OPEN ACCESS Top-Quality Science Peer Reviewed
Open Peer Reviewed

Review of Communication Research
2023, Vol.11
ISSN: 2255-4165

Post-COVID Evolution of Digital Communication in Online Education: A Review of Student–Teacher Interaction Models (2018–2022)

Lubna Yasmin Pinky
Department of Computer Science and Engineering,
Mawlana Bhashani Science and Technology University, Bangladesh
lubnacse@mbtu.ac.bd

Mohammad Ashraful Islam,
Department of Computer Science and Engineering, Jahangirnagar University, Bangladesh
ashraful.islam@juniv.edu

Suman Bhadra
Software Engineer,
Smarter AI, UAE
sumanbhadrasuman@gmail.com

Abstract

COVID-19 triggered a massive worldwide transition towards online learning, which years of digital adoption had taken decades to accomplish. This paper provides a systematic review of the development of digital communication in online education in recent years (2018-2022) with a specific emphasis on the models of student-teacher interaction through the prism of Computer Science and Engineering (CSE). We follow the developments since the emergence of Learning Management System (LMS)-centric, mostly asynchronous delivery in the Emergency Remote Teaching (ERT) crisis of 2020, to the intentional hybrid ecosystems that began to coalesce by 20212022. Three main models of interaction, such as synchronous, asynchronous, and hybrid, are explored in terms of their pedagogical quality and applicability to the CSE fields. The top challenges have been observed to be digital divide, academic integrity, loss of face-to-face laboratory experience, faculty digital literacy gaps, fragmentation of tools, and data privacy concerns. These include the future prospects of AI-based personalized learning, immersive metaverse classrooms, credentialing on blockchains, 5G-supported connectivity, and automated feedback powered by NLP. Our results serve as evidence-based policies to CSE teachers, curriculum developers, and policy makers who operate in the post-pandemic digital education landscape.

Keywords: Online education, digital communication, student–teacher interaction, COVID-19, LMS, hybrid learning, CSE education, e-learning, synchronous, asynchronous.

Editor: Giorgio P. De Marchis (Complutense University of Madrid, Spain).
Reviewers who accepted to sign their review: The reviewers prefer to stay blind.

Received: July 9, 2022 **Open peer reviewed:** December 11, 2022 **Accepted:** March 23, 2023 **Published:** May 10, 2023

I. Introduction

The COVID-19 crisis has made the world educational institutions leave face-to-face training almost overnight. Hodges et al. (2020) named this crisis-induced transition as an Emergency Remote Teaching (ERT) - a momentary, crisis-reactive solution, which is fundamentally unlike a planned online learning. At the height of the pandemic in April 2020, the UNESCO estimated that school and university closures impacted more than 1.6 billion learners in 190 countries (Bozkurt et al. (2020)). In a few weeks, hundreds of millions of students and teachers moved to digital platforms, and the use of technology was adopted by an estimated five to ten years.

In the case of Computer Science and Engineering (CSE) fields, this shift had special and urgent implications. CSE is much more focused on practical laboratory work, pair programming, work with hardware, real-time collaborative debugging, and interaction with specialized computing infrastructure than humanities or social sciences, which makes such tasks especially challenging to perform remotely (Alam (2020); Bao (2020)). Embedded systems, computer architecture, networking, and robotics course students were not able to access the physical system at the heart of their learning outcomes.

Before 2020, LMS platforms, including Moodle, Blackboard, and Canvas, were the dominant form of online education, only as content repositories and assessment management systems (Garrison and Anderson (2003)). The pandemic compelled the incorporation of synchronous technologies (Zoom, Microsoft Teams, and Google Meet) into asynchronous LMS processes (Rapanta et al. (2020)). By 20212022, institutions shifted to intentional hybrid architectures, generating empirical data that now makes it possible to conduct systematic review.

In the paper, three research questions will be discussed: (RQ1) How digital communication platforms change in 2018-2022? (RQ2) What interaction models developed and how effective were they in CSE education? (RQ3) What are the main challenges and future opportunities in digital CSE education? It is based on a literature review of more than 230 articles found in Open Access Journals, ResearchGate, Google Scholar, and ArXiv, with the 2018-2022 window and prioritized by the number of citations.

II. Related Work

A. *Prior Studies on Digital Education and Interaction Models*

A meta-analysis by Means et al. (2014) revealed that blended learning yielded considerably positive learning results compared to face-to-face or online-only delivery, and the empirical basis of the hybrid models that gained prevalence after 2020. Bernard et al. (2014) demonstrated that students in all-asynchronous online courses had lower completion rates and lower satisfaction scores especially in disciplines that were technologically intensive.

Dhawan (2020) was one of the first to give a comprehensive review of e-learning during COVID-19, listing the opportunities, such as scalability, flexibility, accessibility, challenges, such as connectivity, faculty readiness, student engagement. Rapanta et al. (2020) claimed that to achieve sustainable digital education, one needs to design and teach intentionally, not replicate face-to-face formats in a crisis situation. The authors of the study by Bozkurt et al. (2020) reported the state of responses of institutions in 31 countries to the pandemic, revealing the similar patterns of platforms acquisition, pedagogical modification, and equity issues.

Bao (2020) in the CSE-related literature found the following to be key success factors: pre-recorded libraries of lectures, active discussion forums, and regular office hours. Trust and Whalen (2020) discovered that only 95 percent of the teachers were confident about using the basic features of the platform, and less than 30 percent were confident about creating interactive online activities. The three fields of AI that Zawacki-Richter et al. (2019) deemed to have the greatest potential to impact in the near future include personalization, assessment automation, and predictive analytics.

B. *Theoretical Frameworks*

This review is informed by three theoretical frameworks. The concept of the Transactional Distance Theory (1993) by Moore forms the psychological distance between learners and instructors, which is incorporated as a result of dialogue, course design, and learner autonomy. The ERT pivot of 2020 had often increased the distance between transactions as instructors reverted to asynchronous content delivery that maximized structure but not interaction.

The Community of Inquiry (CoI) model (Garrison et al. (2000)) recognizes three overlapping presences: cognitive presence (meanings constructed by learners in a discourse), social presence (learners projecting themselves as real people), and teaching presence (design and facilitation of learning). The CoI framework offers an ethical perspective to assess how platforms are effective in the context of interaction models.

According to the TPACK model (Mishra and Koehler (2006)) to be effective in integrating technology, content, pedagogical, and technological knowledge of the intersection is required. The pandemic highlighted the TPACK shortages across the faculties who had good content and pedagogical knowledge and required technological skills to create an engaging interactive online learning experience (Trust and Whalen (2020)).

III. Platform Evolution (2018–2022)

Figure 1 shows the three phases of platform development that took place between 2018 and 2022.

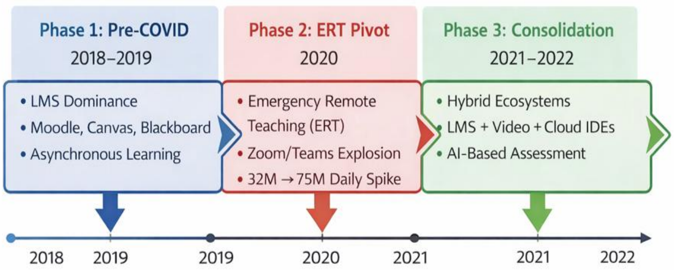

Figure 1: Timeline of digital platform evolution in online education (2018–2022).

A. Pre-COVID Era (2018–2019): LMS Dominance

Prior to the pandemic, CSE digital education was typified by LMS-based, predominantly asynchronous teaching. Moodle, Blackboard, and Canvas offered course content organization, discussion forums, submission of assignments, and grade book management (Dhawan (2020)). The possibilities of synchronous work were minimal; some institutions used separate applications like Adobe connect or BigBlueButton as an LMS plug but their popularity was low (Garrison and Anderson (2003); Means et al. (2014)). The online tools were used as an addition to face to face teaching and not as a delivery mode. In the case of CSE, the use of programming assignments was through LMS portals and automated grading tools like online judge systems were also emerging but had not yet reached a mainstream level of adoption.

B. COVID Pivot (2020): Emergency Remote Teaching

Early in March 2020, the situation with the pandemic caused an explosion of the popularity of synchronous videoconferencing. According to Zoom, the number of participants of daily meetings grew by 2,900% during the period between December 2019 and April 2020 (Dhawan (2020)). In weeks, Microsoft Teams increased its number of daily active users by 32 million to 75 million users (Bao (2020)). The basic pedagogical alteration was the replacement of the asynchronous delivery of content with live replication of classroom lessons a method that was not only expedient but not necessarily the best pedagogical solution (Hodges et al. (2020)).

C. Post-COVID Consolidation (2021–2022): Hybrid Ecosystems

By 2021, institutions shifted to purposeful hybrid structures. Microsoft Teams and Google Workspace became the single platform that integrates videoconferencing, chat, and managing assignments (Rapanta et al. (2020)). Conventional LMS websites augmented synchronous: Moodle widened BigBlueButton connections, Canvas solidified Zoom alliances, and Blackboard enhanced Collaborate Ultra (Bao (2020)). In the case of CSE, the barrier of environment setup was overcome with cloud-based IDEs, such as Replit, GitHub Codespaces, and Google Colab, and the educational practice was adjusted to professional software development processes with the help of GitHub Classroom (Dhawan (2020); Trust and Whalen (2020)).

D. Comparative Platform Analysis

Table 1 captures the most significant platforms, their advantages and drawbacks as it was experienced in 2018-2022.

Table 1: Features and CSE Suitability (2018-2022) Digital Platforms.

Platform	Strengths	Limitations
Moodle	Open-source, extensible, mature LMS	Admin overhead, uneven faculty training
Blackboard	Enterprise analytics, wide adoption	Costly, complex interface
Canvas	Clean UI, API/GitHub integrations	Requires institutional setup
Zoom	Low-barrier live sessions, breakout rooms	No LMS course management
MS Teams	All-in-one: chat, video, files	Complexity, steep learning curve
Google Classroom	Easy setup, Google Workspace integration	Limited analytics for large courses

IV. Student–Teacher Interaction Models

Figure 2 compares the three interaction models across five key pedagogical dimensions, and Table 2 provides a detailed feature comparison.

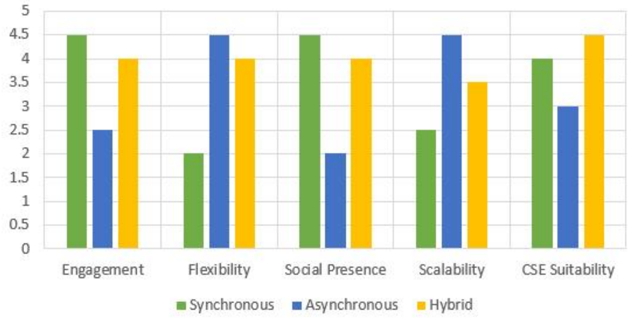

Figure 2: Comparison of interaction models across key pedagogical dimensions (scores based on synthesized literature evidence; 1 = low, 5 = high).

Table 2: Detailed comparison of student–teacher interaction models in CSE online education

Dimension	Synchronous	Asynchronous	Hybrid / Blended
Primary Tools	Zoom, MS Teams, Google Meet, Webex	Moodle, Canvas, Blackboard, recorded lectures, forums	Combination: LMS + videoconferencing + collaboration tools
Interaction Type	Real-time, two-way, immediate feedback	Time-shifted, self-paced, forum-based dialogue	Scheduled sync sessions + flexible async components
CSE Use Cases	Live coding demos, debugging, design reviews, Q&A	Automated grading, pre-recorded lectures, GitHub assignments	Flipped classroom, live lab + async micro-lectures, Discord support
Engagement Level	High (real-time interaction, social presence)	Moderate (depends on forum design and instructor responsiveness)	High (leverages strengths of both modes)
Flexibility	Low (fixed schedule, timezone constraints)	High (anytime, anywhere access)	Moderate-High (sync anchor + flexible async)
Social Presence	High (face-to-face video, immediate non-verbal cues)	Low-Moderate (text-based, delayed interaction)	High (video sessions + persistent community channels)
Key Challenges	Zoom fatigue, connectivity, passive lecture replication	Isolation, low completion rates, delayed feedback	High design complexity, increased faculty workload
Academic Integrity	Moderate (proctored live exams possible)	Lower (code sharing, contract cheating easier)	Moderate (authentic project assessments recommended)
Scalability	Limited (instructor bottleneck in large cohorts)	High (automated grading, recorded content)	Moderate (scalable async + targeted sync for high-value tasks)
Best Suited For	Conceptual instruction, collaborative problem-solving	Self-paced programming practice, content review	Full CSE curriculum delivery post-2020

A. Synchronous Interaction

Live video conferencing is a reproduction of the dynamics in a traditional classroom and allows live questions and answers, demonstrations of codes, and social presence (Dhawan (2020)). In the CoI model, teaching presence can be achieved directly with the aid of synchronous sessions based on the real-time facilitation and social presence based on face-to-face video interaction (Garrison et al. (2000)). In the case of CSE, live coding demonstrations, debugging walkthroughs, and design review sessions are especially useful with synchronous sessions.

Synchronous models are however very challenging. Students in rural areas or with low bandwidth are disproportionately impacted by network connectivity problems (Czerniewicz et al. (2020)). By the end of 2020, Zoom fatigue became a high-priority topic, and Bailenson (2021) singled out four factors that contribute to it: an excessive amount of close-up eye contact, self-monitoring cognitive load, reduced mobility, and increased non-verbal communication decoding effort. Numerous teachers reverted to inactive lecture modes, which did not take advantage of interactive affordances, like polls, breakout rooms, and shared whiteboards (Trust and Whalen (2020)).

B. Asynchronous Interaction

The content available on LMS, pre-recorded lectures, discussion forums, and automated assessments can be flexible and self-paced (Means et al. (2014)). In the case of CSE, the asynchronous models allow automatic grading with real time feedback and lecture libraries. Asynchronous discussion forums designed well may promote high levels of cognitive presence based on the length of written reflection and teacher-learner discussions (Garrison et al. (2000); Anderson et al. (2001)).
The dangers of purely asynchronous models are great. Loss of social and teaching presence will result in isolation and disengagement of students unless it is actively addressed by engaging with the instructor (Moore (1993); Bozkurt et al. (2020)). The completion rates and satisfaction scores are always lower among students in purely asynchronous courses (Bernard et al. (2014)). Lack of real time communication also eliminates instantaneous error-correction feedback which has pedagogical significance in teaching programming.

C. Hybrid and Blended Models

The integration of both synchronous and asynchronous aspects emerged as the institutional paradigm after 2020 (Hodges et al. (2020); Rapanta et al. (2020)). The most efficient hybrid CSE designs are those that use synchronous sessions to conduct live coding, design reviews and Q&A, and asynchronous elements to deliver content, e.g., GitHub Classroom assignments, and formative assessment (Garrison and Vaughan (2008)). The hybrid model has the highest score on CSE Fit because it balances engagement and flexibility. Nevertheless, hybrid models also require a lot of complexity in instructional design and faculty effort (Trust and Whalen (2020); Bozkurt et al. (2020)).

V. Challenges and Drawbacks

Figure 3 (right) will provide a hierarchical taxonomy of the major challenges identified in the literature.
Digital Divide and Connectivity: More than 4 of the South African university students did not have stable internet connectivity at home during the 2020 lockdown (Czerniewicz et al. (2020)). In the case of CSE students, older devices were not able to execute IDEs, virtual machines, or simulation software (Bozkurt et al. (2020)).

Academic Integrity: Plagiarism of the code and solutions in private repositories increased. MOSS and JPlag were not very effective in the face of intentional obfuscation (Guangul et al. (2020)). Online proctoring platforms brought up severe privacy and equity issues, and facial recognition has demonstrated racial biases (Nigam et al. (2021)). A large number of CSE instructors changed over to project-based authentic assessments that inherently resist traditional cheating.

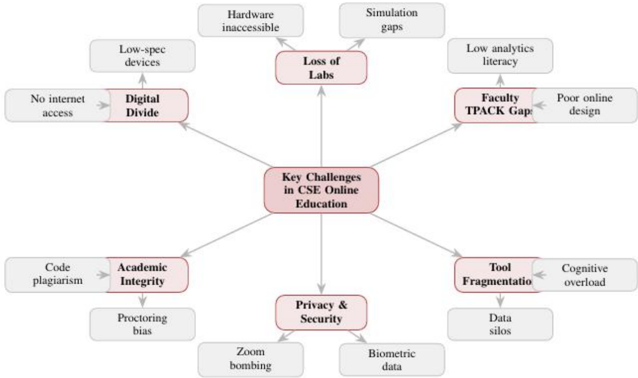

Figure 3: Key challenges in CSE online education (2018-22).

End of Hands-On Laboratory Work: Remote Interaction with Hardware Remote hardware interaction, such as embedded systems, robotics, networking, could not be simulated without costly remote lab infrastructure (Alam (2020)). Virtual circuit simulators and simulation-based evaluations were sought by the institutions as inaccurate alternatives.

Gap in TPACK among Faculty: Trust and Whalen (2020) discovered that less than 30 percent of the teachers were sure they can design interactive online activities. This led to a proliferation of face-to-face lecture patterns to the Internet, and not taking advantage of the opportunities of digital platforms (Mishra and Koehler (2006)).

Fragmentation of Tools and Data privacy: Students used several incompatible platforms at once, which caused cognitive overload (Dhawan (2020); Rapanta et al. (2020)). Initial security weaknesses in zoom and a biometric collection of data by proctoring systems posed considerable data sovereignty issues (Bailenson (2021); Nigam et al. (2021)).

VI. Future Prospects

AI-Based Personalized Learning: Adaptive learning systems will dynamically respond to the continuous performance analysis of the learner by dynamically changing their level of difficulty, pacing, and assessment (Holmes et al. (2019); Zawacki-Richter et al. (2019)). Demand programming tutors are already being made with LLMs including GPT-4, which provide code explanation and debugging assistance, potentially democratizing access to expert tutoring. Ensemble machine learning-based predictive analytics will be used to detect at-risk students at the early stages based on LMS engagement patterns (Baker and Inventado (2014)).

Metaverse and Immersive Learning: Virtual persistent worlds will bring back social presence and physical experience, virtual programming labs, and hardware simulation spaces, and collaborative hackathon spaces (Radianti et al. (2020)). The next step to mainstream adoption is to overcome hardware cost constraints, motion sickness in 20-40% of VR users, and the pedagogical design skills to make immersive learning effective (Pellas et al. (2020)).

Table 3 summarizes emerging technologies and their expected impact on CSE online education.

Table 3: Emerging Technologies and Their Projected Impact on CSE Online Education

Technology	CSE Application	Readiness
AI / LLMs	Personalized code tutoring, adaptive curriculum, automated	Medium–High
VR / Metaverse	Virtual labs, 3D data structures, collaborative	Low–Medium
Blockchain	Tamper-proof credentials, verifiable transcripts	Medium
5G / Edge	Low-latency remote labs, mobile VR/AR	Medium
NLP Analytics	Sentiment analysis, essay scoring, code doc quality	Medium–High
Digital Twins	Personalized learning, path and risk prediction	Low–Medium

Blockchain Credentials and 5G/Edge Computing: Blockchain-based educational records provide verifiable credentials that are immune to tampering. The implementation of 5G networks and edge computing will minimize the barriers to connectivity and make high-fidelity VR/AR on mobile devices accessible to students in developing countries (Shi et al. (2016)).

NLP and Adaptive Learning Analytics: The NLP tools will be used in automating formative feedback in various forms, including technical reports, code documentation quality, and sentiment analysis of forums to detect early disengagement (Zawacki-Richter et al. (2019)). Live learning analytics monitors will allow instructors to intervene in time to prevent the solidification of dropout threats.

VII. Conclusion

The online education shift of 2018-2022 was an era of radical change of online communication, which was triggered by the COVID-19 pandemic. Out of LMS-based asynchronous delivery, the area developed by crisis-induced ERT to discuss hybrid ecosystems that combine synchronous videoconferencing, collaborative tools, and AI-assisted assessment. In the case of CSE education, this change showed how digital platforms can be leveraged and the limits of these platforms to mimic hands-on collaborative engineering.

The hybrid interaction model was found to be the most pedagogically efficient model, with its flexibility of asynchronous interaction and the real-time engagement. It is superior to single-mode methods in all three dimensions of engagement, social presence, and CSE fit as demonstrated in Figure 2 and Table 2. The main issues, namely, the digital divide, academic integrity, access to laboratories, and TPACK gaps in the faculty (Figure 3) are partially addressed, and will need long-term institutional and policy focus.

The future of AI personalization, immersive VR/AR, and 5G connectivity (Table 3) provide avenues to more equitable, effective and engaging digital CSE learning. The reviewed evidence forms the basis on which the curriculum can be designed based on evidence, the choice of the platform, and policy-making in the post-pandemic educational environment. With the transition of institutions to digital strategy rather than crisis management, the experiences of 2018-2022 can be viewed as an empirical treasure trove of how to create resilient, inclusive, and pedagogically sound online education systems in the next generation of computer science and engineering students.

References

Alam, A. (2020). Challenges and possibilities in teaching and learning of calculus: A case study of India. Journal for the Education of Gifted Young Scientists, 8(1), 407–433. https://doi.org/10.17478/jegys.660201

Anderson, T., Rourke, L., Garrison, D. R., & Archer, W. (2001). Assessing teaching presence in a computer conferencing context. Journal of Asynchronous Learning Networks, 5(2), 1–17. https://olj.onlinelearningconsortium.org/index.php/olj/article/view/1875

Bailenson, J. N. (2021). Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. Technology, Mind, and Behavior, 2(1). https://doi.org/10.1037/tmb0000030

Baker, R. S., & Inventado, P. S. (2014). Educational data mining and learning analytics. In Learning Analytics (pp. 61–75). Springer. https://doi.org/10.1007/978-1-4614-3305-7_4

Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. Human Behavior and Emerging Technologies, 2(2), 113–115. https://doi.org/10.1002/hbe2.191

Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education. Journal of Computing in Higher Education, 26(1), 87–122. https://doi.org/10.1007/s12528-013-9077-3

Bozkurt, A., Jung, I., Xiao, J., Vladimirschi, V., Schuwer, R., Egorov, G., & Rodes, V. (2020). A global outlook to the interruption of education due to COVID-19 pandemic. Asian Journal of Distance Education, 15(1), 1–126.https://www.asianjde.com/ojs/index.php/asianjde/article/view/462

Czerniewicz, L., Agherdien, N., Badenhorst, J., Bali, M., Cassim, A., Christowitz, M., & Wissing, G. (2020). A wake-up call: Equity, inequality and COVID-19 emergency remote teaching and learning. Postdigital Science and Education, 2(3), 946–967. https://doi.org/10.1007/s42438-020-00187-4

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. Journal of Educational Technology Systems, 49(1), 5–22. https://doi.org/10.1177/0047239520934018

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. The Internet and Higher Education, 2(2–3), 87–105. https://doi.org/10.1016/S1096-7516(00)00016-6

Garrison, D. R., & Anderson, T. (2003). E-learning in the 21st century: A framework for research and practice. Routledge. https://www.scirp.org/reference/referencespapers?referenceid=631566

Garrison, D. R., & Vaughan, N. D. (2008). Blended learning in higher education: Framework, principles, and guidelines. Jossey-Bass. https://www.scirp.org/reference/referencespapers?referenceid=1424115

Graham, C. R. (2006). Blended learning systems: Definition, current trends, and future directions. In Handbook of blended learning (pp. 3–21). Pfeiffer. https://www.scirp.org/reference/referencespapers?referenceid=2143722

Guangul, F. M., Suhail, A. H., Khalit, M. I., & Khidhir, B. A. (2020). Challenges of remote assessment in higher education in the context of COVID-19. Educational Assessment, Evaluation and Accountability, 32(4), 519–535. https://doi.org/10.1007/s11092-020-09340-w

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. EDUCAUSE Review, 27. https://www.scirp.org/reference/referencespapers?referenceid=2775840

Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for Curriculum Redesign. https://www.scirp.org/reference/referencespapers?referenceid=3796624

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? Contemporary Issues in Technology and Teacher Education, 9(1), 60–70. https://www.scirp.org/reference/referencespapers?referenceid=1565932

Means, B., Toyama, Y., Murphy, R., & Baki, M. (2014). The effectiveness of online and blended learning. Teachers College Record, 115(3), 1–47. https://www.scirp.org/reference/referencespapers?referenceid=1568083

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record, 108(6), 1017–1054. https://www.scirp.org/reference/referencespapers?referenceid=1831215

Moore, M. G. (1993). Theory of transactional distance. In D. Keegan (Ed.), Theoretical principles of distance education (pp. 22–38). Routledge. https://www.scirp.org/reference/referencespapers?referenceid=2868375

Nigam, A., Pasricha, R., Singh, T., & Churi, P. (2021). A systematic review on AI-based proctoring systems: Past, present and future. Education and Information Technologies, 26(5), 6421–6445. https://doi.org/10.1007/s10639-021-10597-5

Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2020). Augmenting the learning experience in primary and secondary school education. Interactive Learning Environments, 27(2), 138–151. https://doi.org/10.1080/10494820.2018.1515199

Prinsloo, P., & Slade, S. (2017). An elephant in the learning analytics room: The obligation to act. In Proceedings of the 7th International Learning Analytics & Knowledge Conference (pp. 46–55). ACM. https://doi.org/10.1145/3027385.3027406

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education. Computers & Education, 147, 103778. https://doi.org/10.1016/j.compedu.2019.103778

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2020). Online university teaching during and after the COVID-19 crisis. Postdigital Science and Education, 2(3), 923–945. https://doi.org/10.1007/s42438-020-00155-y

Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge computing: Vision and challenges. IEEE Internet of Things Journal, 3(5), 637–646. https://doi.org/10.1109/JIOT.2016.2579198

Trust, T., & Whalen, J. (2020). Should teachers be trained in emergency remote teaching? Journal of Technology and Teacher Education, 28(2), 189–199. https://www.sciepub.com/reference/371875

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge: A review of the literature. Journal of Computer Assisted Learning, 29(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. International Journal of Educational Technology in Higher Education, 16(1), 39. https://doi.org/10.1186/s41239-019-0171-0

Corresponding author

Lubna Yasmin Pinky
Department of Computer Science and Engineering,
Mawlana Bhashani Science and Technology University,
Tangail-1902, Bangladesh.
lubnacse@mbstu.ac.bd