the adoption of digital proctoring technology.

Considering emergency situations, such as that imposed by COVID-19 pandemic, the review results provide several practical implications as well. For example, the findings show that there is need for the educators, instructional designers, policymakers, and decision makers at the higher education institutions to understand the challenges and the opportunities of online digital exams supported by digital proctoring systems. As one of the most recent means of students' performance assessments, it is necessary that they understand how the technology works and why such tools should be used and then carefully deciding amongst the different categories of digital proctoring, (i) live proctoring programs (LP), (ii) recorded proctoring programs (RP), and (iii) automated proctoring programs (AP).

In the end, we discuss the limitations of this review. Though we searched for scientific publications on digital proctoring systems from nine databases, the queries and the search terms used in the search may not have retrieved all the relevant studies. However, the final corpus consisted of 115 articles, which is a sufficient dataset for performing a topic modeling analysis. It should be noted that because the literature review was conducted in September 2021, there may be new publications that are relevant but not included in this study (e.g., Henry and Oliver, 2021).

In addition, the authors' subjective understanding may influence the labeling and interpretation of the eight topics. This is valuable to involve other experts to solicit the objective opinions found in the review in the future. The relationship among the topics is not examined because of the small dataset, and the largest numbers of studies were found between 2020 to 2021 (September). The pandemic had a dominant effect on the adoption of the systems and lead to disrupted changes of examination practices for both campus and online education. These effects are reflected in the eight topics which weaken the exclusiveness between the topics.

6 Conclusion

This paper aims to provide new knowledge and insights by performing a systematic literature review of the current research on digital proctoring in higher education. Through support of topic modeling methods, we are able to identify the eight topics of the research trends between 2008 to 2021. We believe that the knowledge gained through this literature review will guide future research as well provide support for proctoring systems implementation in higher education. The challenges and issues found in the literature may limit and hinder the continuous use of digital proctoring after campus-based education returns to higher education following the pandemic. We do not know what future crises may occur, but we think that digital proctoring practice should continue as a crucial process for digital transformation in higher education, a process that can then enable the foundation to provide equal access to knowledge to all humans and equal assessments of learning outcomes in remote and distance environments. To this end, multidisciplinary work should be undertaken with collaborations across all academic disciplines, higher education institutions, proctoring systems providers and educational policy, regulation, and law makers in society.

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