№ 3(17) 2023
НАУКА і ТЕХНІКА СЬОГОДНІ
серії: право, економіка, педагогіка, техніка, фізико-математичні науки

UDC 378.681.5

https://doi.org/10.52058/2786-6025-2023-3(17)-231-240

Tarasevich Iryna Grygorivna PhD (Engineering Sciences), Professor Associate, Professor Associate of Production Process Automation Department, Institute of Industrial and Business Technologies Ukrainian of State University of Science and Technologies, Gagarina Ave., 4, Dnipro, 49600, tel.: (066) 211-48-81, https://orcid.org/0000-0002-3249-619X

Tarasevich Alena Viktorivna MA (Applied Linguistics), MPH, MSc (Epidemiology), PhD (c), The University of Western Ontario, Schulich School of Medicine and Dentistry, Centre for Education, Research and Innovation (CERI), 1151 Richmond St, London, Ontario, N6A 3K7, Canada, tel.: +1 647-982-2614, https://orcid.org/0000-0003-0798-0569

Foris Svitlana Mikolaivna PhD (Engineering Sciences), Professor Associate, Professor Associate of Energy Systems and Energy Management Department, Institute of Industrial and Business Technologies Ukrainian of State University of Science and Technologies, Gagarina Ave., 4, Dnipro, 49600, tel.: (067) 931-01-70, https://orcid.org/0000-0001-7104-640X

Kuzmenko Mykhailo Yuriyovych PhD (Engineering Sciences), Professor Associate of Production Process Automation Department, Institute of Industrial and Business Technologies Ukrainian State University of Science and Technologies, Gagarina Ave., 4, Dnipro, 49600, tel.: (066) 428-05-16, https://orcid.org/0000-0002-1989-242X

MAJOR LESSONS LEARNT FROM AN ONLINE TEACHING OF AUTOMATION AND CONTROL COURSES DURING THE PANDEMIC AND THE WAY AHEAD: A CRITICAL INTERPRETATIVE SYNTHESIS

Abstract. Covid-19 brought in adapted frameworks, concepts, and tools into the design and delivery of automation courses at technical universities. Although university digitalization has been around for a while, it has been used primarily for the administrative purpose rather than for teaching and learning. A natural, powerful stimulator, the pandemic pushed the universities to explore new avenues in further digitalization of education.

The goal of this critical interpretive synthesis is to make a summary of the major lessons learnt from the online teaching of automation courses during the

pandemic and their further implementation. It is also aimed at exploring major tensions and barriers that users (teaching faculty, students, and administrative personnel) have been grappling with. The tensions and barriers are presented in this paper from three distinct perspectives – from the perspectives of students, teaching faculty, and university administrators.

Whether students thrive or survive, the faculty rethink and upskill their teaching, and the institution is capable of meeting multiple, often competing needs and shifting priorities of the market – warrants further research on the topic. An important question to be addressed in future inquiries is whether the stakeholders that are engaged in the process of developing, teaching, and taking an automation course, are able to reconceptualize their roles and continue to grow professionally.

Keywords: university education, pandemic, digitalization, automation.

Тарасевіч Ірина Григорівна кандидат технічних наук, доцент кафедри автоматизації виробничих процесів, Навчально-науковий інститут «Інститут промислових та бізнес технологій» Українського державного університету науки і технологій, 49600, м. Дніпро, пр. Гагаріна, 4, тел.: (066) 211-48-81, https//orcid.org/0000-0002-3249-619X

Тарасевіч Олена Вікторівна магістр гуманітарних наук (прикладна лінгвістика), магістр суспільної охорони здоров'я, магістр природничих наук (епідеміологія та біостатистика), аспірант, Університет Уестерн провінції Онтаріо, факультет медицини та стоматології Шулік, Інноваційний науково-освітній центр CERI, 1151 Річмонд стріт, Лондон, Онтарио, N6A 3K7, Канада, тел.: +1 647-982-2614, https://orcid.org/0000-0003-0798-0569

Форись Світлана Миколаївна кандидат технічних наук, доцент кафедри енергетичних систем та енергоменеджменту, Навчально-науковий інститут «Інститут промислових та бізнес технологій» Українського державного університету науки і технологій, 49600, м. Дніпро, пр. Гагаріна, 4, тел.: (067) 931-01-70, https://orcid.org/0000-0001-7104-640X

Кузьменко Михайло Юрійович кандидат технічних наук, доцент кафедри автоматизації виробничих процесів, Навчально-науковий інститут «Інститут промислових та бізнес технологій» Українського державного університету науки і технологій, 49600, м. Дніпро, пр. Гагаріна, 4, тел.: (066)428-05-16, https://orcid.org/0000-0002-1989-242X

ДОСВІД ОНЛАЙН-ВИКЛАДАННЯ ДИСЦИПЛІН З АВТОМАТИЗАЦІЇ ВИРОБНИЧИХ ПРОЦЕСІВ У ПЕРІОД ПАНДЕМІЇ: КРИТИЧНИЙ ІНТЕРПРЕТАТИВНИЙ СИНТЕЗ

Анотація. Covid-19 адаптував під нову реальність моделі, концепції та інструментарій для розробки та викладання університетських дисциплін з

автоматизації виробничих процесів. Хоча діджиталізація університетів проходить вже досить довго, вона ніколи широко не застосовувалася з педагогічною метою. Як природний потужний стимулятор, пандемія підштовхнула університети використовувати діджиталізацію в навчальному процесі, а не тільки в адміністративних цілях.

Даний критичний інтерпретативний синтез присвячений методології онлайн-викладання у ЗВО дисциплін з автоматизації на основі здобутого практичного досвіду під час пандемії та її подальшого застосування у навчальному процесі. Даний критичний інтерпретативний синтез також спрямований на вивчення основних протиріч та бар'єрів, з якими стикаються користувачі технологій, а саме: викладацький склад, студенти та адміністрація. Саме з цих трьох основних груп користувачів розглядаються далі основні протиріччя і перешкоди, викликані діджиталізацією навчального процесу.

Подальшим напрямком науково-практичних досліджень може стати вивчення питань, пов'язаних з тим: 1) наскільки студенти «досягають успіху або виживають» у нових реаліях вищої освіти; 2) наскільки викладачі змогли перебудуватися та підвищити свою педагогічну компетентність; 3) наскільки ЗВО, у свою чергу, спроможні задовольнити численні потреби, що часто конкурують одна з одною, а також пріоритети ринку і споживачів, які змінюються. Важливе питання, на яке мають відповісти дослідники: чи здатні всі учасники навчального процесу переосмислити свою роль у ньому та продовжити зростати професійно?

Ключові слова: вища освіта, пандемія, діджиталізація, автоматизація.

Introduction. Although in a disruptive manner, nothing stimulates people better for development than any sort of crisis: a pandemic, a revolution, a war, or any other major natural disaster or a socioeconomic change in the human history. This has been the case with the wide-reaching impact of Covid-19 on university digitalization that brings in its associated tensions and challenges – both pre-existing and Covid-specific. Similar to many areas of educational practice, the literature on digital universities is large, complex, and diverse. It includes various types of evidence, such as quantitative and qualitative studies, theoretical and methodological work, and epidemiological studies. A ‘hot shot’ for several years now, the pandemic has stimulated a lot of interesting projects and inquiries being run around the world, and many relevant articles are being published daily on its impact on university education. That is why it would be beneficial to conduct a review of the area that could produce a "mid-range" theoretical account of university digitalization under a crisis that can be applied to a variety of educational settings [1].

Research questions. What are the major tensions of and barriers to university digitalization that users (teaching faculty, students, and administrative personnel) have been grappling with during the pandemic? What are the lessons learnt from the online teaching of automation courses at technical universities during the pandemic and how can they be further translated into educational practice?

Literature Review. Critical interpretive synthesis (CIS) is a relatively new type of review methodology that synthesizes different types of evidence to critically develop new theory of a phenomenon. Originated in health equity research in 2006 [1], CIS was initially taken up in health professions education and since 2013 other social sciences studies have begun using it in their reporting practices [2]. Sensitized to both conventional systematic review methodology and qualitative methods of interpretative synthesis, CIS does not prioritize quantitative evidence over qualitative inquiry and assumes that both have something to add to theory building in a topic area. While a conventional systematic review is beneficial for appraising and summarizing evidence from primary studies [3] with the aim of testing theories and finding out "what works" (aggregative synthesis), it is more limited when the aim of a review is to develop theories (interpretive synthesis) [1]. Contrary to the conventional systematic review methodology with its clear account of pre-defined and reproduced searching strategy [3], CIS relies on a more organic review process. It fits better the emergent nature of a review question and combines several search strategies. CIS provides not a definitive answer, but rather important insights into human experiences of a phenomenon, acceptability of policy, and a deeper understanding about why something might or might not work. It can also open up a floor for future inquiries into aspects of theory that have long been taken for granted and need to be problematized for their resolution. When carefully executed, CIS is also useful for synthesizing literature in preparation of a research grant or a practice project.

The objectives of the paper are: 1) to major tensions of and barriers to university digitalization that users (teaching faculty, students, and administrative personnel) have been grappling with during the pandemic; and 2) to summarize major lessons learnt from the online teaching of automation courses during the pandemic and their further implementation into educational practice.

Methodology. The aim of this review is to construct a critical analysis of a complex and diverse body of literature on university digitalization during the COVID-19 pandemic. Although the two approaches described above – aggregative and interpretive syntheses – serve their own goals of theory developing or testing, for the purpose of exploring tensions and barriers to university digitalization in the pandemic context, interpretive synthesis seems to be more relevant. Given the relative novelty and diversity of university digitalization under Covid, it is neither desirable, nor feasible to formulate a review question – accurately and a priori. First, a tightly defined review question would make it difficult for new insights to emerge from the literature review. Second, the aim is to broadly explore tensions and barriers to university digitalization, with a focus on theory building on the topic, rather than on testing a specific hypothesis. For this purpose and contested at the outset of the study, the review question should be tentative and fuzzy, emergent and exploratory in nature [1].

A compass rather than an anchor [1], our research question is explored during the review process around three major tenets: 1) tensions and barriers to university digitalization from multiple perspectives of its main users or agents (students, faculty

members and university administration); 2) how pandemic reality (the enacted) impacts the inscribed features of technology (the espoused); 3) and what lessons can be learnt from this experience in order to meaningfully advance university digitalization in the future. Guided by an iterative approach to review and informed by emerging insights from the literature, the review question has been answered along the review process. Multidisciplinary reviewers are also a benefit, allowing the team to probe a few perspectives to be incorporated into different review stages.

In the literature search, we first retrieved relevant papers dated 2019-2022 from two electronic databases, the Web of Science and Scopus. The database search was then complimented with reference chaining, expert contacts and using the team expertise. As a result, some of the retrieved papers were not explicitly related to university digitalization, per se, yet important to the aim of the review [1]. Given the already diverse, large body of literature on university digitalization during the pandemic, the aim of the searching phase was shifted from including all the relevant literature (conventional systematic review) with a broad, exhaustive search strategy (university* education* COVID* key words in the topic field that searches titles, abstracts, and author keywords) to developing a sampling frame of some relevant papers that were identified with a narrower search strategy (university* digitalization* COVID* key words). Therefore, for practical reasons, we moved away from 14,004 potentially relevant papers retrieved from Scopus and the Web of Science to 380 relevant records. At the initial stages of the review, purposeful sampling was used to select papers that are relevant to the review purpose, i. e., information-rich papers that directly address barriers and challenges of university digitalization and their impact in the titles, abstracts, or authors' keywords. Later in the review process, theoretical sampling, i. e., sampling for the purpose of theory development, guided data collection and analysis. In other words, as the theory of COVID-19 impact on university digitalization was emerging from the literature, we decided which data to collect next and where to find them [4].

Findings: major challenges and barriers to university digitalization. As a result of this critical interpretive synthesis of literature, some key challenges and barriers to university digitalization were identified from the perspectives of main agents: students, professors, and university administrators. However, the most challenging part of university digitalization that all three groups of agents share is to overcome people's resistance to change (an entirely human factor). As a primary and most powerful barrier, a human factor is always at play and relates to knowledge, skills and culture [5], shaping any automation process. Furthermore, emergency remote teaching reveals a number of human factors that have been largely ignored by university education: lack of motivation, socio-emotional distance, socio-economic gaps and cultural isolation [6]. In an attempt to balance technology, pedagogy and the 'new normal', agents involved in university education are forced to be proactive and productive in their work while developing new skills fast in a stressful environment.

From students' perspective, the major challenge is technology [7] that in itself can further amplify the digital divide for vulnerable student populations [8]. Some also report it difficult to stay focused [7] while others suffer from lack of self-management and time to follow different subjects. Moreover, in a purely online context of self-isolation, the feeling of competitiveness as a powerful stimulator of learning can be missing. Whether students thrive or survive or are situated in-between is still to be explored by future research.

Professors also report isolation as a barrier to designing courses. The rapid transition to online teaching left some educators grappling with the necessity to redesign their courses to modalities they might have never taught in. This was particularly problematic at the beginning of the pandemic when they had no pedagogies for online teaching and evaluation [9]. With little training in some cases and in no time, the faculty were pressured to adapt quickly to new online methodology and acquire new competencies in technology use. Given the diverse levels of preparedness to use technology by faculty members (a digital divide), it is also reasonable to add a generational divide [8] to a list of powerful barriers and challenges to automation. What remains unresolved, however, and is particularly problematic for training students in the automation subspecialty, specifically, is providing feedback and ongoing support to students. Mainly dependent on laboratory equipment and IT-infrastructure, automation students, while on remote learning, cannot always receive prompt feedback from their instructors. Oftentimes, the process of saving, converting, and sending huge chunks of electronic control packages to their instructors for review is so time-consuming that feedback no longer serves its purpose. This is the case with any subspecialty that heavily relies in its training on physical, technological resources that are available only on campus and cannot be substituted otherwise.

At the institutional level, universities deal with similar tensions and barriers while also being challenged by financial constraints and limitations of their in-built IT infrastructures [10]. More than anything, such human factors, as lack of IT knowledge and skills to apply automation in specific contexts, pose a major challenge for administration. Similar to faculty members, administrators are expected to rapidly acquire skills in using new technologies while still grappling with a lack of culture for new modes of communication [5].

Findings: adapted frameworks and tools for automation course delivery. Due to the COVID-19 restrictions, the most efficient mode of e-learning (EL) turned out to be modified *blended learning* mode [11; also see Figure 1]. It entails a combination of technical contents and reading study materials available on virtual platforms and virtual class meetings with an instructor. The meetings are organized in the form of case-based, problem-solving discussions and brainstorming when students are encouraged to engage into active learning with their instructor. Therefore, asynchronous, self-paced learning (through reading study materials

available online) is efficiently supported by interactive, synchronous sessions with instructors, as well as by a remote mode of communication between them. From an operational standpoint, however, this modified mode of learning requires additional technical resources and mental preparation both for students and instructors. Although instructors can use the previously prepared and available online repositories of reading study materials, they still have to completely reorganize the structure of a course to match lectures with laboratory classes [12].

Although laboratory activities are essential for training automation engineers, the pandemic made it impossible for students and problematic for instructors to access laboratory space and stands. The issue of access can be partially mitigated through the use of ICT networks, social media, cloud services, and virtual tools. In practice, however, it is costly and time-consuming to develop appropriate standards and learning programs. It also means that laboratory operation principles need to be completely revised which makes the change relatively slow in educational practices at technical universities.

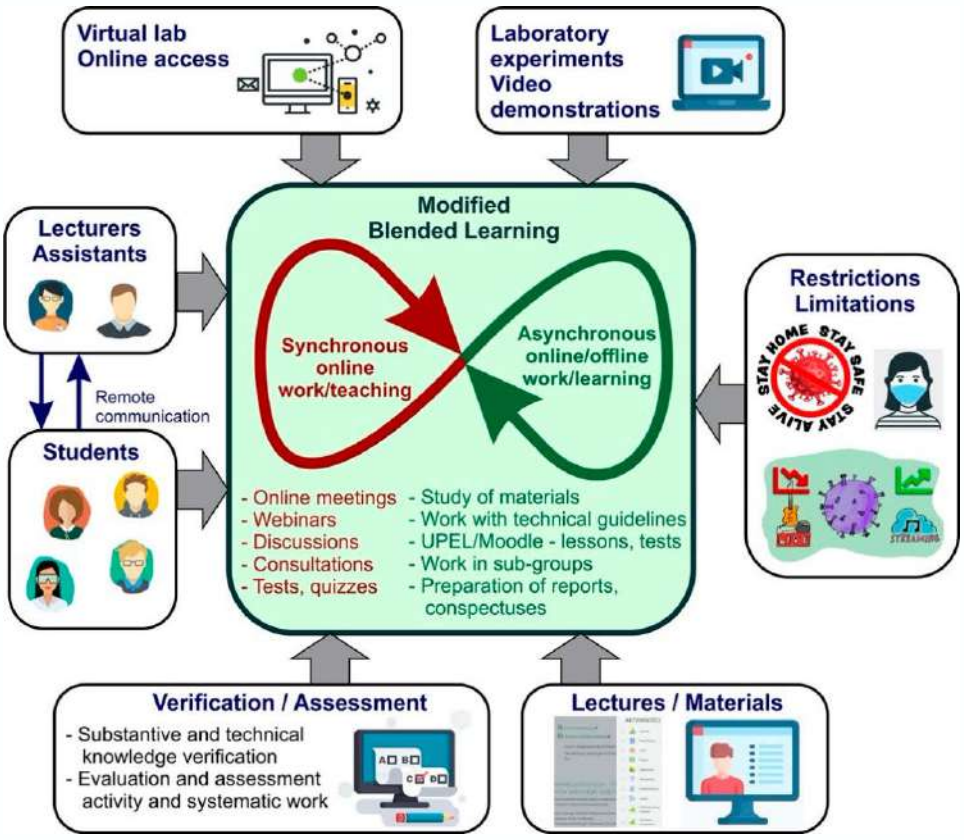

Fig. 1. *A modified blended mode of learning for designing an automation course with lectures, laboratory and other activities delivered remotely*

From: A. Ożadowicz, A, (2020). "Modified blended learning in engineering higher education during the COVID-19 lockdown—Building automation courses case study," *Edu. Sci.*, vol. 10, no. 10, p. 292, 2020, doi: 10.3390/educsci10100292.

Because laboratory classes cover a wide range of technical and application issues that are necessary for building automation engineers, instructors need to find a meaningful balance for their students between theory, substantive knowledge, and installation and integration practice classes [11]. Essentially, laboratory classes are pivotal for familiarizing students with different standards and technologies of building automation and instructors are urged to adjust the teaching and learning processes and come up with new modalities to be able to teach students practical aspects of building automation systems. In this respect, virtual platforms with a fully remote access to software and devices at the laboratory stands are particularly helpful. They allow instructors to work synchronously and almost directly with student although it is arguable the most time- and resource-consuming mode of conducting laboratory classes [11].

Discussion. The pandemic has demonstrated the necessity of rethinking roles in university education digitalization. It has demonstrated the great potential of technology and its biggest challenge of overcoming material and social dimensions of traditional educational practices. Socially, organizationally and materially, there are multiple digital learning spaces that can overlap with hybrid and physical spaces. For example, within a matter of minutes and almost effortlessly, a student can move from an in-person to a virtual lecture, from Wikipedia articles to an industry webinar, from an international discussion group to social media. All these ‘platforms’ are valid, legitimate ways of teaching and learning and that is why some farseeing researchers have long argued that future university digitalization will entail outside agents to be included into the process [13, 14]. In the years to come, this new experience can help bridge the gap between in-person and online learning. University digitalization, as experienced and lived through under Covid, is dual in nature because we clearly deal with digitalization of education and digitalization of subjects, i. e., all human agents involved in the process (students, faculty members, administrators, technical support staff, etc.).

Future research. The final account of the impact COVID-19 had had on university education, was shaped later in the review process. Moreover, much of the subsequent sampling was directed at developing and purposively challenging the theory of an impact as it began to emerge from the critical interpretive synthesis of the review findings. As mentioned above, such sampling methods and iterative nature of theory development are neither reproduced nor audited. Testing whether interpretations of COVID effects on university education change with new evidence, will be an important avenue to pursue in future research. It will also be interesting to assess further uptake of critical interpretive synthesis methodology and its potential in re-conceptualizing complex phenomena in quantitative and qualitative empirical work.

Conclusion. The critical interpretive synthesis of the literature of the pandemic impact on university digitalization, in general, and on the delivery of

automation courses at technical universities, in particular, reveals a few challenges and barriers along the process. These challenges and barriers are from the perspectives of three main groups of technology users: students, professors, and administrators. This summary work is timely and important because ever evolving digital learning spaces are here to stay. They will likely coexist with traditional delivery modes of university education. Although the importance of physical spaces and technology/laboratory resources of universities is hard to underestimate, remote teaching and learning will continue to thrive. That is why it is crucial to find a meaningful balance between traditional face-to-face courses and blended learning courses as well as develop new participatory culture shared by the key stakeholders.

References:

1. M. Dixon-Woods, S. Bonas, A. Booth, D. R. Jones, T. Miller, A. J. Sutton, R. L. Shaw, J. A. Smith, and B. Young, "How can systematic reviews incorporate qualitative research? A critical perspective," *Qual. Res.*, vol. 6, no. 1, pp. 27–44, 2006, doi: 10.1177/1468794106058867.

2. J. Depraetere, C. Vandeviver, I. Keygnaert, and T. V. Beken, "The critical interpretive synthesis: An assessment of reporting practices," *Int. J. Soc. Res. Methodol.*, vol. 24, no. 6, pp. 669–689, 2021, doi: 10.1080/13645579.2020.1799637.

3. M. Egger, G. Davey Smith, and A. Phillips, "Meta-analysis: Principles and procedures," *BMJ*, vol. 315, 1533–1537, 1997.

4. I. T. Coyne, "Sampling in qualitative research. Purposeful and theoretical sampling; Merging or clear boundaries?" *J. Adv. Nurs.*, vol. 26, no. 3, pp. 623–630, 1997.

5. E. Stefanova, "Digital transformation catalyzed by Covid-19 pandemic: Challenges and solutions," *Pedagogica*, vol. 94, no. 3s, pp. 13–24, 2022, doi: 10.53656/ped2022-3s.01.

6. C. Rapanta, L. Botturi, P. Goodyear, L. Guàrdia, and M. Koole, "Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education," *Postdigit. Sci. and Educ.*, vol. 3, no. 3, pp. 715–742, 2021, doi: 0.1007/s42438-021-00249-1.

7. L. Mishra, T. Gupta, and A. Shree, "Online teaching-learning in higher education during lockdown period of COVID-19 pandemic," *IJEDRO*, vol.1, no. 100012, 2020, doi: 10.1016/j.ijedro.2020.100012.

8. V. Govindarajan and A. Srivastava, "What the shift to virtual learning could mean for the future of higher education," Harv. Bus. Rev. Accessed: Sept. 29, 2022. [Online]. Available: https://hbr.org/2020/03/what-the-shift-to-virtuallearning-could-mean-for-the-future-of-higher-ed

9. C. Carolan, C. L. Davies, P. Crookes, S. McGhee, and M. Rox-Burgh, "Covid-19: Disruptive impacts and transformative opportunities in undergraduate nurse education," *NEP*, vol. 46, no. 102807, 2020, doi: 10.1016/j.nepr.2020.102807.

10. S. Krishnamurthy, "The future of business education: A commentary in the shadow of the Covid-19 pandemic," *J. Bus. Res.*, vol. 117, pp. 1–5, 2020, doi: 10.1016/j.jbusres.2020.05.034.

11. A. Ożadowicz, A, (2020). "Modified blended learning in engineering higher education during the COVID-19 lockdown—Building automation courses case study," *Edu. Sci.*, vol. 10, no. 10, p. 292, 2020, doi: 10.3390/educsci10100292.

12. S. Nogales-Delgado, S. Román Suero, and J.M.E. Martín, "COVID-19 outbreak: Insights about teaching tasks in a chemical engineering laboratory," *Educ. Sci.*, vol. 10, no. 9, p. 226, 2020, doi: https://doi.org/10.3390/educsci10090226.

13. R. Hazemi, S. Hailes, and S. Wilbur, Eds. *The Digital University: Reinventing the Academy*. Springer Science & Business Media, 2012.

14. N. C. Jackson, “Managing for competency with innovation change in higher education: Examining the pitfalls and pivots of digital transformation,” *Bus. Horiz.*, vol. 62, no. 6, pp. 761–772, 2019, doi: 10.1016/j.bushor.2019.08.002.

Література:

1. M. Dixon-Woods, S. Bonas, A. Booth, D. R. Jones, T. Miller, A. J. Sutton, R. L. Shaw, J. A. Smith, and B. Young, “How can systematic reviews incorporate qualitative research? A critical perspective,” *Qual. Res.*, vol. 6, no. 1, pp. 27–44, 2006, doi: 10.1177/1468794106058867.

2. J. Depraetere, C. Vandeviver, I. Keygnaert, and T. V. Beken, “The critical interpretive synthesis: An assessment of reporting practices,” *Int. J. Soc. Res. Methodol.*, vol. 24, no. 6, pp. 669–689, 2021, doi: 10.1080/13645579.2020.1799637.

3. M. Egger, G. Davey Smith, and A. Phillips, “Meta-analysis: Principles and procedures,” *BMJ*, vol. 315, 1533–1537, 1997.

4. I. T. Coyne, “Sampling in qualitative research. Purposeful and theoretical sampling; Merging or clear boundaries?” *J. Adv. Nurs.*, vol. 26, no. 3, pp. 623–630, 1997.

5. E. Stefanova, “Digital transformation catalyzed by Covid-19 pandemic: Challenges and solutions,” *Pedagogica*, vol. 94, no. 3s, pp. 13–24, 2022, doi: 10.53656/ped2022-3s.01.

6. C. Rapanta, L. Botturi, P. Goodyear, L. Guàrdia, and M. Koole, “Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education,” *Postdigit. Sci. and Educ.*, vol. 3, no. 3, pp. 715–742, 2021, doi: 0.1007/s42438-021-00249-1.

7. L. Mishra, T. Gupta, and A. Shree, “Online teaching-learning in higher education during lockdown period of COVID-19 pandemic,” *IJEDRO*, vol.1, no. 100012, 2020, doi: 10.1016/j.ijedro.2020.100012.

8. V. Govindarajan and A. Srivastava, “What the shift to virtual learning could mean for the future of higher education,” Harv. Bus. Rev. Accessed: Sept. 29, 2022. [Online]. Available: https://hbr.org/2020/03/what-the-shift-to-virtuallearning-could-mean-for-the-future-of-higher-ed

9. C. Carolan, C. L. Davies, P. Crookes, S. McGhee, and M. Rox-Burgh, “Covid-19: Disruptive impacts and transformative opportunities in undergraduate nurse education,” *NEP*, vol. 46, no. 102807, 2020, doi: 10.1016/j.nepr.2020.102807.

10. S. Krishnamurthy, “The future of business education: A commentary in the shadow of the Covid-19 pandemic,” *J. Bus. Res.*, vol. 117, pp. 1–5, 2020, doi: 10.1016/j.jbusres.2020.05.034.

11. A. Ożadowicz, A, (2020). “Modified blended learning in engineering higher education during the COVID-19 lockdown—Building automation courses case study,” *Edu. Sci.*, vol. 10, no. 10, p. 292, 2020, doi: 10.3390/educsci10100292.

12. S. Nogales-Delgado, S. Román Suero, and J.M.E. Martín, “COVID-19 outbreak: Insights about teaching tasks in a chemical engineering laboratory,” *Educ. Sci.*, vol. 10, no. 9, p. 226, 2020, doi: https://doi.org/10.3390/educsci10090226.

13. R. Hazemi, S. Hailes, and S. Wilbur, Eds. *The Digital University: Reinventing the Academy*. Springer Science & Business Media, 2012.

14. N. C. Jackson, “Managing for competency with innovation change in higher education: Examining the pitfalls and pivots of digital transformation,” *Bus. Horiz.*, vol. 62, no. 6, pp. 761–772, 2019, doi: 10.1016/j.bushor.2019.08.002.