A Macro-Ergonomics Perspective on Educational Planning and Design

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Abstract

The interdisciplinary nature of ergonomics makes it markedly applicable to various fields that involve human performance. Education is one field where ergonomics can make a significant contribution. Yet, educational ergonomics is still not receiving sufficient attention by ergonomists, as opposed to workplace ergonomics [1, 2, 3, 4]. As defined by Smith [5], “Educational ergonomics is that branch of ergonomics/human factors concerned with the interaction of educational performance and educational design”. The extensive literature review provided by Smith [2, 3] in this area has conclusively shown that, with the exception of a few early studies, research in educational ergonomics has tended to focus on “microergonomic issues” [4]. These are issues concerned with the physical environment and its effects on the health of students. However, far too little attention has been paid to the macroergonomic perspective that encompasses learners’ performance, productivity, and wellbeing [2, 6]. Scarcity of research in this area has been attributed to the limited understanding of the interactions between the ‘learner’ and the different components of the educational system [4]. Thus, there is a thirst to move out of the limited microergonomic scope into a higher level holistic perspective [4] that examines user performance in relation to the project/task design.

This paper examines the implications of ergonomics in educational setups, emphasizing the importance of employing a holistic ergonomic approach to create and maintain a safe, rewarding, and effective learning environment. Supporting the view that ‘learning’ is a type of ‘work’, in which ‘acquiring skills and knowledge’ corresponds to ‘performance’ [6], this essay aims to investigate the possible parallel relationship between workplace and educational ergonomics. Theories and case studies from both disciplines will be critically examined in an attempt to highlight the role of early ergonomic interventions in reducing user-system conflicts and design errors.

Keywords: Computer labs for Education, Ergonomics.

1. The Value of Ergonomic Planning

The role of ergonomics has been increasingly emphasized at the project planning stage to optimize system performance and minimize risks and errors [2, 7, 8]. However, there is a lack of research investigating ergonomic planning approaches within educational contexts, with the exception of one study recently published by Benedyk et al. [9]. The study introduced the Hexagon-Spindle Model, a framework for planning and assessment of learning tasks/systems. Although Benedyk et al.’s model is not going to be the focus of this essay, it is pertinent to briefly highlight its contribution to the field of educational ergonomics. The Hexagon-Spindle Model is basically an enhanced version of one of the oldest models of ergonomics, the Concentric Model of Ergonomics [10], adapted to accommodate the complexity of the learning process. The enhanced model serves as a tool...
to analyse personal, contextual, and organisational factors that could affect the learning task [9], allowing project designers to detect potential ergonomic issues associated with their designs. For example, a university introducing a globally interactive student project can apply this model to examine the languages and cultural barriers of interaction among students (personal factors), the human-computer interaction involved in the project and the universal communication methods that can be used to accommodate cultural differences (contextual factors) [7], and the budget limitations that can affect the project as a whole (organisational factors). Visualizing these factors at the project planning stage can facilitate the assessment of potential challenges and opportunities and the proposal of early interventions. Although Benedyk et al.’s [9] study provides a new macroergonomic perspective into education, it still needs to be validated through application in different educational setups [6].

A considerable amount of literature has tried to establish the link between ergonomic planning and system performance in a workplace context [11]. Some of these studies could be adapted to educational designs, while taking into consideration the specific requirements of the learning environment [12].

Dul & Neumann’s [13, 8] studies depict the disparity that exists between the two processes of strategic “planning & control” and “labour inspection”. By limiting the role of ergonomics to occupational health safety (OHS), organizations overlook the profound role ergonomics can play in reducing operational costs through optimizing employee performance and psychological wellbeing [14, 15]. As a result, design teams develop products and processes in isolation from the ergonomic needs of labour, eventually leading to misallocation of resources and increased employee vulnerability to occupational risks [13, 8, 11]. To deal with these issues, Dul & Neumann [13, 8] suggest a “paradigm shift”, whereby ergonomics becomes linked to strategy, decision making, and business outcomes, while evaluation is carried out throughout the design process and “feeding back into modifications to the design” [7].

A good example of this “paradigm shift” is what the Dow Chemical Company (DCC) did in 2001. When the company’s Environmental, Health and Safety (EH&S) department reported that “53% of the Company's ergonomic injuries resulted in lost work time or advanced medical treatment”, DCC realized the need for a strategic change. Instead of its retroactive approach of responding to injury reports from the EH&S department as they occurred, DCC adapted a new strategy, whereby the management and the EH&S teams interacted closely to control work injuries. The DCC teams introduced an ergonomics training course for new employees and implemented a follow-up strategy, requiring employees to complete the training course within 30 days of their job assignment. Within two years of adapting the new strategy, the rate of serious injuries dropped from 53% to 30% [16]. The following section will examine a contrasting example, showing the disadvantages of excluding ergonomics from the design process.

2. Computer Lab Redesign Project: A Case Study on Design Flaws

GEMM1 is a private university operating under a corporate structure. In 2012, the university management decided to upgrade a number of computer teaching labs to reduce operational costs. The upgrade process involved replacing old recessed-monitor desks (Figure 1) with new workstations equipped with energy saving 17 inch all-in-one computers (Figure 2). In addition to accommodating more computer machines in each lab, the new design reduced energy consumption by 87%. Nevertheless, the project generated dissatisfaction among lab instructors who were excluded from the decision making process [17]2. They claimed that the new design disregarded key pedagogical needs by installing “large desktops” that obscured the view between them and their students. Accordingly, some instructors moved their

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1 University name has been disguised for privacy protection
2 Name of source has been disguised for privacy protection
classes back to the old labs, leading to unbalanced use of university resources [17]. While this example of poor design is not supported by statistically reliable data, it emphasizes the importance of ergonomic planning and dialogue among stakeholders within educational environments.

In 1993, the American Psychological Association (APA) outlined the first learner-centred principles of education, delineating the key factors that affect the learning process [18]. Those factors include, but are not limited to, context of learning, environmental factors, and motivational and emotional influences. The APA principles “provide a framework for developing and incorporating the components of new designs” that support a healthy, productive, and motivating learning environment [19]. In light of those principles, the following section will investigate the main performance impediments that may result from bad educational designs, as in the GEMM example. While the scope of educational technology involves a variety of topics, like software and interface design, equipment, anthropometrics, and physical space, among others [20], the forthcoming analysis will primarily focus on the effect of desktop size and position on students’ health, mental engagement, and satisfaction.

3. Case Study Analysis

3.1 Health Implications

The large body of literature investigating the physical classroom environment [21] has given special attention to musculoskeletal symptoms associated with poor classroom posture [22]. Some studies have shown that neck and shoulder flexion resulting from bad positioning of computer screens may lead to neck and shoulder strain [22, 23]. Other literature has shown that bad classroom posture is correlated with adult musculoskeletal symptoms, especially neck and back pain [22]. However, to date, there is no proven causal relationship between poor working posture and the development of neck and back pain [24]. It remains pertinent, however, to consider the “possibility that an inappropriate posture” may result in musculoskeletal symptoms and try to take preventive measures accordingly [22].

Relating this to the GEMM example, the big monitors obstructed the students’ line of vision, preventing eye contact and communication with the instructor [23]. As the focal point of the classroom, the instructor should be comfortably visible to the students [25, 23]. But, with the large desktops, students may crane their necks and maintain a poor
classroom posture in order to see the instructor [25, 23].

3.2 Mental Engagement and Performance

“For all ages, improvement in cognitive performance and ability is a prominent theme in education and training” [26]. Classroom design is one of the factors that affect student performance [2], for a poor classroom layout can contribute to a 10-25% drop in performance [27]. One of the factors Mayers [25] found essential for maintaining a “level of synergy” in classrooms is face to face interaction among students and instructors, thus “students should dominate the scene and not the technology”. Similarly, Dix et al. [7] noted that eye contact in classrooms is essential to establish “a sense of engagement and social presence”. Those who forgo eye contact are likely to disengage from the lesson or exhibit disinterest in the discussion [7]. Singh [23] corroborates the ideas of Mayers [25] and Dix et al. [7], drawing specific attention to computer setups that help maintain the connection between students and instructors. The author suggests that smart desks permit “high visibility”, fewer posture adjustments, and less distraction. When these conditions are absent, like in the GEMM example, students may have to frequently adjust their posture to see the instructor, which may disrupt their attention [23]. Singh’s [23] observations, however, should be examined with caution since his study was based on a small sample size and cannot be generalized to all learning environments. With all evidence taken together, it can be confidently inferred that, regardless of how compelling a lesson is, maintaining a natural posture and unobstructed eye view are among the important factors for effective performance [28].

3.3 User experience

Beyond the health and performance implications examined above, there is also an emotional facet that impacts the student’s overall satisfaction with the learning process [19]. Research in user experience has identified the emotional usability of a design as a key component of a rewarding user experience [19, 29]. Satisfaction involves not only the functionality and efficiency of a design, but also the positive emotions, stimulation, and excitement it offers [30]. “Put another way, it is about creating user experiences that enhance and augment the way people work, communicate, and interact” [31]. The positive effect of an ergonomic design may enhance performance, especially on difficult tasks. On the other hand, the negative emotions associated with using bad designs can lead to error, even with the simplest tasks [19, 32]. Thus, it is relevant to consider emotional aspects in work settings that require engagement and motivation [19]. This applies to educational settings where a relaxed atmosphere is essential to the learning process [19]. It also applies to environments that involve human-machine interaction, where negative emotions, like anxiety, can be fatal if an emergency occurs [33].

The design of educational systems, tasks, or facilities needs to take into consideration the needs of its users, namely the ‘learners’ and ‘educators’ [9]. The GEMM design is considered an example of poor ergonomics because it failed to include the right stakeholders in the decision making process.

4. Conclusion and Future Research

This essay defends the view that educational ergonomics should receive the same attention by ergonomists as workplace ergonomics since the classroom is the “workplace of future workers” [22]. Through examining some of the factors affecting learning and performance, this essay revealed the importance of employing a holistic ergonomic design approach that takes into account the physical, mental, and emotional facets of human performance.

Although it may involve major strategic changes, integrating ergonomics into the decision making process can support educational goals, reduce operational cost, and improve system and user performance. Conversely, the problems emerging from poor designs can impair health, performance, and user satisfaction, which interferes with the educational and managerial goals.

Literature has valued the interdisciplinary scope of ergonomics that
allows researchers to compare, adapt, and transfer ergonomic concepts from one context to another, while taking into regard the circumstances influencing each system. This essay was an attempt to cross the boundaries between academic disciplines by providing a glimpse into the implications of workplace ergonomics in educational contexts. More research establishing links between the different fields of ergonomics can provide a better understanding of human-system interactions and the underlying performance implications. This study was used to guide the development of a global software engineering lab [42].

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