Heliyon 9 (2023) e13424

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

A Collaborative Metaverse based A-La-Carte Framework for Tertiary Education (CO-MATE) ☆

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ARTICLE INFO

Keywords:
Collaborative Tertiary Educational Framework
Metaverse
Blended Learning
Emerging Technologies
e-Learning
Virtual Learning Environment
Futuristic Ed-Tech Platform
Learning Management System

ABSTRACT

The paper aims to propose a futuristic educational and learning framework called CO-MATE (Collaborative Metaverse-based A-La-Carte Framework for Tertiary Education). The architectural framework of CO-MATE was conceptualized in a four-layered approach which depicts various infrastructure and service layer functionalities. CO-MATE is a technologically driven educational metaverse environment involving loosely coupled building blocks to provide an a-la-carte model for platform designers. For this, the authors had undertaken a systematic mapping study of the pre/post-COVID period to review the application of various emerging technologies. Further, the paper also discusses the core attributes and component offerings of CO-MATE for a technology-driven and automated immersive-learning environment and exemplifies the same through various use cases.

1. Introduction

The recent pandemic has brought two key challenges for the education sector in the twenty-first century. The surge in rapid learning and knowledge sharing; coupled with reduced mobility and access to physical resources, has revolutionized teaching and learning approaches around the world.

The Covid-19 pandemic has led to the widespread migration of face-to-face education to online [1], blended [2–4] and virtual training scenarios [5]. Beyond adopting the latest technology, this digital migration has effectively changed the routine life pattern of millions of students and faculties [6] [7]. It has brought innovative educational and technology-based business models [8] and new economic value propositions [9]. The educational system, thereby significantly leveraged this advancement in technology and interdependence of pedagogy [10], to transform the way we perceive the 21st-century skills-based training environment in tertiary education [11].

Approaches such as Blended Learning [12] and Virtual Instructor-Led Training (VILT) [13] have enhanced the engagement and learning experiences of participants. Maintaining the fundamentals of classroom training and replicating shared learning concepts in an online environment has improved flexibility, ease of access, inclusion, and cost-effectiveness. Smart use of technology and ed-tech tools have automated complex data capturing such as knowledge gaps, learning habits, user feedback, progress assessment,

☆ Authors are grateful to Centre for Development of Advanced Computing (C-DAC) for encouraging our efforts in pursuing R&D in the areas of Metaverse. This work was carried out as part of "FutureSkills PRIME" project implemented by Human Resource Development, Ministry of Electronics & Information Technology, Government of India.

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https://doi.org/10.1016/j.heliyon.2023.e13424
Received 29 July 2022; Received in revised form 13 October 2022; Accepted 30 January 2023

Available online 8 February 2023
2405-8440/

etc. These advancements facilitated better precision for effective faculty intervention and provided a customized in-depth learning experience by handling candidates with varied abilities, skills, backgrounds, and learning needs.

While, advances in digital learning through technology concepts like XR (Extended reality represents AR, VR & MR), Metaverse, AI/ML, etc. [14] [15] [16] [17] evolved much earlier; the advent of the global pandemic obligated the rapid need for deployment and use of learning solutions at the application level. The impact of Covid is here to stay; it is further mutating the ongoing transformation of instructional methods by systematically and gradually reshaping the existing learning environment.

The novel metaverse [18] incorporates an immersive virtual world where both the real and the unreal co-exist. The concept is rapidly evolving and revolutionizing the existing educational approaches. The authors believe that a Collaborative Metaverse based A-La-Carte framework for Tertiary Education (CO-MATE), with its anytime-anywhere, cost-effective and all-encompassing ecosystem is the future of tertiary education. CO-MATE is envisaged to create the foundation for a full-fledged virtualized learning ecosystem to provide immersive learning experiences involving advanced digital personas, ed-tech assets, self-driven and collaborative learning models, and supervised study spaces. The paper attempts to elaborate and conceptualize CO-MATE in detail.

The rest of the paper is organized as follows. The following section summarizes the current technological interventions in tertiary education which involve service platforms, standardization efforts, and factors driving the learning ecosystem. A systematic review to identify the emerging technologies envisaged to contribute to the CO-MATE framework is elaborated in section 3. Section 4 presents the theoretical prototype of the CO-MATE framework along with the perceived core architecture. The core attributes of CO-MATE, and the envisaged functionality under consideration, are elaborated in Section 5. Section 6 discusses the impact and future perspective along with the conclusion.

2. Technology intervention in tertiary education: Current Scenario

The advent of various global initiatives (Coursera [19], edX [20], Khan academy [21], Udacity [22], Canvas Network [23], iversity [24], Cognitive Class [25], Kadenze [26], FutureLearn [27], Udemy [28] etc.), European Union initiatives (OpenupEd [29], MOONLITE [30] etc.) and initiatives from 900+ universities have played a tremendous role in promulgating technology-assisted learning in tertiary education.

Being a demographically benefited country, India has digitally accelerated the concept of learning platforms and resources to enhance outreach in tertiary education. Various initiatives for academic education (NPTEL [31], SWAYAM [32], e-PG Pathshala [33], Swayam Prabha [34]), Professional Skills & Learning (FutureSkills PRIME [35], BharatSkills [36]), eSkillIndia [37], iGOT [38]), experimental/practical learning through virtual labs (Vlabs [39]), Faculty Education & Learning (DIKSHA [40]), Researcher Networks (Vidwan [41]), Learning Resource (NDLI [42], E-ShodhSindhu [43], Sodhganga [44]), competitive examination preparation (Unacademy [45], BYJU's [46], testbook [47]) and many more steered the progress of ICT based education in the country.

The current digital learning and teaching ecosystem are centered around two prominent aspects namely (a) Edtech Enablers and (b) Edtech Drivers as illustrated in Fig. 1. Faculties, learners, and educational administrators serve primarily as Edtech Drivers to undertake a variety of automated and semi-automated activities across diverse educational settings. They essentially embrace Edtech's Enablers involving tools and platforms which are supported by technologies and standards. The Edtech Enablers and Drivers are further elaborated below.

2.1. Edtech Enablers

Edtech enablers incorporate *service platforms* and *standards* for an online learning environment to facilitate design, development, and operationalization. The enablers support the digitization of learning pedagogy for anytime-anywhere knowledge delivery, customization, and re-use of learning resources, Implement processes and approaches for a personalized learning experience, and automate support components such as FAQ/QA, Evaluation, Assessment, and Certification. At the same time, standardization efforts by IEEE, ISO/IEC, IMS Global Consortium, and associated organizations have enabled interoperability and widespread acceptance of ICT-based educational service platforms.

2.1.1. Service platforms for online learning

Service platforms for online tertiary learning environments are broadly classified under Learning Management System (LMS), Authoring Tools, Virtual/Online Laboratories, Gaming Platforms, Web Conferencing Systems, Digital Assessment Tools, and Social Media/IM. An overview of these platforms and their existing landscape is outlined below.

A) LMS: The learning management system essentially functions as an infrastructure platform for faculty and learner activities and serves primarily as a repository of learning materials [48] to support course delivery. Such open source (e.g., see Moodle [49], Open edX [50]) or commercial/proprietary platforms (e.g., see Blackboard [51]) facilitate the following four major aspects:

- Administration: Registration and Admission, Platform Administration, Data Storage and Management, Resource Utilization, Progress Capturing and Monitoring
- Course Development and Planning: Curriculum Outlining, Lesson Development, Learning Materials, Planning, and Teaching
- Delivery and Communication: Teaching, Doubt Clearance through QA/FAQ, Discussion Forums, Online Chats through IM, Files/Resource Exchange
- Performance Evaluation: Resource Repository, Proctoring, Evaluation, Assessment, Marking and Grading, Reward Allocation, Certification

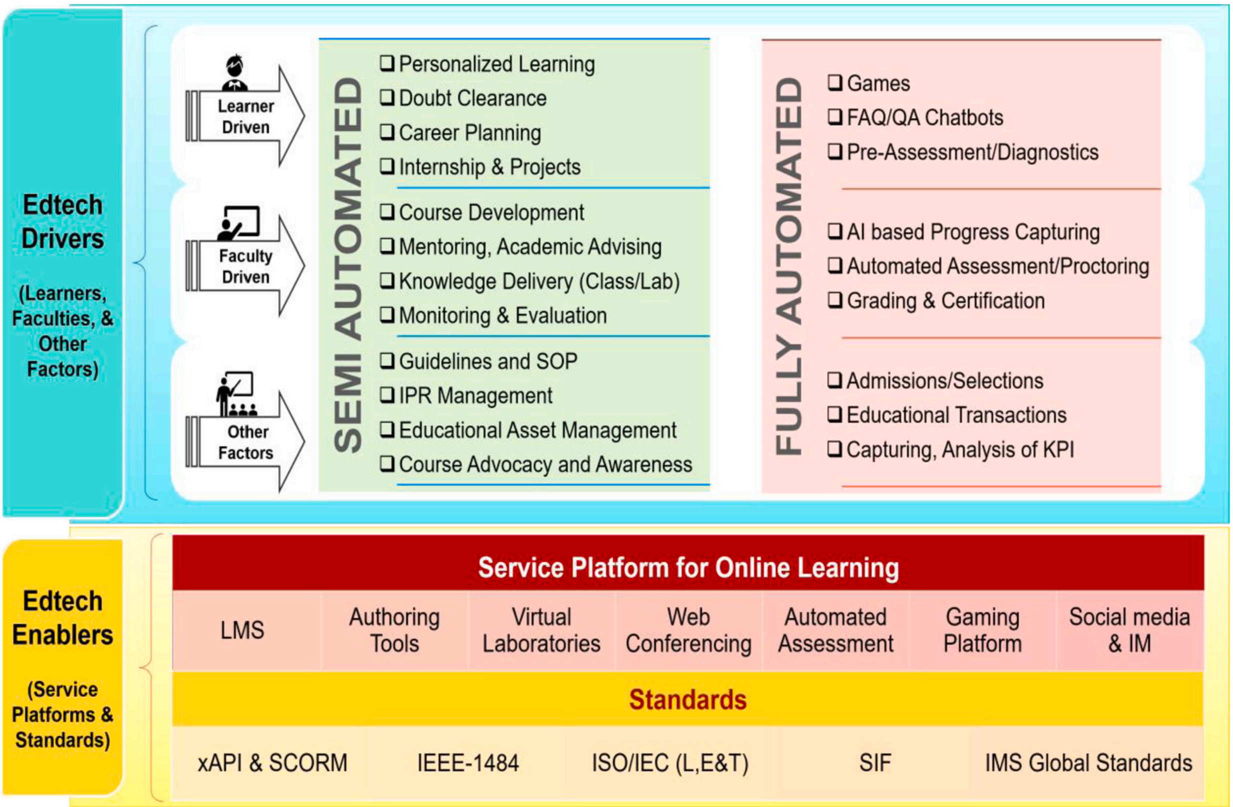

Fig. 1. Current Scenario in Tertiary Education.

B) Authoring Tools: Interactive educational content authoring includes tools for multi-modal interaction [52] and Augmented Reality (AR) content creation with fun and engaging elements. The enhancement of the current learning experience using Extended Reality (XR) has also leveraged the importance of applying XR-based authoring tools that require a higher level of technical skills and programming experience.

The five classes of XR authoring tools categorized by Nebeling et al. 2018 [53] is as follows: (a) Tools for mobile and web designing such as InVision, Sketch, and Adobe XD (b) Tools for basic AR/VR scenes and interactions like DART, Proto.io, Halo, and HoloBuilder (c) Tools like ARToolKit, Tiles, Studierstube and ComposAR which are focused on AR camera-based interactions (d) 3D content creation tools like Teddy, Lift-Off, SketchUp, Blocks, 3ds Max, Maya and (e) Tools like Unity, Unreal, and A-Frame, which are comprehensive Game and application development platforms.

These tools are envisaged to further improve realism and flexibility in updating the background of virtual objects according to the user's situation [54], thereby enhancing the user's immersion and interests.

C) Virtual Laboratories: Virtual labs are widely used by faculties during the pandemic period for student training. Diverse approaches were experimented with to provide virtual or remote laboratory facilities to learners for practical/hands-on training that involved simulators, remotely triggered virtual labs and the use of immersive technology [55]. This includes a fully simulated microprocessor and micro-controller environments; Virtual Programming Labs (VPL) in moodle [56] [57] virtual dissection software and videos to visualize structures in medical and dental studies [58]; Virtual laboratories along with gamification methodologies for microbiology labs [59]; Neuro-science laboratory with interactive Neuro-anatomical virtual activities and clinical case sessions [60]; and Cutting-edge microscopy systems for research labs [61].

D) Instructional Gaming Platforms: The emergence of applied/serious games and game-based-learning has leveraged platforms such as Roblox [62] and Unity [63] among Edtech Drivers. These platforms maintain the interest, focus, and continuous engagement of learners through meaningful gaming activities.

The combination of learning with gaming facilitates the enhancement of learning traits, paves the way for maximum involvement [64], cognitive development [65], triggering continued attention [66], and improved social engagement [67]; thereby making the learning effective and successful [68].

E) Web Conferencing System: In general, the web conferencing system in an online learning environment integrates a variety of unicast and multicast scenarios. Conferencing platforms such as Microsoft Teams, Google Meet, Zoom, Skype, and JioMeet are popular for providing a real-time interactive learning experience. The functionalities and features provided by most of these platforms are proven to be effective in handling Quality of Service (QoS) parameters (such as Jitter, Bandwidth, and Packet Loss) and Quality of Experience (QoE) i.e. the perceived video quality experienced by user [69].

Key factors in determining the choice of suitable video conferencing service through online learning include the cost, number of attendees, screen sharing functionality, whiteboard, availability of mobile applications, interoperability, recording, and storage [70].

(F) Automated Assessment: AI-based technological advancements and sophistication facilitate large-scale assessment processes using automated and computer-based assessment tools like CourseMarker [71], DOMjudge [72], and Formative [73]. Significant research has also leveraged mechanisms like concept mapping [74] for automated self-assessment through tools such as HIMATT [75], Betty's Brain [76], Conlon's Reasonable Fallible Analyzer (RFA) [77] and COMPASS [78].

Mimicking human judgment and tool training in formative assessment for relevant outcome-based decision-making has not only reduced the workload of faculties; but has also facilitated in gaining insights to formulate strategies which created an effective learning environment in many full-time and part-time online classrooms [79]. The Covid pandemic has also propelled the acceptance and uptake of such fully automated assessments among students and faculties.

G) Social Media and Instant Messaging (IM): Various online learning platforms facilitate both instructors and learners in carrying out AI/ML-based learning analytics through online footprints such as discussion messages between participants [80] and also in establishing a constant communication channel through IM for academic information and file sharing. This has significantly improved real-time interaction between students and faculties [81].

2.1.2. Standardization efforts for online learning

Tertiary education systems growingly use frameworks and standards to enhance their uniformity and competitiveness in online education. The development of a wide range of learning platforms, tools, and resources entails the need for appropriate interoperable mechanisms to facilitate widespread use with reduced redundancy. Standardization efforts in the online and blended learning environment have facilitated different types of interoperability which include technical interoperability, information/knowledge interoperability, and organizational/management interoperability [82]. In addition, this has also facilitated interchangeability (reuse, re-purpose and reassemble) of related aspects and their adaptability across portable devices. Prominent standardization efforts in the online learning environments are as follows:

- Shareable Content Object Reference Model (SCORM): SCORM is a set of technical specifications and standards for Web-based electronic educational technology that defines a methodology for the development of learning materials that achieve the goal of re-usability and interoperability [83,84].
- Experienced API (xAPI): xAPI by ADL [85] enables tracking of learning experience and behavioral data [86] from a variety of formal and informal learning environments like LMS, Social media, and Web/Video-based learning [87]. xAPI facilitates transacting and storing of data through the Learning Record Store (LRS) that provides meaningful insight into the performance, learning experiences, and achievements. The device, platform, and status independence of xAPI [88] provides a more flexible means for the application and users to adopt the technical specifications.
- Systems Interoperability Framework (SIF): The SIF specification consists of SIF Infrastructure Implementation Specification and SIF Data Model Implementation Specification [89]. The specification defines architectural needs, interfaces & rules of interaction, communication protocols, and common data formats which enable teaching/administrative entities across diverse applications to interact as well as share data.
- IEEE Standard 1484 series [90]: A series of around fourteen standards that describes the high-level system design and the components for e-Learning systems & related technologies to support architecture, object metadata, application programming interface, resource aggregation models, communication, reuse, exchange abstract model mapping, multimedia framework, metadata encoding transmission, atom syndication format mapping, and IMC content packaging information model mapping.
- ISO/IEC Standards on Learning, Education & Training (L, E & T) [91]: ISO/IEC 40180 is a widely recognized fundamental reference framework for enhancing quality management, quality improvement and quality assurance in e-Learning and related training environment. In addition, ISO/IEC has also issued standards for learning, education, and training in the areas of Content Packaging, e-Textbooks, Virtual Experiments, Virtual Reality Content, Shareable Content Object Reference Model, Adaptability/Accessibility, Collaborative Technology/Workplace/Learning, ICT Evaluation, Metadata for Learning Resources, Language Accessibility, Learning Analytics Interoperability, Mobile Technologies, Quality Management, Assurance, and Metrics.
- Standards by IMS Global Consortium [92]: IMS Global Consortium at varied intervals has issued a specification for Security Framework, Comprehensive Learner Record Standard, Data Privacy, Caliper Analytics, Learning Tools Interoperability (LTI), Competencies and Academic Standards, Course Planning & Scheduling, Digital Repositories Specification, Question and Test Interoperability (QTI), Grade Pass Back and Deep Linking, Reusable Definition of Competency or Educational Objectives, etc. to facilitate better development and learning experience.

2.2. Edtech Drivers

Online learning has integrated and incorporated various innovative mechanisms which combine classroom education (face-to-face or brick-and-mortar) and e-Learning to evolve the concept of Blended Learning and Virtual Instructor Led Training (VILT) [93–95] which reinforce and strengthen the learning and teaching experiences of both world. Such synchronous and asynchronous activities [96] are driven by Edtech platform users like faculties and learners.

Edtech Drivers would essentially act as operators to unfold the underlying facilities provided by the Edtech Enablers, thereby harnessing the online tertiary educational components like teaching methodology, curriculum development, assessment/evaluation, collaboration/discussions, doubt clearance, etc. across the classroom, online and blended learning verticals to realize the desired outcomes.

The online learning components which essentially drive the tech platform are classified into three categories based on the engagement and activity requirements of each of the involved groups. The identified categorization includes (a) Faculty Driven Activities, (b) Learner Driven Activities, and (c) Educational Administrator Driven Activities.

2.2.1. Faculty Driven Activities

The faculty-driven activities would essentially span across Curriculum and Content Development, Course Delivery, and Assessment/Monitoring. The components which are leveraged by faculties for each of these are as follows:

- *Curriculum and content development:* The activities in this component include defining the course syllabus, learning material (including reference resources, virtual lab setup, case studies, mini-projects, and question bank), outlining pedagogy, lesson planning, and sequencing, etc. [97] for which the faculties utilize content authoring tools, LMS, virtual Laboratory and gaming platforms.
- *Course Delivery:* These activities call for User to user interaction. During course conduction, the faculty would drive various activities involving Lecturing, Laboratory sessions, Mentoring, Group discussion, Case studies, etc. Edtech Enablers leveraged by the faculty to conduct these activities are video conferencing, virtual laboratories [98], LMS, Gaming platforms, and Social Media/IM.
- *Assessment/Monitoring:* Progress capturing, evaluation, assessment, certification, remote interaction & monitoring, submissions and demonstrations through virtual labs, intermittent quizzes, and similar assessment aspects are integrated and facilitated through Ed-tech enablers [99] like automated assessment tools, Gaming Platforms, Virtual Labs and LMS. Many of these have advanced to a fully automated stage with active AI-based intervention.

2.2.2. Learner Driven Activities

Learners are the center around which the overall learning ecosystem revolves. Though the learning objective involves various activities driven by faculties; learners would also initiate and drive learning essentials namely customized support; peer interaction for discussion/doubt clearance, projects, case studies; internships, and career planning. In addition, various features like game-based learning [100], learning through applied games (serious games), FAQ/QA chat-bots, pre-assessment, and diagnostics are also driven by learners.

2.2.3. Educational Administration Driven Activities

Online educational platform has various components involving routine management and decision-making aspects concerning infrastructure and associated systems. This encompasses processes like defining standards, documentation, strategic planning, legal compliance, monetary transactions, quality, advertisements, and asset management-related aspects which are essentially handled by educational administrators. Repetitive procedures like registration and admission activities, financial management, academic record management, quality, and feedback management-related concerns have become human-independent with hybrid involvement of AI/ML, Big Data, Hyperautomation/RPA, and related technologies [101].

3. Systematic review of emerging technologies for CO-MATE

To fortify the probable technology building blocks of the CO-MATE platform, the authors have carried out a Systematic Mapping Review (SMR) of emerging technologies about the current ICT-based educational scenario. As part of the review, a preliminary assessment of the available literature was carried out to better understand the current online scenario and deduce a broad conclusion regarding the influence of emerging technologies. Four major phases [102] involving Research Question (RQ) definition, Conduction & Screening, Classification, and Data Extraction/Mapping were adopted as part of SMR.

3.1. RQ definition phase

In the *definition phase*, the following research questions were defined concerning ICT enabled Educational System,

- RQ1: What are the key technologies which registered above-average publications during the pre and post-COVID era (2018-2021)?
- RQ2: What are the technologies that outperformed and reflected steep surge/growth post-COVID (2020-21)?

The process resulted in the definition of scope which included, (a) Review domain: ICT enabled education system (b) Period: Equally distributed across pre/post Covid (c) Mapping elements: Emerging technologies

3.2. Conduction and screening phase

In the *conduction phase*, two digital forums which are more relevant to the RQs were identified. Studies were selected from the shortlisted technical libraries (IEEE and Springer) which contain publications of interest. Strings for command line-based search were defined keeping in view the search operators and related facets.

As part of the screening, the following inclusion and exclusion criteria were defined:

- First Level Screening: First-level screening of shortlisted documents was performed with a focus on manuscripts available in e-learning and related domains.
  - Inclusion Criteria: R&D works related to Online/e-Learning/Blended and concerned field. The results were obtained by conducting a command-based search with relevant keywords namely "e-learning", "blended learning", "virtual learning" and "online learning"
  - Exclusion Criteria: Publications not focused on application/intervention/contribution in the concerned field were excluded as they are not directly related to the envisaged purpose. This includes papers concerning standards, courses, surveys, reports, feedback, etc.

  The screening in the first level resulted in the identification of a total of 178,018 manuscripts with 112,800 for Springer and 65,218 for IEEE Xplore.
- Second Level Screening: Towards analyzing the progression during post Covid scenario, samples needed to be collected from around the COVID period. Four years was defined equally between pre and post-COVID outbreak to review this trend. Thus, second level screening was conducted with the following inclusion/exclusion criteria:
  - Inclusion Criteria: Extraction of works obtained for pre-COVID (2018-19) and post-COVID (2020-21) period.
  - Exclusion Criteria: None

  The screening resulted in shortlisting of manuscripts to a total of 25,885 documents under pre-Covid and 38,455 under post-COVID category from among the two digital libraries resulting in 64,340 overall works (Pre/post COVID).

3.3. Classification phase

The filtered manuscripts obtained till now shared data concerning the research and developmental work in e-learning and ICT-enabled educational system. Towards understanding the effectiveness of cutting-edge emerging technologies in ICT enabled education, further identification and classification were required to be undertaken.

Considering the large volume of filtered manuscripts, the broadness of research questions, and the diversity of activities in the technology domain, a coarse-grained review of selected abstracts was carried out manually to eliminate papers that are not relevant to the research questions. The preliminary review has also considered the futuristic requirements of an online educational framework about contribution of emerging technologies.

During the abstract review of the categorized publications, eight technologies were observed to have significant impact on e-learning/online educational platforms. This resulted in the classification of overall data set into eight categories namely AI/ML, XR, Big Data, Cloud Computing, Internet of Things, Blockchain, Hyperautomation/RPA and Quantum Computing related works.

Keywords that are predominantly used in publications were identified for each of the eight technologies and the search strings for the respective digital library were defined. Based on the same, a command based search was conducted across full text of the documents with technology relevant keywords. However, it may be noted that the papers under review may have technology overlaps.

3.4. Data extraction & mapping phase

In the data extraction and mapping phase, the categorized data were analyzed with an emphasis on identifying the possibilities and gaps as per the proposed research questions. Towards this, necessary statistical analysis was performed and visual maps were created to attain the required results as elaborated in the following sections.

3.4.1. Leading emerging technologies driving current online educational system

Analysis was carried out to identify the leading technologies with significant impact on developmental research and application related activities for online educational systems. The average publication per technology for the duration of this pre/post COVID period (2018-2021) were 12,414 papers per technology.

Observations revealed that AI/ML, Big Data and Extended Reality (XR) led the contribution above average by listing 29084, 25286 and 13937 publications respectively. This figure concludes that around 68.8% of the total publications were from these three key technologies namely with AI/ML (29.2%), Big Data (25.4%) and XR (14%) as individual share percentages. The technology-wise impacts observed for other technologies are as follows: Cloud Computing (9.9%), Internet of Things (9.2%), Blockchain (5.7%), Hyperautomation/RPA (3.6%), Quantum Computing (2.6%). The Fig. 2 depicts the detailed statistical analysis.

3.4.2. Technologies that outperformed and reflected steep surge/growth post COVID (2020-21)

- Overall Pre/Post Covid Impact: A review of technology impact during post and pre Covid were carried out to capture variances after the pandemic period. The average yearly pre/post COVID trend analysis of emerging technologies' influence

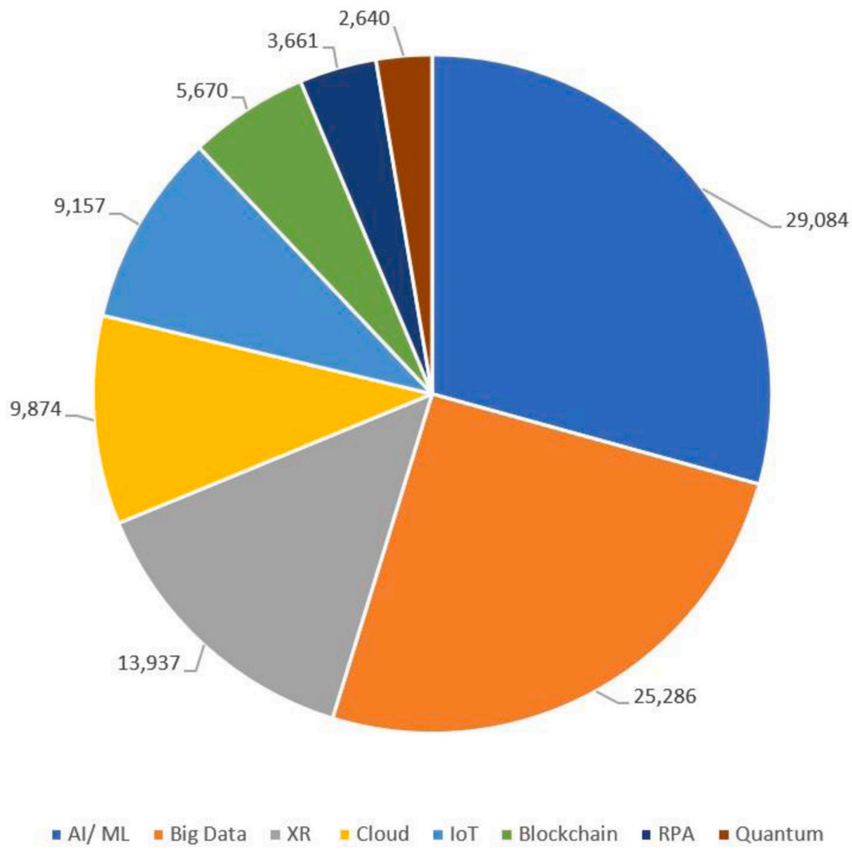

Fig. 2. Leading Emerging Technologies (above average performers).

in online education indicated 192.74% growth with Average 16,962 publications during Pre-COVID against 32,693 Post COVID Publications.

- Post Covid Technology specific impact: For understanding individual growth, a comparative analysis was performed for Pre/Post Covid contribution by each technology. The results were obtained as reflected in Fig. 3.
  All eight technologies were observed to have shown significant post COVID increment in comparison with pre COVID period as observed: Blockchain (292.93%), RPA (275.87%), Quantum computing (255.32%), Internet of Things (IoT) (214.03%), Cloud Computing (211.09%), AI/ML (183.83%), XR (172.31%) and Big Data (171.66%).
  It was observed that the digital libraries jointly reflected drastic increase for Blockchain (292.93%), RPA (275.87%) and Quantum computing (255.32%). Individually, in Springer maximum surge of 388.15% was reflected by RPA while in IEEE Xplore it was Blockchain which showed steep growth of 288.70%.
  Further, the technologies such as AI/ML, Big Data and XR that were overall leading the group had shown minimum surge post COVID and their growth remained almost uniform. The ones which had been performing least (Blockchain, RPA, Quantum) have brought a steep surge post COVID.

3.5. Review of identified emerging technologies

The technologies namely Quantum Computing, Cloud Computing, XR, Blockchain, AI/ML, Hyperautomation/RPA, Big Data, and Internet of Things (IoT) were observed to have the potential of bringing newer avenues to evolve a futuristic virtual learning ecosystem. They facilitate in establishing Intelligent, Powerful, Automated, and Inter-Connected Systems for better Inter-Disciplinary Collaboration, Immersive experience, digital replica of individuals / resources / physical environment, Large scale data handling, enhanced efficiency and time management through automation, varied transactions, and a higher level of data protection requirements.

Considering these aspects, the authors have reviewed publications which are relevant to these emerging technologies. It was identified that a significant amount of these works have the potential to contribute towards CO-MATE framework as indicated in the upcoming subsections.

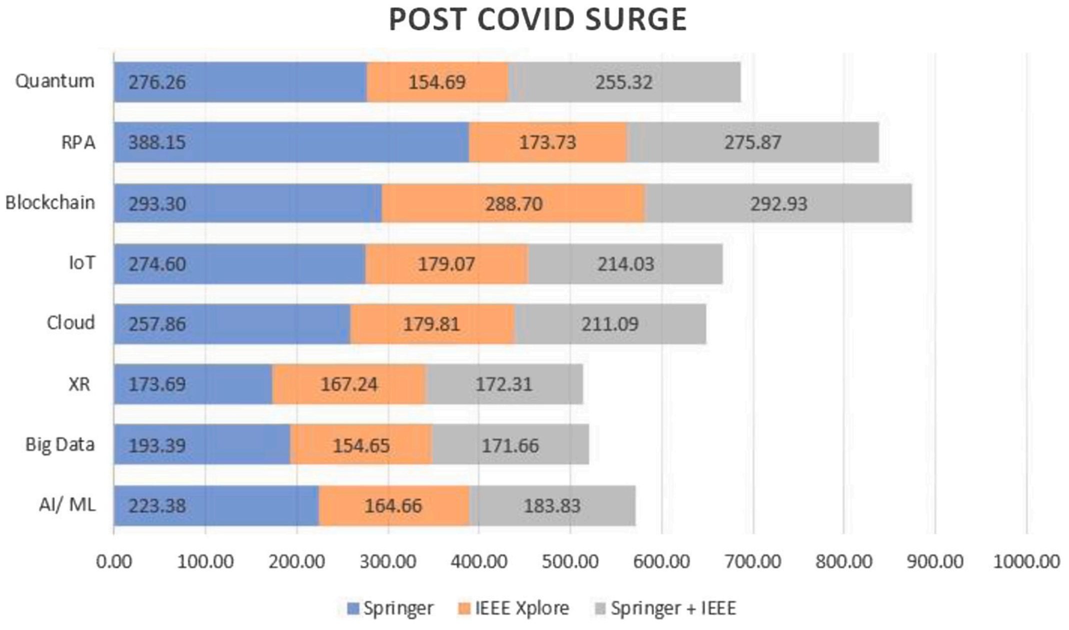

Fig. 3. Post Covid surge in manuscripts.

3.5.1. Quantum computing

At present, quantum computing technology is in a complex research-driven phase where there is a need for specialized expertise. However, major advances in quantum computing hardware and related services by companies such as IBM, Google and Microsoft have resulted in Quantum Computing Development Environments like Cirq [103], Qiskit [104], and Azure Quantum [105]. Although the domain is in its infantile stage, the suitability of various aspects of this technology in real-world applications has been researched for Supply Chain Finance [106], 5G [107], Cyber Security [108] [109], Military [110] and related fields.

The technology has a significant potential in accelerating the futuristic educational infrastructure, especially in areas related to the simulation/emulation of futuristic XR based educational laboratory, secured communication through Quantum Key Distribution [111] and Quantum based search algorithms like Grover's algorithm [112]. Process optimization and faster computation challenges in automated decision making and related areas for advanced problem solving is envisaged to be harnessed by the power of some advanced Quantum Oracular algorithms like Shor's Algorithm [113] and Welded tree algorithm [114].

3.5.2. Hyper-automation/RPA

Towards enhancing the process and productivity of repeatable decisive activities in a virtualized learning environment, effective automation is realized through Hyperautomation/RPA based bots using tools or platforms like iBPMS, leia by prolifics, Automation Anywhere, Blue Prism, EdgeVerve, Kofax, Kryon, NICE, Pega, Thoughtonomy, UiPath and WorkFusion [115] [116] [117].

Hyperautomation/RPA facilitates Data Cleansing, Intelligent Document Processing, Automated Query Processing (eMails, chats etc.), Order Processing, Shortlisting, Scheduling and Automated Report Generation [118] [119] which essentially bring efficiency in various aspects of education such as Course Administration, Curriculum Management, Admission Automation, Attendance and Class Management, Interview Scheduling, Evaluation/Assessment, Certificate Generation, Logistics/Asset Management, Complaint Handling, Compliance Reporting, and Financial Management.

3.5.3. Blockchain

Blockchain technology provides a unique full-fledged online educational information platform [120,121] which is immutable and decentralized. The technology facilitates efficient storage management [122] and sensitive information management in a tamper resistant way through concepts such as Ubiquitous Learning Environment (ULE) [123] through effective deployment of decentralized peer-to-peer publicly distributed ledgers such as Bitcoin, Ethereum and Ripple [124]. The technology is also envisaged to facilitate accreditations [125], identity management [126], crypto-currency based transactions, managing digital assets (including NFTs), certificates [127,128] and credential verification like academic transcripts [129,130] with benefits such as reduced cost and transparent access. Some of the practical use-cases of Blockchain in education include Blockchain of Learning Logs (BOLL) Platform [131] for managing lifelong learning records transfer, Smart Ecosystem for Learning and Inclusion (SELI) [132] [133] to create didactic content with accessibility features and special care needs and EUREKA - Blockchain-based Rating and Publishing System [134].

3.5.4. Internet of Things (IoT)

IoT devices with communication (e.g., 5G, Wi-Fi) capabilities are able to listen, observe, and perform diverse tasks. When such devices are deployed around faculties and learners, it would open up new avenues to monitor, manage and administer the course development, conduction and administration. In such an environment it would be able to capture and monitor real-time information of learners like body movements, facial expressions, time taken to answer the questions, etc. which facilitate in personalizing and dynamic customization of teaching and assessment activities [135], [136].

Case studies and projects involving IoT-based student monitoring system which utilizes Bluetooth Low-Energy Technology (BLE) and Closed-Circuit Television (CCTV) system [137] [138], IoT based wearables for students with special care needs [139,140], and IoT-ready platform such as MaTHiSiS H2020 EU project [141] are some key initiatives in this field. Many IoT devices are further connected to Cloud Computing, Big Data and other computing environments to provide dedicated computational and storage features to procreate new possibilities in future educational ecosystem.

3.5.5. Cloud Computing

Data Management & Storage is an indispensable part of online educational systems. Cloud computing provides various services like SaaS (Software as a Service), CaaS (Communication as a Service), DaaS (Desktop as a Service), PaaS (Platform as a Service), HaaS (Hardware as a Service) and IaaS (Infrastructure as a Service) for creating shared spaces to carry out joint activities such as virtual laboratories [142], collaborative research & development and testing environment. The technology harnesses hardware capabilities like CPU time, memory, and bandwidth for providing services like computation, storage, virtualization and communication. This would also facilitate in providing learners and researchers with specialized shared software for efficient utilization of licenses.

3.5.6. Extended Reality (XR)

As experiential learning is taking center stage in a post Covid scenario, exposure to virtual work spaces like cyber-physical systems [143] [144] in an XR based learning environment for skilling the future ready workforce is becoming essential to be embraced in tertiary educational system. XR technology is synonymous to VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality), which are detailed below:

- VR provides simulated experience beyond time and spaces based on 3D modeling and 360-degree images
- AR provides overlays or computer-generated improvements in the form of sounds, 3D models, images, videos, graphics, animated sequences, games, and GPS information into real-world environment to an existing reality to make it more realistic [145].
- MR integrates the AR and VR concepts to facilitate immersive realism.

Latest studies reveal that XR can benefit tertiary education through powerful optical imagery, ability to rewind, fast-forward and repeat the events to foster quick learning and better retention along with saving the cost for physical infrastructure [146]. Platforms like Nearpod and EON REALITY [147] are currently facilitating augmented and virtual reality based learning environments. Various APIs and toolkits based on OpenXR [148] are being utilized to interface dynamic applications and tools such as HTC Vive, Monado, HP Reverb, Oculus Quest and Pico Neo for creating a range of semi-immersive to fully immersive simulations.

In a Metaverse (synonymous to Multiverse, digital transforming, and mirror world) based environment, the avatar (with variations such as digital twin, digital me) of learners, peers and faculties becomes the active subject which represents a physical entity. In such an environment, XR acts as a medium which interconnects the real and virtual learning environments through Human-Machine Interactions (HMI).

3.5.7. Big Data

Concept of big data in education [149] utilizes educational data mining and learning analytics [150] to facilitate automated decision making and microscopic real time data acquisition. The concepts are being adopted in the field of teaching methods, education management, education evaluation, learning methods, and education research [151] through utilization of Hadoop, Stats iQ, Sisense, Microsoft Power BI and CogniFit [152].

Educational Positioning System (EPS) to facilitate navigational tools for educational journey [153], PABED (Project Analyzing Big Education Data) - a tool implementing Google BigQuery and R programming language for yearly comparison of undergraduate enrollment data [154], visualization tools like AxiSketcher [155], VisMatchmaker [156], VisFlow [157] and senseMap [158] for map based method are some key edu-tech solutions using Big Data Technology.

3.5.8. AI/ML

Artificial Intelligence has a profound impact on the field of education and brings in greater convenience for students, faculty and educational administrators. The benefits include enhanced personalization involving identifying different type of blind-spots and automated remedial measures for learners. Faculties leverage targeted teaching by identifying learning demand, automated performance estimates of learner weaknesses and progress by candidates. The decision making of educational administrators through AI/ML would be more meaningful and dynamic by accumulating experiences thereby reducing the human mistakes [159].

Various AI/ML based solutions are being used in the field of Education like KERMIT, Querium, Entity Relationship (ER) tutors, Ivy Chatbot, cognitive Tutor Authoring Tools (CTAT), Third Space Learning, Little Dragon and Carnegie Learning [160] [161]. The gesture recognition technology, Intelligent Tutoring System, adaptive Group Formations, Voice Assistant [162] are some recent enhancements reflected on part of AIED (Artificial Intelligence in Education) Systems.

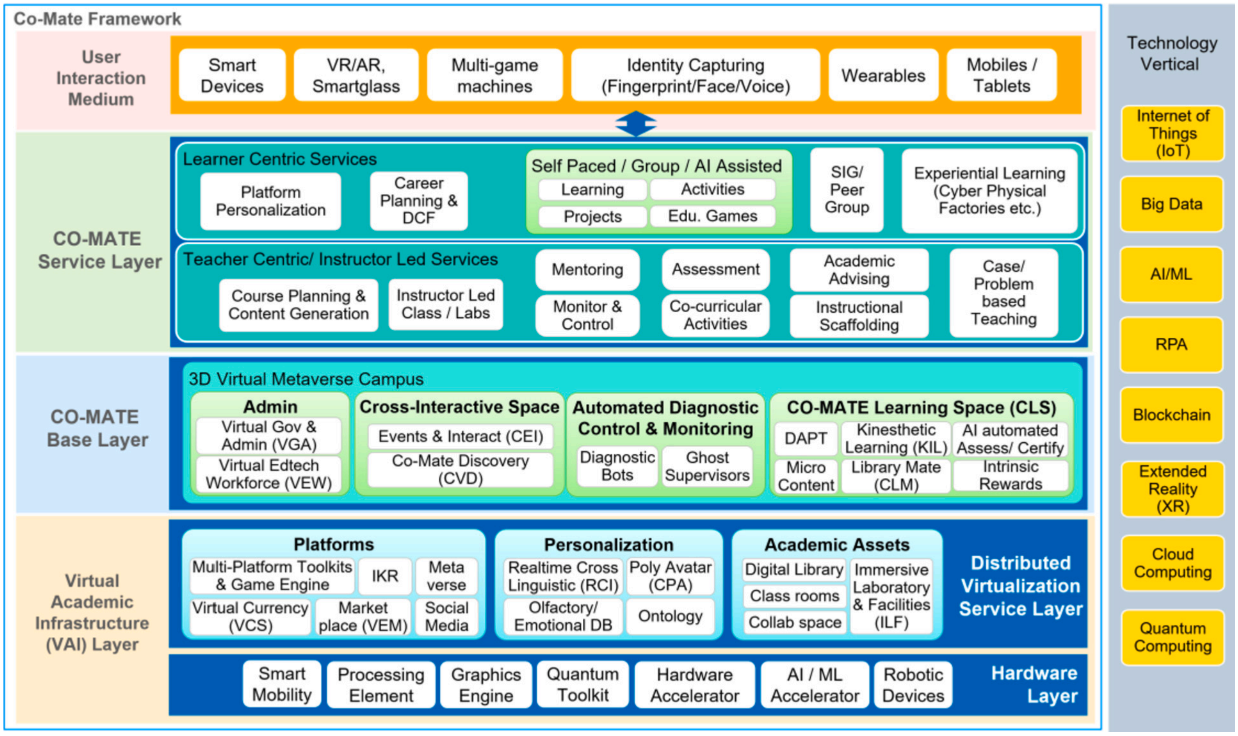

Fig. 4. CO-MATE Framework.

4. CO-MATE architectural framework

The authors perceive CO-MATE as a tertiary educational framework that facilitate a fully immersive, virtualized and globalized learning environment. The framework aims to create a holistic learning ecosystem through blend of Physical, Online and Metaverse environments. The key features which act as a basis for the design and architecture of CO-MATE framework involve the following:

- Tightly coupled and fully virtualized Metaverse based Virtual Academic Infrastructure (VAI) with core DGM (Distributed, Globalized & Modularized) capabilities
- 24x7 Learning support/mentoring through CO-MATE Poly-Virtual-Avatar (CPA) which are re-configurable and emotional/ knowledge adaptable for activity specific resilience
- Ghost supervisors for automated and dynamic candidate activity monitoring and control
- CO-MATE Library Mate (CLM) through visual recreation of authors, characters and real life environments
- Highly Immersive Laboratory and Facilities (ILF)
- Certification through assessment of Knowledge and Skills
- Immutable and universally accessible Knowledge & Record Management (IKR)
- Hyperpolyglot and Context-Aware Personalization for Real-time Cross-Linguistic (RCL) communication
- Multi-environment exposure to learners through XR assisted Kinesthetic Immersive Learning (KIL) Environment
- Dynamic, Adaptive and Personalized Course Curriculum for Learning (DAPT)
- Dynamic Career Forecasting (DCF) through concept mapping of candidates
- AI/ML driven academic administration

4.1. Architecture of CO-MATE framework

The overall CO-MATE framework is divided into four layers which involve (a) Virtual Academic Infrastructure (VAI) Layer (b) CO-MATE Base Layer (c) CO-MATE Service Layer and (d) User Interaction Medium. The components of these layers are loosely coupled to provide an a-la-carte model, which offers varied choices for platform designers to develop customized CO-MATE frameworks for specific educational requirements. The Fig. 4 illustrates the mentioned four layers with associated components.

4.1.1. VAI Layer

The generic infrastructure layer incorporates component which can essentially be set up by the host institution or taken as service for the purpose as envisaged for. The layer is further classified into two (2) sub-categories as follows (a) Hardware layer and (b) Distributed Virtualization Service Layer.

a. Hardware layer: The Hardware layer essentially involves processing elements, graphical engines, accelerators, quantum computing tool-kits, robotic devices and smart mobility components which facilitate in providing dynamic resources for the operationalization and running of the entire CO-MATE platform. Such resource allocation would essentially be based on the anticipated number of concurrent users who simultaneously access the system. Elasticity, Scalability and Modularity are key factors needed for service provisioning of hardware tools and equipment on a virtualized framework with multiple users.

b. Distributed Virtualization Service Layer: A higher-order framework like CO-MATE with varied services would involve components for personalization, platforms and academic assets. Such distributed and suitably customized virtualized functionalities would act as building block for providing services for the higher layers of CO-MATE. These components may be locally deployed with necessary underlying hardware or taken as a service from a third party based on the number of users, manageability and cost factor.

The three major categories under distributed virtualization service layers include:

- **Platforms:** A significant number of distributed applications/services would need to be leveraged by CO-MATE for offering a virtualized learning services as part of the framework. This involves multi-platform toolkits, gaming engines, social networking platforms, metaverse, crypto-currency and micro-payments. Such applications would be abstracted through a suitable wrapper stack for integration into the CO-MATE platform.
- **Personalization:** Towards personalization of the platform to support varied services, the VAI layer facilitates real-time Cross Linguistic (RCL) support and CO-MATE Poly Avatar (CPA) along with databases for Olfactory emotional and ontology.
- **Academic Assets:** Various academic-specific virtualization services which include online classroom, digital library, virtual collaborative space and Immersive Laboratory Facility (ILF) would need to be utilized and suitably customized by the CO-MATE platform for facilitating the academic assets across the framework.

4.1.2. CO-MATE base layer

The base layer of CO-MATE would leverage the Virtual Academic Infrastructure (VAI) layer in developing a Metaverse-based virtual campus. The layer would create various traditional campus-specific modules and related components with a 3D immersive feel which includes CO-MATE Learning Space (CLS), Automated Diagnostic Control and Monitoring Components, Cross-Interactive Spaces and CO-MATE Administrative components. Each of these components will have suitable subgroups to perform specific functionalities such as:

- *CO-MATE Learning Space (CLS):* In the learning space of CO-MATE, various aspects involving content development, delivery, co-curricular support, assessment and certification are carried out. Modules such as Dynamic, Adaptive and Personalized Course Curriculum for Learning (DAPT), Micro Content, Kinesthetic Learning (KIL), CO-MATE Library Mate (CLM), AI Automated Assessment/Certification and Intrinsic Rewards would facilitate these aspects.
- *Automated Diagnostic Control and Monitoring Components:* Diagnostic Bots which facilitate students in self evaluation and personalizing of the CO-MATE learning ecosystem; along with automated monitoring/guidance module (Ghost Supervisor) are the key components under this category.
- *Cross-Interactive Spaces:* Being a virtual tertiary education space involving large number of communication requirements for collaboration, the need for platforms to discover and interact across various inter and intra groups become essential. CO-MATE Events and Interact (CEI) and CO-MATE Virtual Discovery (CVD) module fulfill such requirements.
- *CO-MATE Administrative Module:* The module involves various AI, Blockchain and Hyper-automated components such are Virtual Governance & Administration (VGA) and Virtual Edtech Workforce (VEW).

4.1.3. CO-MATE Service Layer

The CO-MATE service layer would essentially serve two categories of users (a) Learners and (b) Faculties. Considering this aspect, the layer is further subdivided into Learner Centric Services (LCS) and Teacher Centric Services (TCS). TCS would essentially facilitate in providing services related to Course planning, Classroom Teaching, Virtual Laboratories, Content Generation, Mentoring, Academic Advising, Instructional Scaffolding, Co-Curricular Activities, Problem based teaching, Assessment and Certification. Meanwhile, learners are enabled with services like AI assisted/self paced (learning, projects, activities and educational games) activities, peer group interactions, experiential learning, platform personalization, Dynamic Career Forecasting (DCF) and Planning through concept mapping mechanisms to harness CO-MATE as a deeply immersive learning platform which provides pragmatic exposure and support in diverse topics. These building blocks of CO-MATE services need to be tailored and adapted to specific deployments after taking into account the scope and scalability requirements of corresponding educational systems.

4.1.4. User Interaction Medium

The users involving learners and faculties would interact with the CO-MATE platform through multiple devices with varied features involving XR based head mounted displays and smart glasses, identity capturing components, smart wearables, plug n play interface for smart devices, AI/ML based image and sound processing units, controllers with multiple sensors/actuators for kinesthetic mobility, multi-game machines, olfactory interfaces, and communication (wireless/wired) modules.

5. Core attributes of CO-MATE framework

5.1. CO-MATE Campus

The CO-MATE campus incorporates virtualized replication of all foundational structures that form the base of traditional education. The decentralized, autonomous and Metaverse based Virtual Academic Infrastructure (VAI) forms the core of CO-MATE framework. The framework facilitates a globally accessible cross-border tertiary educational ecosystem with infrastructure/facilities involving work spaces like classrooms, laboratories, libraries, collaborative spaces, events, marketplace etc. to provide an immersive experience among the learners. The VAI is modularized for an effective plug-and-play of components involving platforms (toolkits, marketplace, IKR etc.), personalization (poly-avatar, ontology, RCL etc.) and embedded academic assets (digital library, immersive laboratory, classrooms etc.) from diverse geographical locations. Further, there is a provision for owning, operationalization and management of cross-metaverse digital assets & platform for academic research & prototyping for multi-faceted interaction among learners and faculties.

The components of VAI leverages hardware based computation platforms including Quantum Computing Technology, Accelerators and Cloud based Infrastructure to provide a virtual environment for users. The utilization is to carry out simulation/emulation of research and developmental activities to handle a higher user base for design, computation and rendering of complex structures for diverse device access and interactions. Such integrated VAI platforms would also be shared across various CO-MATE campuses. Few examples of CO-MATE Campus use-case may integrate distributed and diverse components such as augmented real-time surgical skill training laboratory in Baltimore, Virtual Medical Library from Cambridge, and Mixed Reality Physical Operating room from Hyderabad for teaching Medical students in Japan.

In terms of interoperability and reuse of diverse infrastructure and facilities, it would be essential to develop appropriate guidelines and approaches for standardization. The interaction through this digital infrastructure would be frequently captured, monitored, analyzed and processed for better Quality of service (QoS) and Quality of Experience (QoE). In addition, necessary data analytics and reporting of Key Performance Indicator (KPI) including platform utilization by users would provide better insight in reducing cost and increasing efficiency. The necessary security and confidentiality aspects would also be built into each layer during integration, facilitating the construction of a security-oriented architecture from the core.

5.2. CO-MATE Poly-Avatar (CPA)

CO-MATE learners and faculties utilize avatar which provides a sense of embodiment and digital identity. The distinction among user categories is attained prima-facia through its visual appearance and behavioral aspects, and through controls on data/mobility for taking up different characteristic dimensions which is contextual; based on the multi-fold activities undertaken as part of the role played by the original user. Functionality to configure character profile, emotional and intellectual range, knowledge module, access control for sensory modules/interfaces, digital freedom through multiple alias, defining security and privacy levels etc. will be appropriately programmed as integrated features of avatar for a CO-MATE framework. However, suitable Digital Identity verifiable credentials via provisions like KYA (Know your Avatar) and other compliance measures and undertakings shall be essential for enabling such functionalities in a cross platform tertiary educational environment to address aspects concerning Cyber Bullying, Online Harassment etc.

An Educational Environment in CO-MATE would essentially require faculties to be omnipresent in multiple environment; irrespective of their physical engagement. A Poly-Avatar capable to replicate as per the defined scope and its functionality is the key for driving the CO-MATE. CPA methodology allows a single individual (Faculties & Virtual Ed-tech Workforce (VEW)) to possess multiple virtual personalities and knowledge banks with different visual, behavioral and Spatio-temporal access control features. This would facilitate dynamic adaptability and re-configurability of avatars against multiple teaching environment, course delivery for multiple subjects, practical training, and involvement in non-teaching and extracurricular activities for varied learner age groups. Similar to an automated and manually controlled robotic device, Poly-Avatar can be event/time triggered to operate autonomously, but at the same time possess the ability to be manually piloted.

5.3. CO-MATE Learning Spaces (CLS)

As an integrated component of VAI, CO-MATE Learning Spaces (CLS) provides highly immersive and adaptive personalized real-time learning ecosystem and simulations with user and end-device based adaptability. The CLS consist of curriculum, learning aspects and personalized digital guidance as the key components. The facilitation extends to course curriculum, content, instructional medium including dynamic language adaptability, user interactions through gestures, behavioral analysis, laboratory environment adaptability, and platform optimization based on various users (Learner/Faculty) requirements. Towards achieving a user based dynamic adaptability of the framework, a provision for self-diagnostic would be provided to facilitate higher order learning experience in the platform.

5.3.1. Dynamic, Adaptive and Personalized Course Curriculum for Learning (DAPT)

The framework would facilitate the development of an adaptable curriculum with dynamic aggregation of course content through data mining from the web-based pool of course knowledge resources. For example, learners in medical foundation course may define a learning objective like drug administration and dosage in pharmacology and basis the same CO-MATE framework would carry-out data mining and content sequencing. The results shall have the provision to be further customized depending on user preference in Audio/Video/Data and self-diagnostic feeds to devise effective teaching strategies as per user timing schedule, handheld device configuration, language adaptation, data/account access restriction and related policies etc.

5.3.2. Kinaesthetic Learning (KiL)

The universal VARK (Visual, Auditory, Reading & Kinaesthetic) based learning model is leveraged by the CO-MATE framework to achieve a holistic tertiary learning ecosystem. The system incorporates devices like gaming consoles, wearables, haptics, sensors which offer to interact with digital 3D world through avatars and intelligent AI systems. The kinesthetic components like audio-visual, olfactory and tactile interfaces would facilitate in providing a better interaction by responding to various sensory events, keeping in view the parameters involving time, mobility, control etc. as a key part of learner interaction strategy. Such tempo-spatial experiences would essentially involve hands-on, practical, workshops for activities like emergency response training, combat drills, pilot training etc. as indispensable components for knowledge delivery.

5.3.3. CO-MATE Library Mate (CLM)

Being a tertiary educational platform, having access to a wide variety of digital content like research papers, publications, books and related course materials is vital for the learning of a candidate. Conventional digital libraries are more inclined towards the content which essentially concentrate towards creation and preservation of learning materials; whereas choice of selection and studying the literature resides with the learner.

CLM in CO-MATE platform is envisaged to act a digital-interactive mentor throughout the learning phase. The CO-MATE Library Mate (CLM) shall provide an immersive and personalized interface of various scripted works to the learner, dynamically adapted to the individual learning styles. CLM would be prepared by an AI/ML based biographer who would recreate the author and its related works under different modules thereby hand-holding like a mentor based on author's philosophy, ideology and concepts. For example, Maharshi Charaka, who lived in the second century BC engages with aspirants for offering direct virtual guidance of ancient Sanskrit textbook on Indian traditional medicine entitled Charaka Samhita.

5.4. Diagnostic, monitoring and control

As personalization and context aware system is the key driving force behind the futuristic tertiary education framework; diagnostic, monitoring and control is a significant element that provides ease of interaction and learning. The negligible gap between a technology assisted and human supervision is envisaged to be achieved by the network of CPA, VEW and tech-driven analytical engines to form diagnostic & supervising bots.

Various processes and interactions shall be leveraged for diverse aspects like rewards, badges, milestones, formative/summative assessments, certifications and feedbacks. Data feeds and information through such mechanisms would be utilized to create a concept map of the skills and knowledge. This information would be dynamically evolved during the entire phase of learning. Further analysis on a macro scale would provide a digital landscaping of knowledge creation to identify future requirements in a learning ecosystem; whereas at a micro level facilitate in the future planning, adaptive continuous improvement [163] and candidate profiling for admissions in higher learning and job recruitment.

5.4.1. Self-Diagnostic Bots (SDB)

The Self-Diagnostic Bots acts as a feeder to provide static inputs to the analytical engine for creating a permanent/long term personalized experience for the user. It will have provision to capture data related to physical needs, health status, mental compatibility, emotional intelligence, rational intensity, cognitive development and knowledge base concerning the enrolled course for a learner. Summarizing these inputs shall provide a customized ecosystem for adapting a learner towards choices like interface customization (language, font size, color, contrast, voice etc.) to deeper aspects like content vocabulary, learning pedagogy, teaching styles, scheduling pattern, monitoring frequency etc.

5.4.2. Ghost Supervisors

Ghost Supervisors refers to the holistic monitoring systems involving sensors, diagnostics, AI bots, xAPIs which are unified in the CO-MATE system to drive the routine control, monitoring and supervision of the learner. The monitoring is passive such as progress and completions received from learners' surfing habits, sign-in/out patterns, gesticulation capturing, clicks, eye patterns, sensory inputs etc. as well as active monitoring obtained from pre-defined and routine assessments, progress capturing and exams. The monitored statistics nourishes the automated control system of the CO-MATE framework towards constructive habit building and devising progressive learning strategies. For instance, an observation of considerable learning gap for a subject, shall trigger the control system to auto-lock the entertainment channels until the learner achieves the specific study target.

5.5. Cross Interactive Space

Active interaction among learners and teachers is significant for a wider exposure and gaining pragmatic knowledge which is beyond the learning ecosystem. CVD and CEI are two such elements that empower the learners to have a cross metaverse interactive environment across the virtual world for enriching their experience and knowledge.

5.5.1. CO-MATE Virtual Discovery (CVD)

An all-encompassing platform framework like CO-MATE would need to facilitate a significant level of Metadata collection and resource/user discovery features. CVD also entails the need for having a virtualized knowledge map of various course materials/topics. Towards this, there is a need to create a knowledge map which resembles a cartographical grouping and modeling of course metadata and concerned resources spread across diverse online platforms. Resources would be suitably tagged including presence, features for real time identification and search of IPRs, books, lab facility etc. whereas the framework would facilitate identifying and locating digital avatar / personalities for education and related linkages and connecting to like minded friends and groups depending on digital proximity.

5.5.2. Cross-Metaverse Events and Interaction Environment (CEI)

A virtual metaverse based educational platform would essentially need to have significant interactions and communications with platforms of similar nature for various learning and educational activities like seminars, workshops, conferences, competitions and related events. Such interactions would involve participants (Poly-Avatars of various categories) to visit and actively participate in cross CO-MATE and cross-metaverse frameworks via interfaces and APIs for forums, search engines, edu-tech initiatives & knowledge repositories. Such requirements would involve the host framework to establish connectivity with visiting framework in providing necessary permission and flexibility for related events.

Facilitation for NFT token gated spaces for carrying out private interactions, discussion, and messaging among frameworks would bring in administrative and financial aspects being handled in such an environment. In addition, the cross-framework interaction may also need to provide necessary security for prevention of information leakage and cyber assault among the user community.

5.6. Ed-Tech Marketplace (ETM)

Over and above the previously defined attributes focussed primarily on knowledge and support, various attributes that contribute towards required monetary and transactional interactions are also required to be defined for self-sustenance of the entire CO-MATE system. ETM covers the modules for implementation of such activities through VEM and VCS.

5.6.1. Virtual Currency Service (VCS)

The module comprises decentralized transaction systems comprising of tokens, digital currencies, channels and permissible modes for undertaking transactions of assets, services, information, achievements and records in CO-MATE framework. It may include academic wallet consisting of traditional or legacy payments rails including credit cards, pay by bank, debit, ACH/wires, virtual currencies, virtual assets, crypto, NFTs, digital assets, digital currency services etc., for a safe cross-border usage for learners.

5.6.2. Virtual Educational Marketplace (VEM)

VEM is a cloud based virtual and non-tangible infrastructure and framework for undertaking monetary and non-monetary transactions across the CO-MATE platform. The VEM is an open marketplace with a provision for barter and currency transactions among users with equal share from learners, faculties, VEW, parents, guardians etc. The transactable items include services offered across the CO-MATE platform, digital wearables, NFTs, digital assets, physical assets etc.

5.7. CO-MATE Administration & Management

The unique proposition offered by CO-MATE is reflected in the form of technologically leveraged Administration & management system. Emerging technologies like AI/ML, Blockchain, Hyperautomation/RPA, Big Data contributes towards development of VGA, VEW and IKR systems. The smart administration & governance shall automate monotonous activities and simplifies the complexities about security, privacy and authentication through decentralized yet safe practices.

5.7.1. Virtual Governance and Administration (VGA)

AI/ML driven learning management and administration shall be inter-woven to support all core educational attributes like Infrastructure, CLS, user-interaction & identification attributes, supporting services like ETM, CIS and supervisory feature including monitoring and control. Setting up rules and mechanisms with adherence to jurisdictional requirements along with capability to regulate financial transactions, accounting, tax payments, etc. as per geographical needs are the salient obligations envisaged to be undertaken by the VGA.

5.7.2. Virtual Edtech Workforce (VEW)

VEW comprises of an entire team of CO-MATE workforce along with their digital counter-parts and AI Bots which exist behind the establishment of complete system spanning across physical & virtual worlds for planning, developing and delivery of all educational activities. Educational planners to define architecture, pedagogies, and curriculum; ed-tech content creators for general content, micro-learning, games, and multimedia content formation; designers and developers for modeling avatar, education wearable, objects, architectures and interiors; event managers for meetings, conferences, competitions and recreational activities including sports; community managers to strengthen academic relationships and enhance interaction for platform engagement and stickiness; delivery partners including teachers, digital faculties and mentors fulfill the criteria defined for Virtual Edtech Workforce (VEW).

5.7.3. Immutable Knowledge & Record Management (IKR)

An educational institution would create a large amount of knowledge pool through papers, patents, project records, academic transcripts, degrees etc. Such records which require digital signature, owner-ships through IPR, confidentiality and integrity which would essentially need to be secured and maintained through a blockchain based immutable yet decentralized mechanism. It would also facilitate a cross-border access for various requirements like record verification, research data sharing, skill passports etc. The IKR shall further speed up the proceedings and services through technologies like Quantum Computing and edge computing.

6. Conclusion

In this work, the authors have presented a theoretical prototype of CO-MATE; the concept for futuristic tertiary education. The framework is driven by Metaverse and assisted through a set of identified emerging technologies such as Big Data, AI/ML, Extended Reality, Hyperautomation/RPA, Blockchain, Cloud Computing, Quantum Computing and Internet of Things.

CO-MATE framework and its architecture evolved as part of this work are envisioned to provide a kinesthetic and immersive learning experience through a distributed cross-interactive decentralized system. The framework provides an a-la-carte of functionalities for developers of Edtech platforms to customize various factors involving courses, components, learning pedagogy and attributes according to the envisaged online educational requirements of the institution.

The base layer in CO-MATE architectural framework defines various innovative components such as virtual education framework, poly-avatar, immersive and adaptive personalized learning ecosystem with kinesthetic learning mechanism, library mate, self diagnostic bots, ghost supervisors, virtual discovery, cross metaverse environment, edtech marketplace & currency services, immutable knowledge/records, governance and management. These components would act as a plug and play module in the CO-MATE framework to provide various innovative teaching and learning functionalities. Existing ICT solutions may also be strengthened by utilizing some of these components independently.

The future possibility is to realize the relevant components from the proposed CO-MATE framework so as to create a standalone immersive educational platform for a specific tertiary educational setup. An envisaged possibility in this regard is to implement a virtual university with a cross-border accessibility for learners to experience the state of the art facility and services distributed across the world.

Being an educational framework, which essentially involves formal long duration academic programs, the challenge is to bring suitable regulatory and standardization requirements to operate CO-MATE in a globally accepted manner. Also, certain technological limitations and socio-economic aspects beyond apprehension may need to be acknowledged and addressed during the implementation phase.

Declaration of competing interest

The authors declare that there is no conflict of interest in this paper.

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