

ONLINE LEARNING ERGONOMICS

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ABSTRACT

Online learning and examinations have become inevitable post-pandemic and a new normal has been seen globally. Virtual learning (VL) is a relatively new model that has grown pervasively in our academic life. The paradigm shift (face-to-face to virtual learning) is inevitable as VLEs like Google Meet, Zoom, Microsoft Teams, Google Classroom, and Skype are realized, but without apprehensions about lacking appropriate experimental and experiential support. Most importantly, the “ergonomics” element influences the health of the stakeholders, particularly kids. Previous research shows the need to address online ergonomic concerns. With the realization of a set of relevant, prescriptive, evidence-based, and adaptive recommendations, a review and research survey were performed. Thus, to address the issue at hand, we developed a sizable set of ergonomic guidelines and proposed a series of recommendations as derived from the study. The set of pertinent ergonomic guidelines covers and caters to each of the identified actors (contents, surrounding environment, the learners) regarding cognitive, psychomotor, and affective domains of learning. We highly anticipate that contextual adaptation of these guidelines by online learners will be useful from several perspectives and valuable implications.

Keywords: *online learning, e-learning, m-learning, learning-ergonomics, ergonomic factors, e-content*

INTRODUCTION

In traditional education systems, learning happens within the predefined classroom boundaries where a single teacher is responsible for managing a limited-size class. In the new online paradigm, a single teacher caters similarly to a relatively larger group of students via a virtual learning environment (VLE). Moreover, there has been a shift in the mode from teacher-centered to learner-centered education while distance has become meaningless. However, these changes have not been sudden but gradual. The concept of distance learning (d-learning) goes way back to 1828 with two main features related to *time* and *distance*. After some time, with the advent of ICT (information communication technology), the concept of e-learning (learning through electronic devices) came into existence, which became popular during the 1990s when multimedia and the internet became a reality. The concept of e-learning derives from d-learning (Ozuorcun & Tabak, 2012).

The first time the concept of the learner-centered approach was semantically and contextually supported by emerging e-learning models. Most generally and broadly, the production and/or delivery of intended learning content via ICT is known as “e-learning.” Moreover, both d-learning and e-learning may be regarded as special cases of online learning. The concept of “online learning” became popular back in the mid-1980s, when IBM launched the world’s first personal computer. In 1994, the CALCampus (i.e., CAL = computer assisted learning) delivered the first real-time instructions. To support this, the California Virtual University launched approximately 700 online courses in free online mode. Researcher Argudo et al. (2017) defined the term “online learning” as a learning tool that refers to educational discipline and occurs over the internet, with its dominating omnipresence. Everyone is accepting the need for online learning, especially in the Coronavirus period. People have been compelled to stay indoors

due to the Covid-19 pandemic. Schools, universities, and other educational institutions were forced to close their doors.

As a result, online learning, training, and gatherings have become increasingly important and inevitable. Children spend more time on androids, laptops, computer systems, desktops, and other similar gadgets. However, neither the students nor their parents or teachers were aware of the dangers connected with inappropriate ergonomics around health, psychomotor, and cognitive aspects in their online learning environment (Bakhtiar Choudhary et al., 2020). Education through digital means, commonly known as “digital learning,” significantly differs from traditional face-to-face learning. Consequently, distinct pedagogies, learning strategies, and flexible ergonomic guidelines are imperative to foster effective education in the rapidly growing online learning environment. Furthermore, a poor ergonomics-driven environment appears to aggravate health issues, such as stamina, neck pain, wrist pain, neurological disorders, eye pain, MSD (musculoskeletal disorders), CTD (cumulative trauma disorder), and so on. This paper summarizes some vital literature regarding our research problem. Such literature shows the following: most organizations include online learning as part of their professional development programs; most importantly, online learning allows students to study at their own pace, which suits their learning preferences and living situations; increased involvement, engagement, and adoption can all be achieved through online learning; however, a consistent ergonomic framework to harmonize the “online learning actors,” on the other hand, is urgently required. Several pertinent research studies have been reported in the literature with respect to online learning ergonomics.

LITERATURE REVIEW

Gruber et al. (2019) reviewed ergonomics in instructional design, covering usability, accessibility, and user-friendliness. The study also includes instructional designers’ ideas about online learning ergonomics, including design, correction, awareness, and involvement. Following usability is accessibility and then user-friendly design as the most difficult topics in learning ergonomics. Descriptive literature also provided significant evidence for desirable attributes that may overcome

the limitations outlined. Visual hierarchy, appealing graphics, visual consistency, and human factor principles are some of the ideal features. It may help to improve work performance and productivity, reduce physical tensions, reduce stress among e-learners (those who participate in online learning), and eventually help to build a safer and better work environment (Knight, 2004; Kovacs, 2004; MasterClass, 2021; Meyen et al., 2002; Skiba, 2017; Smith, 2007; Wang & Yang, 2005; Wheeler & Carey, 1991; Zaharias, 2009; Žunjić et al., 2015).

Online learning environments should be designed with respect to individual e-learners (Merrill, 1988). The use of graphics and animation features in the online learning environment makes learning content more appealing by applying simplicity, consistency, readability, and interactivity principles. It may also improve information retention, especially in digital learning (Knight, 2004; Kovacs, 2004). Visual consistency is a design strategy that keeps similar information together across the screens. As a result, the learning materials become more user-friendly (Wheeler & Carey, 1991; Zaharias, 2009). The phrase “visual hierarchy” refers to arranging design elements in order so that accessing the desired one becomes user-friendly. Using contrast, scale, and balance can assist placing each element in its right perspective and highlight the most important parts (MasterClass, 2021; Wang & Yang, 2005).

Bakhtiar Choudhary et al. (2020) conducted an important survey on online learning to address ergonomic issues. The poll included 186 students and their parents. It indicates that most parents are unaware of the importance of online learning ergonomics and its importance. These include concerns with “improvised” workplace adjustments, sitting hours, display time, eye monitor ergonomics (e.g., backrests, footrests), and keyboard and mouse ergonomics (e.g., work breaks and gadgets) (Smith, 2007; Žunjić et al., 2015). To solve these ergonomic concerns, we investigated the available literature and discovered several possible solutions. Included once are optimal sitting postures, the 20:20:20 learning rule, and learner-centered tailored tactics (Bakhtiar Choudhary et al., 2020; Bellia et al., 2011; Fountain et al., 1996; King & Marans, 1979; Soltaninejad et al., 2021; Vimalanathan & Babu, 2017; Wargocki & Wyon, 2007). The ideal working temperature for virtual learning is between

20–23.3°C. A central heating and cooling system is the greatest choice for climate control. The air quality should meet thermal comfort standards, such as temperature, humidity, and learner clothing. To achieve this, sufficient ventilation should be given in the virtual learning room.

In the context of online learning, selecting appropriate lighting is crucial. This involves utilizing adjustable lighting, incorporating natural light sources, and avoiding the use of blue lights. The 20:20:20 guideline advises taking a 20-second break to look at something 20 meters away every 20 minutes to reduce eye strain and maintain visual well-being. Maintaining this practice can safeguard your eyes, minimizing dryness and redness, thereby enhancing your chances of survival and reducing mental fatigue. Adopting proper sitting postures is essential for preventing issues like hunger, excessive calorie consumption, and body fat. Lastly, learner-centered design solutions play a crucial role in mitigating concerns related to learning ergonomics. Multiple navigation, adjustable presentation, personalized learning possibilities, and other actors' demands are significant learning tactics.

According to Argudo et al. (2017), static postures, difficult sitting and standing positions, repeated actions for long periods of time and unergonomically designed surroundings are some of the rising disorders. Several occupational diseases can cause musculoskeletal disorders, also. Thus, a set of online learning ergonomics standards for a healthy environment is required. Optimal sitting postures, types of devices used by e-learners, device configuration, lack of proper lighting, lack of proper vision among e-learners, and lack of short breaks during virtual lectures are some of the possible ergonomic issues (Bakhtiar Choudhary et al., 2020; Barrett et al., 2017; Juslén et al., 2007; Soltaninejad et al., 2021; Wargocki & Wyon, 2007). Excellent guidance for e-learners, their parents, and teachers should be provided to tackle developing challenges. These guidelines must include healthy seating postures, optimal learning equipment selection, and online ergonomics awareness.

Yuan & Garaudy (2021) establish essential guidelines on dos-and-don'ts principles for online learning ergonomics. The dos principles include an optimum sitting place for learning (Bellia et al., 2011; Fountain et al., 1996; Smith, 2007;

Vimalanathan & Babu, 2017; Žunjić et al., 2015), the use of the 20:20:20 rule while learners sit at their desks, the use of varying sitting postures, scheduling multiple short breaks in between the virtual classes, and the use of digest chunks (small digital contents) (Knight, 2004; O'Malley, 2017). The don'ts principles are as follows: students' screens should be kept away from congested areas, as well as kept away from other distractions when studying (MasterClass, 2021; Merrill, 1988; Wang & Yang, 2005; Žunjić et al., 2015). The active presence of ergonomics in instructional places for children will lessen the strain and anxiety by applying various gaze fitness guidelines, and other healthful and safe environments may be very valuable for e-learners (Smith, 2007; Soltaninejad et al., 2021). We hereby explore a sizable set of essential ergonomic guidelines for online learning to address these emerging issues. This set caters to and covers the three crucial online actors—content, surrounding environment, and the learner. Apropos to these, an attempt has been made to provide evidence-based prescriptive guidelines that may mitigate the negative effects while optimizing learning achievements.

However, there appears to be a lack of concerted effort on evidence-based prescriptive and practicable guidelines for online learning ergonomics. Studies do not categorically cover all three actors affecting online learning. The learning environment is altogether different, in the way that it aims to induce learning (i.e., bring about demonstrable behavioral changes rather than limiting informing otherwise cases). Considering this specialty and the focus of attention by the experts, the crucial actors are identified as the content, the surrounding environment, and the learner. Further, an ergonomic exploration has been made regarding each across Bloom's well-known domains of learning to compile a set of concrete, evidence-based, and prescriptive vital guidelines for online learning. Adaptation of such guidelines shall positively facilitate the online learning stakeholders at large, and especially the learner community.

SURVEY METHODOLOGY

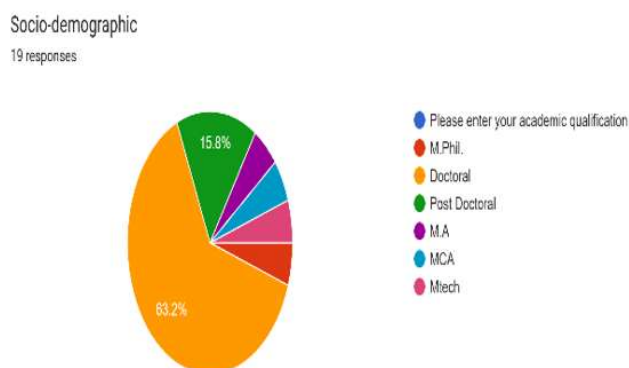
After critically reviewing the literature and related developments, a brief survey was planned to further validate the findings. The online questionnaire-based survey — focusing on online

learning, specifically examining the ergonomics of learning in virtual environments—was devised and administered. We performed the survey via email to 47 identified and willing-to-participate researchers, scholars, and lecturers affiliated with Jamia Millia Islamia (Central University, India). Despite the outreach, only 19 participants provided a response to our survey. Our questionnaire encompassed various aspects, starting with demographic information, such as participants' designations and educational qualifications. Subsequently, we delved into inquiries regarding the challenges digital learners encounter in terms of learning ergonomics. Questions extended to encompass ergonomic principles, actors influencing ergonomics, and guidelines related to ergonomic practices. The proposed survey items are as follows:

- Sa1. Please enter your academic qualification.
- Sa2. Please specify your educational specialization.
- Sa3. Do you agree with the identified ergonomics challenges?
- Sa4. Do you agree with the identified principles of ergonomics?
- Sa5. Do you agree with the identified actors in an online learning environment?
- Sa6. Do you agree with the proposed ergonomics guidelines?

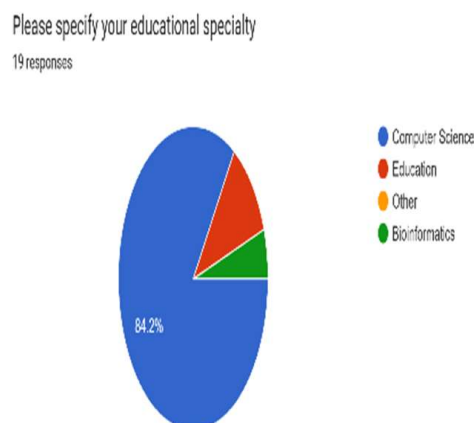
Of the 19 respondents, approximately 63% identified as research scholars, around 15% as post-doctoral candidates, and the remaining respondents fell into other categories (Figure 1).

Figure 1.
Participant Demographic Profile



The educational background of the participants was predominantly in the field of computer science, constituting approximately 84% of the respondents (Figure 2). Following closely, around 15% of participants had educational disciplines related to the field of education. This distribution reflects a strong representation from the computer science domain, providing a focused perspective on online learning and ergonomics within that academic context. Note that the answers to other survey questionnaires have been given in the upcoming Learning Ergonomics, Proposed Model and Discussion, and Proposed Guidelines sections.

Figure 2.
Participant's Educational Disciplines



Building upon the analysis of pertinent literature reviews and insights gathered from survey participants, this paper puts forth a comprehensive set of essential ergonomic guidelines aimed at tackling the emerging challenges linked with online learning. This proposed set strategically addresses three pivotal online actors, namely content, surrounding environment, and the learner. In alignment with these key actors, we have endeavored to formulate evidence-based prescriptive guidelines. These guidelines are intended not only to alleviate potential negative impacts but also to optimize the overall learning experience and achievements of individuals engaged in online learning. The process involved a thorough exploration of online learning dynamics, followed by an examination of associated ergonomic issues. Finally, drawing on the understanding gained, we present a set of guidelines tailored to enhance the online learning environment.

Learning has changed completely from teacher-centered (face-to-face learning) to learner-centered (online learning). In online learning, teachers have three main components for better online teaching: (1) enhancement (using technology for interactive instructions); (2) blended teaching (a combination of both conventional and online learning teaching methods; and (3) an online approach (delivering instruction material fully online) (Almahasees et al., 2021). Online education is referred to as “online learning.” Most significantly, it allows students to study at their own pace and in a way that matches their lifestyle. It also allows various learner-centered approaches for their learners, has 24/7 accessibility, and provides an exciting way to study.

Online learning has demonstrated its capacity to provide numerous benefits for students, as highlighted by Almahasees et al. (2021). Even in the challenging context of the Covid-19 environment, online learning proves highly advantageous, capitalizing on popular and interactive technologies. The widespread adoption of these learning models has notably increased in recent years, with educators globally resorting to these models when faced with limited alternatives. However, opinions on online learning remain diverse, with some expressing admiration while others hold reservations.

To capture a global perspective on online learning amid the pandemic, this paper curates a set of sample papers, as documented by Žunjić et al. (2015). Within our sample (Table 1), the authors focused on seven studies specifically examining the impact of online learning during the Covid-19 pandemic. The table comprises six columns, evaluating various aspects such as research methodology, learning tools, paradigm shifts, the need for reassessments, future scope, and outcomes.

Notably, most of these studies employed online surveys to gather user input on online education. During the pandemic, the most widely used learning technologies included Microsoft Teams, Zoom, Google Meet, WebEx, Byju’s, Vedantu, Udemy, and Whitehat Junior. More than half of the studies indicated a pressing need for a paradigm shift in educational approaches (Abdelhafez, 2021; Almahasees et al., 2021; Kansal et al., 2021; Yudheksha et al., 2020). There was no paradigm shift in the remaining three studies: Halupa (2016), Karyala & Kamat (2020), and Sathishkumar et al.

(2020). But all seven studies favored reevaluation of present online learning models, which revealed several indications about online learning models. Two studies, Kansal et al. (2021) and Abdelhafez (2021), strongly agreed that online learning should be implemented in the future, with the next two studies, Yudheksha et al. (2020) and Jamal (2021) stated that the need of online learning will be in future irrespective of any pandemic.

However, there has been a lot of research seen in the field of online learning, but during the pandemic it has surpassed all previous records. As seen in Table 1, some researchers support this new learner-centered approach (online learning), but the majority are either opposed or neutral. They also dislike paradigm-shifting concepts because they seem very rapid, lack sensory inputs, are without experimental evidence, and more. As we all know, online learning and face-to-face learning have differed in many aspects; so, we need different learning strategies for them. Inappropriate learning principles or strategies may result in undesired learning outcomes. Moreover, without proper learning of ergonomics principles or theories, our students may suffer from some serious health issues. For example, stamina, neck pain, wrist pain, eye pain, MSD, and CTD. A sample of five research studies was taken to investigate learning ergonomics regarding online learning (Table 2).

The side effects of online learning manifest across various dimensions, impacting the mental, physical, emotional, and social well-being of learners. Notably, Halupa (2016) is the only paper that comprehensively addresses all four types of health issues: mental, physical, emotional, and social. Meanwhile, Shivram Choudhary (2021) specifically delves into three emerging health concerns—physical, emotional, and social. Baltà-Salvador et al. (2021) contributes to the discourse by discussing mental, emotional, and social health issues faced by online learners. Choudhary (2021) acknowledges both mental and physical challenges encountered by online learners, while Maryville University (2021) focuses primarily on emotional and social wellness, omitting the physical dimension.

A list of mental health issues associated with poor virtual learning environments encompasses effects on enterprise skills (motivation, individuality, creativity, sensory-motor skills), psychological

Table 1.
Online Learning During the Pandemic

Methodology	Learning Tools	Paradigm Shift	Need of Reassessment	Future Scope	Study Outcomes	Reference
Through texts analysis of Google trends (India)	Microsoft Teams, Zoom, Google Meet, WebEx, Byju's, Vedantu, Udemy, and Whitehat Junior	✓	✓	Strongly needed	Current educationists are trying to convert conventional learning systems into new age learning systems (virtual learning), due to their inherent nature.	Kansal et al. (2021)
Meta-review (Egypt)	General tools	✓	✓	Strongly needed	The article discussed the technical issues that occurred during online learning.	Abdelhafez (2021)
Online survey on UG students (India)	General tools	✓	✓	Needed	This survey was designed to see whether virtual learning will replace classroom instruction. Researchers created a set of persistent RQs on self-motivation, stress, effectiveness, navigation, learning objectives, and interaction to test this idea.	Yudheksha et al., (2020)
Online survey (India)	Zoom, Google Classroom, Microsoft Teams, and so on	✗ (Only 18% of respondents agreed)		Optional	This study explored the importance, goodness, and ugliness of online education in India.	Karyala and Kamat (2020)
National-level online survey of 138 participants (India)		✗	✓	Only 25% respondents agreed	Many successful applications of online learning have been noticed, especially in the pandemic period. Online learning also has some physical and physiological limitations, such as the creation of electromagnetic waves due to uses of e-gadgets and other tools, eye-syndrome problems, back pain, shoulder pain, headaches, mental fatigue, and so on.	Jamal (2021)

distress, post-traumatic stress, lack of interest, and stress and anxiety. Physical health issues include backaches, headaches, and fatigue, with the additional concern of electromagnetic radiation from e-gadgets affecting eyesight and creating ergonomic issues. Furthermore, there is a risk of negative habits, such as smoking, drug and alcohol misuse, and symptoms of depression and other unpleasant emotional states. Ramane et al. (2021) note that inadequate online learning environments can lead to irritation (22%), fatigue (18%), discomfort (26%), and sleep issues (23%).

On the social front, online learners may experience loneliness, low self-esteem, and a distorted sense of time (Baltà-Salvador et al., 2021; Halupa, 2016). This multifaceted analysis underscores the need for a holistic approach in addressing the diverse challenges posed by online learning on learners' health and well-being.

LEARNING ERGONOMICS

Ergonomics is a scientific discipline that studies human-system interactions and applies theories, concepts, data, and methodologies to improve human and system performance. Ergonomics is the process of developing or arranging workplaces, products, and systems such that people can easily use them in their daily lives. In short, it is about the human-machine relationship. This word derives its meaning from the Greek root words *ergo* (work) and *nomics* (law) refer to the laws pertaining to work.

Learning ergonomics refers to the laws governing successful (learning) outcomes. Thus, the goal of ergonomics is to adapt our environment (and other actors, as will be explored in upcoming sections) to reduce health issues, illness, and injury and lead to increased productivity and improve work quality (Rodts & McLaughlin, 2020). Typical

Table 2.
Impact of Online Learning on Learners' Health

Mental	Physical	Emotional	Social	Reference
Effects on enterprise skills of preschool learners	Excessive media consumption leads to obesity, eating disorders, diabetes, hypertension, and attention difficulties.	Excessive use of virtual worlds increased the likelihood of smoking, drug and alcohol misuse, and early sexual engagement.	Excessive use of the virtual world reduces social skills (isolation, low self-esteem, sense of time).	Halupa (2016)
✕	Electromagnetic waves released by e-gadgets can harm the learner's eyesight and other organs, and cause backaches and headaches.	Irritation (22%), fatigue (18%), discomfort (26), and sleep issues (23%) occurred due to a sudden paradigm shift.	Fear of isolation	Baltà-Salvador (2021)
Psychological distress, post-traumatic stress, and others	✕	Depressive symptoms; aversive emotional states (anger, confusion, anguish, disgust, fear, or nervousness, among others)	Lack of relationships between learners, teachers, and other teachers	Baltà-Salvador (2021)
Causes lack of interest, stress and anxiety, and fatigue	Issues have arisen, such as eyestrain, compromising with learning ethics (causing various ergonomics issues), poor ergonomics, and a lack of vitamin D have been noticed.		✕	Choudhary (2020)
✕	✕	Chances of depression (because of social isolation and limited feedback); Covid-19 concerns (especially health and financial)	Disengagement issues; feelings of isolation; issues of lack of motivation	Maryville University (2022)

ergonomics involve human-environment interactions, organizational-balancing happiness and commitment through technology's effects on human connections, processes, and institutions.

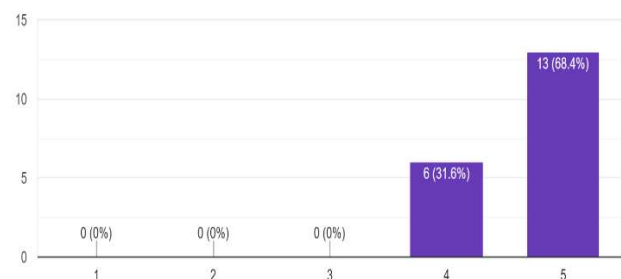
Online learning ergonomics is the study of how to adjust the actors in a new (virtual) learning environment. We can better integrate technology and e-learners by implementing better adjustment protocols (precautions, procedures, and mechanisms). The learning environment, objects, and attributes are used to evaluate online learning ergonomics. Ergonomics improves usability, performance, visibility among screen components, user interfaces, and general "comfort, reduced mental strain, and improved cooperation" amongst learners. By incorporating efficient ergonomics recommendations into online learning modes, we may be able to maintain the health of learners, increase performance and productivity, create a comfortable work environment, and adapt the educational process to their capacities (Smith, 2007; Žunjić et al., 2015).

In the development of guidelines for online learning, specifically addressing learning ergonomics, our

initial phase involved identifying the relevant challenges associated with virtual learning. This paper's research conducted sought the opinions of survey participants to gain insights into the challenges faced in virtual learning, as illustrated in Figure 3. Noteworthy sources like Recyclingtoday.com. (n.d.) and "Effect of Online Classes on Children's Physical Health" (Narayana Health, 2020) provide valuable insights. Among the participants, 68%

Figure 3.
Participant's Opinions Regarding Online Ergonomic Challenges

Do you agree with the following identified ergonomics challenges?
19 responses



assigned the highest rating of 5, while the remaining participants rated the challenges at 4. Through critical analysis and consideration of participant opinions, we have identified the top five challenges in terms of ergonomics that are currently being faced by virtual learners in the realm of online learning.

PROPOSED MODEL AND DISCUSSION

In any learning system, three primary domains or actors play pivotal roles: content, environment, and the learner, as highlighted in Recyclingtoday.com. (n.d.) The field of ergonomics encompasses five key areas: safety, comfort, usability, performance, and aesthetics. Building on these concepts, the focus is on deriving benefits from ergonomics-driven work environment designs. Through a combination of literature review and insights gathered from survey participants, we have identified a set of principles grounded in ergonomics aspects. Out of the 19 participants, approximately 52% assigned the highest rating of 5, while around 32% rated the principles at 4, followed by 16%. Figure 4 visually represents the participants' views on ergonomics principles, and Figure 5 presents these principles as fundamental and basic (Narayana Health, 2020; Oliver, 2018).

Although the basic meaning of all the actors remains the same, we present a model to harmonize them with three domains of learning and typical ergonomic aspects. Additionally, we get the

Figure 4.
Identified Online Learning-Related Ergonomic Challenges

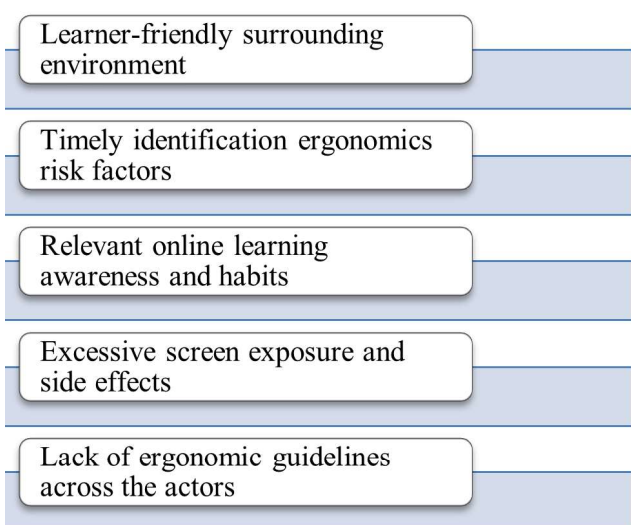


Figure 5.
Participants Opinions on General Principles of Ergonomics

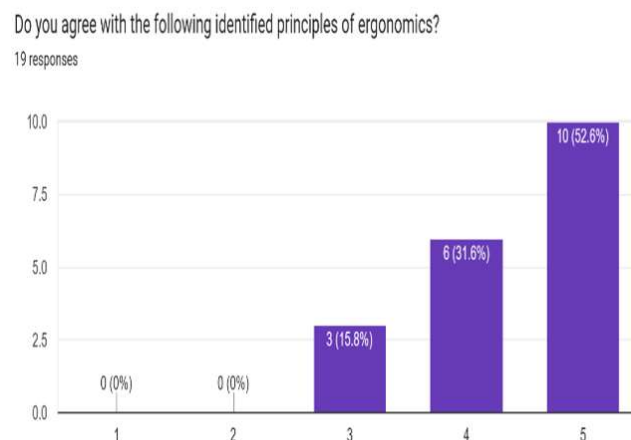


Figure 6.
Identified Fundamental Principles of Ergonomics

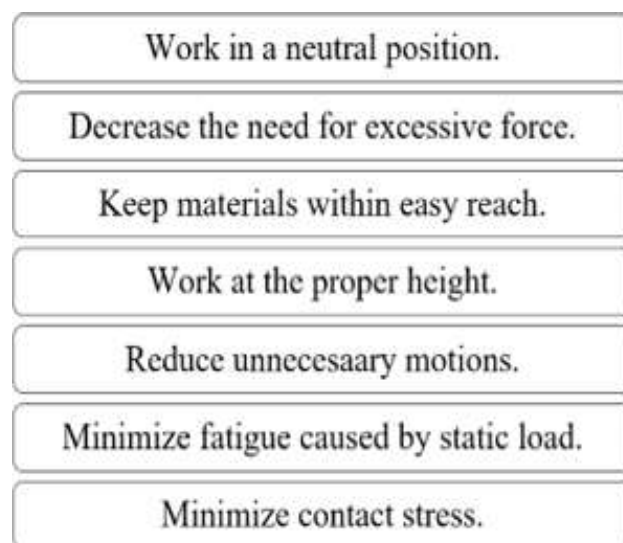


Figure 7.
Participants Opinions Regarding Identified Online Learning Actors

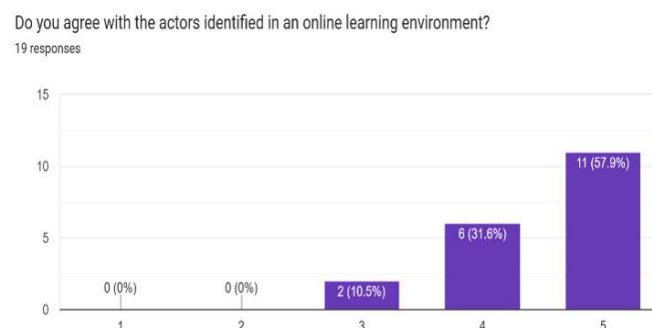
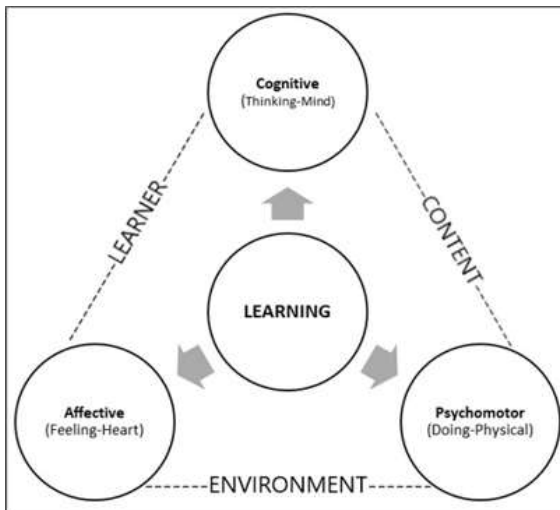


Figure 8.
Tri-Actors Online Learning Model



participants' views regarding the identified learning actors in a virtual learning environment (refer figure 8). Also, each actor has some of the domains and typical ergonomics' emphasized attributes. Interactive, individualization, navigation choices, and digest-chunks are preferred. The word "visual hierarchy" also refers to arranging design elements in the order desired by users. Using contrast, scale, and balance can assist placing each element in its right perspective and highlight the most important parts (MasterClass, 2021; Wang & Yang, 2005).

Environment is the next actor, comprising elements such as air quality and light. Access to controllable light (by shutting off light banks or utilizing adjustable light switches) is required to provide a desirable and pleasant learning environment (refer figure 6). Previous research revealed that light has an 83% impact on procedural learning. The light also has physical, spiritual, and physiological effects on the learners' minds (Barrett et al., 2017; Wargocki & Wyon, 2007) The ideal working temperature for virtual learning is between 20–23.3°C, and the easiest way to control this is with a central heating and cooling system. The educational environment must then be suitable for all young brains to feel healthy, comfortable, and safe (Smith, 2007; Soltaninejad et al., 2021; Žunjić et al., 2015).

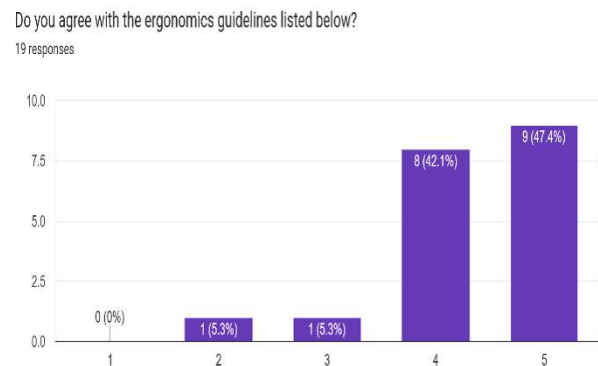
The third actor is the learner, which includes technical involvement, aptitude skills, positive attitude, and preparation. Computer skills, technical skills, and awareness of workstation ergonomics

are all examples of physical activity (psychomotor). The cognitive domain focuses on mental readiness, such as preferred color combinations, text sizes, screen uniformity, regulating external stress factors, and so on. The affective domain is concerned with the learners' attitudes, self-esteem, and more, and explained via results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables, and others that make the reader understand easily (Middlesworth & Middlesworth, 1970). The discussion can be made in several subsections.

ERGONOMICS GUIDELINES

Following the identification of learning actors and integrating feedback from survey participants, we have formulated a set of ergonomic guidelines that hold significant importance for virtual learners. Among the total participants, about 48% assigned the highest rating of 5, while approximately 42% gave a rating of 4 (Figure 9). A smaller proportion of participants, around 5%, assigned ratings of 3 or 2. This distribution reflects a substantial endorsement of the guidelines by most participants, emphasizing their perceived value and importance.

Figure 9.
Participants' Opinions Regarding Proposed Ergonomics Guidelines



We also recommended the unique standards for each of the three relevant actors and their sub-actors. Contents includes the following attributes as the sub-actors: planning contents, division of contents, dos and don'ts rule, graphics attributes (visual hierarchy), and consistency attributes. The surrounding environment actor is subdivided into several meaningful sub-actors, such as working temperature, light, noise, air quality, educational space, and seating positions. Psychomotor, cognitive, and affective are the

comparable sub-actors of the learners. Based on these mentioned actors and pertaining to each domain, we proposed pertinent, concrete, and evidence-based guidelines as state-of-the-art, as follows:

A) CONTENT

- Do proper planning before designing your e-content (online content/ digital content).
- Keep the learning objective as the primary factor while creating the digital content.
- Apply easy-to-digest chunk principles in designing the online content and fix the time duration (maximum 10 minutes) for each chunk.
- Use individualized options while designing e-content.
- Integrate dos-and-don'ts learning principles carefully.
- Use graphics and animation features to make learning content (e-content) more appealing.
- Use real-world scenarios and contextual analyses to facilitate better options for e-learners.

(B) ENVIRONMENT

- Set the working temperature at the ideal level (in between 20–23.3°C) and try to manage it at an optimum level.
- Adopt the human factor principles for a better learning environment.
- Use controllable light to access a desirable and productive learning environment.
- Avoid the usage of blue lights and try to use natural light as the primary source whenever applicable to avoid confusion and distractions.
- Apply various standard hearing guidelines based on the learners' requirements to achieve the desired learning environment.
- Avoid the use of extra learning equipment that may create unnecessary noise and may affect the learners' various activities.
- Attempt to minimize the ergonomic risk factors in VLE by incorporating measurement, adjustment, and smart-fitness elements.

- Avoid the use of poor ergonomics, such as sitting for prolonged periods of time and other factors.
- Utilize ergonomically designed furniture in your VLE, with features such as chair comfort, lightweight, durable, appropriate height, and easily moveable.
- Utilize the 20:20:20 viewing principles (i.e., every 20 minutes, we should look at objects 20 meters away for 20 seconds).
- Apply the adequate air quality principles to meet the optimum thermal comfort requirements, such as air temperature, humidity, proper air ventilation, learner clothing, and so on.

(C) LEARNERS

- The computer skills of the learners should not bear on their success in the new (virtual) learning paradigm.
- Use affordable technical abilities in online courses to accommodate varying tech savviness of learners.
- Provide multiple search and navigation options for your e-learners.
- Provide basic knowledge of fundamentals regarding workstation ergonomics for teachers, parents, and students.
- Try to determine external stress factors and minimize them.
- Utilize adequate fonts sizes, colors, and animations that may assist in achieving cognitive levels of e-learners.
- Try to develop a learner's emotional and social well-being environment for better cognitive development.
- Try to minimize the frequent mouse clicks and trackball/touchpad typing.
- Try to incorporate discussions, collaboration, audio and video sessions, as well as hands-on exercises with text and short video lectures for achieving better ergonomics results.
- Use the learn-and-practice principle as online ergonomics to fulfill the individual learner's needs on stress and increased vulnerabilities.

By adopting a partial self-grading system, students may be given opportunities to take control

of their own grades and achieve ownership of their education. This will eventually alleviate stress and anxiety, thus increasing motivation and engagement in class, which are vital in online classes. Another benefit to the self-grading model is that it creates a platform for students and instructors to engage in meaningful dialogue that creates a two-way learning system.

The goal of the self-grading model is to create a pedagogical environment that creates different perceptions about grades. By doing so, we can create a powerful learning community where students do not feel oppressed by grades, experience enhanced self-esteem, have an increasingly positive attitude, and are more motivated to learn in the remote learning environment.

References

- Abdelhafez, A. (2021). Digitizing teacher education and professional development during the Covid-19 pandemic. *Academia Letters*. <https://doi.org/10.20935/AL295>
- Almahasees, Z., Mohsen, K., & Amin, M. O. (2021). Faculty's and students' perceptions of online learning during Covid-19. *Frontiers in Education*, 6. <https://doi.org/10.3389/feduc.2021.638470>
- Argudo, E., Grehan, J., Leidy, L., Park, J. S. A., Patterson, M., Sanghavi, S., ... & Guerlain, S. (2019, April). Development and Evaluation of an Online Ergonomics Educational Program for Healthcare Professionals. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE.
- Bakhtiar Choudhary, M. S., Bakhtiar Choudary, A., Jamal, S., Kumar, R., & Sanaa, J. (2020). The impact of ergonomics on children studying online during Covid-19 lockdown. *Journal of Advances in Sports and Physical Education*, 3(8), 117–120. <https://doi.org/10.36348/jaspe.2020.v03i08.001>
- Baltà-Salvador, R., Olmedo-Torre, N., Peña, M., & Renta-Davids, A. -I. (2021). Academic and emotional effects of online learning during the Covid-19 pandemic on engineering students. *Education and Information Technologies*, 26(6), 7407–7434. <https://doi.org/10.1007/s10639-021-10593>
- Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2017). The holistic impact of classroom spaces on learning in specific subjects. *Environment and Behavior*, 49(4), 425–451. <https://doi.org/10.1177/0013916516648735>
- Bellia, L., Bisegna, F., & Spada, G. (2011). Lighting in indoor environments: Visual and non-visual effects of light sources with different spectral power distributions. *Building and Environment*, 46(10), 1984–1992. <https://doi.org/10.1016/j.buildenv.2011.04.007>
- Choudhary, S. (2021) Effects of online education on mental and physical health. *India Today*. Retrieved March 5, 2022, from <https://www.indiatoday.in/education-today/featurephilial/story/effects-of-online-education-on-mental-and-physical-health-1854320-2021-09-18>
- Fountain, M., Brager, G., & de Dear, R. (1996). Expectations of indoor climate control. *Energy and Buildings*, 24(3), 179–182. [https://doi.org/10.1016/S0378-7788\(96\)00988-7](https://doi.org/10.1016/S0378-7788(96)00988-7)
- Gruber, C., Vergara, L. G. L., & Gontijo, L. A. (2019). A review of the application of ergonomics in instructional design. *Work*, 64(3), 601–611. <https://doi.org/10.3233/WOR-193021>
- Halupa, C. (2016). Risks: The impact of online learning and technology on student physical, mental, emotional, and social health. *ICERI 2016 Proceedings*, 1, 6305–6314. <https://doi.org/10.21125/iceri.2016.0044>
- Jamal, S. (2021). The impact of online learning on students. *International Journal of Research in Business and Social Science*, 10(3), 522–532. <https://doi.org/10.20525/ijrbs.v10i3.1085>
- Juslén, H., Wouters, M., & Tenner, A. (2007). The influence of controllable task-lighting on productivity: A field study in a factory. *Applied Ergonomics*, 38(1), 39–44. <https://doi.org/10.1016/j.apergo.2006.01.005>
- Kansal, A. K., Gautam, J., Chintalapudi, N., Jain, S., & Battineni, G. (2021). Google trend analysis and paradigm shift of online education platforms during the Covid-19 pandemic. *Infectious Disease Reports*, 13(2), 418–428. <https://doi.org/10.3390/idr13020040>
- Karyala, P., & Kamat, S. (2020). Online education in India—The good, the bad and the ugly! *IndiaBioscience [website]*. Retrieved March 5, 2022, from, <https://indiabioscience.org/columns/education/online-education-in-india-the-good-the-bad-and-the-ugly>
- King, J., & Marans, R. W. (1979). The physical environment and the learning process: A survey of recent research. *Research Report Series*, Institute for Social Research. <https://eric.ed.gov/?id=ED177739>
- Knight, J. (2004). Internationalization remodeled: Definition, approaches, and rationales. *Journal of Studies in International Education*, 8(1), 5–31. <https://doi.org/10.1177/1028315303260832>
- Kovacs, D. K. (2004). Why develop web-based health information workshops for consumers? *Library Trends*, 53(2), 348–359. Retrieved from, <http://www.ideals.illinois.edu/handle/2142/1734>
- Maryville University. (2021). Impact of online education on families: Understanding the transition to remote learning. *Maryville Online [blog]*. Retrieved January 17, 2022, from, <https://online.maryville.edu/blog/impact-of-online-education/>
- MasterClass. (2021). Visual hierarchy in design: 9 principles of visual hierarchy. *MasterClass [website]*. Retrieved March 5, 2022, from, <https://www.masterclass.com/articles/visual-hierarchy#2-ways-to-organize-visual-information>
- Merrill, M. D. (1988). Don't bother me with instructional design—I'm busy programming!: Suggestions for more effective educational software. *Computers in Human Behavior*, 4(1), 37–52. [https://doi.org/10.1016/0747-5632\(88\)90031-3](https://doi.org/10.1016/0747-5632(88)90031-3)
- Meyen, E. L., Aust, R., Gauch, J. M., Hinton, H. S., Isaacson, R. E., Smith, S. J., & Tee, M. Y. (2002). E-learning: A programmatic research construct for the future. *Journal of Special Education Technology*, 17(3), 37–46. <https://doi.org/10.1177/016264340201700303>
- Middlesworth, M., & About Mark MiddlesworthMark Middlesworth

- is the founder of ErgoPlus. (1970, May 3). Software. ErgoPlus. <https://ergo-plus.com/fundamental-ergonomic-principles/>
- Narayana Health. (2020). Effect of online classes on children's physical health. Narayana Health [blog], pp. 4–5. Retrieved from, <https://www.narayanahealth.org/blog/effect-of-online-classes-on-childrens-physical-health/>
- O'Malley, S. (2017). Effective teaching online. Inside Higher Ed [website]. Retrieved from, <https://www.insidehighered.com/digital-learning/article/2017/07/12/7-guidelines-effective-teaching-online>
- Oliver, C. (2018). SQR post. Carl's Teaching Blog [blog]. Retrieved March 5, 2022, from <https://www.coast2coast.me/carl/2018/02/13/sqr-post/>
- Ozuorcun, N. C., & Tabak, F. (2012). Is m-learning versus e-learning or are they supporting each other? *Procedia: Social and Behavioral Sciences*, 46, 299–305. <https://doi.org/10.1016/j.sbspro.2012.05.110>
- Ramane, D. V., Devare, U. A., & Kapatkar, M. V. (2021). The impact of online learning on learners' education and health. *International Journal of Research in Business and Social Science*, 10(3), 2147–4478.
- Recyclingtoday.com. (n.d.). <https://www.recyclingtoday.com/article/5-principles-of-industrial-hygiene-recycling-facilities/>
- Rodts, M., & McLaughlin, M. R. (2020). Ergonomics: The human body and injury prevention. Health Central. Retrieved March 5, 2022, from <https://www.spineuniverse.com/wellness/ergonomics/ergonomics-human-body-injury-prevention>
- Sadowski, J. (2019). When data is capital: Datafication, accumulation, and extraction. *Big Data & Society*, 6(1), 1–12. <https://doi.org/10.1177/2053951718820549>
- Sathishkumar, V., Radha, R., Saravanakumar, A., & Mahalakshmi, K. (2020). E-learning during lockdown of Covid-19 pandemic: A global perspective. *International Journal of Control and Automation*, 13(4), 1088–1099. Retrieved from, <https://www.academia.edu/download/64029090/covid-pandemic-scopus.pdf>
- Saura, J. R., Herráez, B. R., & Reyes-Menendez, A. (2019). Comparing a traditional approach for financial brand communication analysis with a big data analytics technique. *IEEE Access*, 7, 37100–37108. <https://doi.org/10.1109/ACCESS.2019.2905301>
- Skiba, D. J. (2017). Quality standards for online learning. *Nursing Education Perspectives*, 38(6), 364–365. <https://doi.org/10.1097/01.NEP.0000000000000247>
- Smith, T. J. (2007). The ergonomics of learning: Educational design and learning performance. *Ergonomics*, 50(10), 1530–1546. <https://doi.org/10.1080/00140130701587608>
- Soltaninejad, M., Babaei-Pouya, A., Poursadeqiyani, M., & Feiz Arefim, M. (2021). Ergonomics factors influencing school education during the Covid-19 pandemic: A literature review. *Work*, 68(1), 69–75. <https://doi.org/10.3233/WOR-203355>
- Stern, D. (2009). Expanding policy options for educating teenagers. *The Future of Children*, 211–239.
- Vimalanathan, K., & Babu, R. T. (2017). A study on the effect of ergonomics on computer operating office workers in India. *J Ergonomics*, 7.5, 557–567. Retrieved March 5, 2022, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Vimalanathan%2C+K.+and+Babu%2C+R.T.%2C+2017.+A+study+on+the+effect+of+ergonomics+on+computer+operating+office+workers+in+India.+J+Ergonomics%2C+7%285%29%2C+pp.557-567.&btnG=
- Wang, S. -K., & Yang, C. (2005). The interface design and the usability testing of a fossilization web-based learning environment. *Journal of Science Education and Technology*, 14(3), 305–313. <https://doi.org/10.1007/s10956-005-7197-x>
- Wargocki, P., & Wyon, D. P. (2007). The effects of outdoor air supply rate and supply air filter condition in classrooms on the performance of schoolwork by children (RP-1257). *HVAC&R Research*, 13(2), 165–191. <https://doi.org/10.1080/10789669.2007.10390950>
- Wheeler, J. C., & Carey, J. M. (1991). Embedded training for high-turnover computer-based positions. *International Journal of Continuing Engineering Education and Life-Long Learning*, 1(2), 167–179. Retrieved from, <https://www.inderscienceonline.com/doi/abs/10.1504/IJCEELL.1991.030357>
- Yuan, L., & Garaudy, A. (2021, June). Ergonomics of Virtual Learning During COVID-19. In *International Conference on Applied Human Factors and Ergonomics* (pp. 299–306). Cham: Springer International Publishing.
- Yudheksha, G., Poonia, R. P., Pandey, A. A., Singhania, S. & Pandurang, S. (2020). Implications of e-learning during the pandemic: A need to revisit the teaching-learning process as per the needs and demands. *Journal of Critical Reviews*, 7(15), 3552–3559. Retrieved March 5, 2022, from <http://solidstatetechnology.us/index.php/JSST/article/view/261>
- Zaharias, P. (2009). Usability in the context of e-learning. *International Journal of Technology and Human Interaction*, 5(4), 37–59. <https://doi.org/10.4018/jthi.2009062503>
- Žunjić, A., Papić, G., Bojović, B., Matija, L., Slavković, G., & Lukić, P. (2015). The role of ergonomics in the improvement of quality of education. *FME Transaction*, 43(1), 82–87. <https://doi.org/10.5937/fmet1501082z>.