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ERGONOMIC ASPECTS OF IMPLEMENTING COMPUTER TECHNOLOGY INTO SCHOOLS

ERGONOMSKI VIDIK UKLJUČIVANJA KOMPJUTORSKE TEHNOLOGIJE U ŠKOLSKI OKOLIŠ

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Abstract

This paper addresses the issue of implementing computer technology into educational settings from an ergonomic point of view. On the basis of some latest findings in ergonomics and computer science we construct a model of ergonomic implementation of computer technology into schools and highlight some areas that still need researchers' attention in the future. We also present a review of certain findings and polemics in the fields of computerized classroom environment, ergonomic use of computers and ergonomic aspects of computer hardware and software.

Sažetak

U radu želimo razjasniti aspekt uključivanja računalne tehnologije u odgojno-obrazovni okoliš, kod kojeg je u prvom planu ergonomski vidik ovog procesa. Na osnovi sinteze pojedinih spoznaja na području ergonomskih istraživanja upotrebe računala izradili smo model ergonomskog ukjučivanja računala u školu i istodobno iznijeli neka područja, koja bi trebalo u budućnosti nadograđivati. U radu prikazujemo pregled najnovijih istraživačkih spoznaja na području opreme računalne učionice, kvalitete računalne opreme za obrazovne svrhe, ergonomske upotrebe računala i ergonomskog oblikovanja računalnih obrazovnih programa.

1. Introduction

Care for children within the educational process is often associated with cognitive aspects of their development. However, we rarely consider the perspective, which would measure and present student's progress through more holistic approach. Parents and teachers are continuously tempted to equate child's grades, usually presented in some formal school certificate, with the overall development of children in the school environment. For instance, progress, connected with the psychophysical characteristic of students, can hardly be presented in some formal paper. An important goal of school, therefore, is to identify a broad scope of variables that significantly influence the student's overall advancement, and to control them in order to achieve positive social, academic and psychophysical outcomes for children.

Whilst some ergonomic approaches and knowledge are well placed to be of significant use to modern society, ergonomics as a discipline has received very scant attention within the school environment. Legg /**1**/ argues that research has mainly focused on micro-ergonomics issues, such as the weight of schoolbags, the mismatch between anthropological measures of students and the size of school furniture, the musculoskeletal disorders among school students and some aspects of children working with computers. On the other hand, very little research has focused on macro-ergonomics issues, which are associated with classroom environments, ergonomics pedagogy, curricula or organizational structures and environments. However, the importance of research in the macro-ergonomics field is increasingly recognized and some latest studies indicate slight movements in this area. For example, Smith /**2**/ opens up a new perspective on the implementation of ergonomics science into principles for forming effective educational environments. His work sheds light on some learning environment characteristics and emphasizes the need to further investigate their influence on the variability of educational outcomes. Woodcock /**3**/ operates with the term educational ergonomics, which he presents as the subcategory of ergonomics science, and defines some areas that should be of primary concern when

exploring relevant issues in this field. Among other things, he points out and elaborates on the idea of implementing ergonomic knowledge into the educational curriculum as an important aspect of children's personal development.

In Slovenia there is also a lack of quality research seriously investigating the sphere of educational ergonomics. Most insightful studies are directed towards exploring the influence of different ergonomic burdening on children's school work /**4**/ and construction of ergonomically-shaped school furniture /**5**/.

The incorporation of basic ergonomic ideas into school settings demands the search for areas where development of the school environment raises the need for continuous changes, and where some ergonomic implementations would be beneficial for students. The research of ergonomic factors in educational institutions needs to be directed into areas which are constantly upgraded and where interventions would generate some positive, short-term effects. Computers seem to be the dominant technology in modern schools and computer classrooms, as a result of the fast pace of technological development, frequently change their appearance. Carefully chosen ergonomic directions would provide more student-friendly and well-adapted upgrades of computer hardware and software and, moreover, ensure their proper and safe use.

2. Implementation of computers into schools on the basis of some ergonomic directions

Integration of computer technology into an educational process is necessary for school to adequately fulfill its educational purpose. Characteristics and processes relevant to technology implementations in educational practice need deep consideration to be able to assist in achieving important school goals. Therefore, successful integration of computers should be based on (1) strong didactical arguments, (2) reflection, which includes considering the relationship between price, quality and actual school needs, (3) ergonomics knowledge, which would provide rationality and good grounding for safe use of technology. Effective ergonomic implementation of computer technology can be summarized into the following five phases.

2.1 Dissemination of ergonomic knowledge among teachers and school leadership

Docrell and colleagues provided some evidence that teachers are not satisfied with their current knowledge of ergonomic aspects of working with

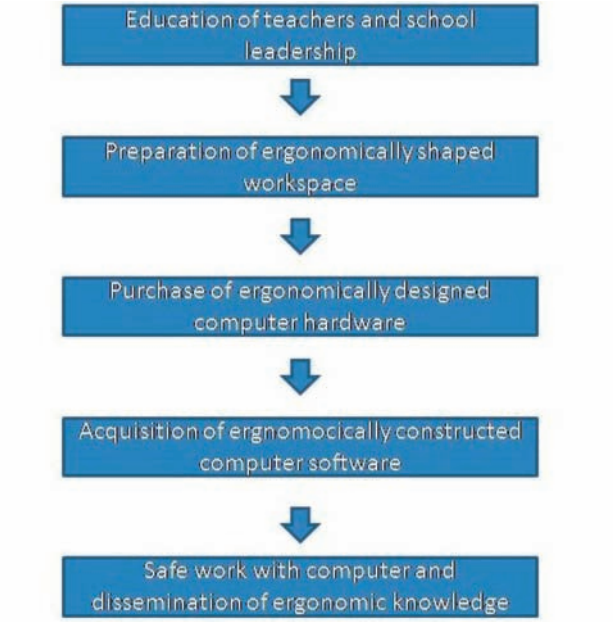

Figure 1: Model of ergonomic implementation of computer technology into school environment

computers, although they have received computer training. Furthermore, research confirmed that teachers would like to obtain more information regarding some important ergonomic questions. With dissemination of ergonomic ideas among educational professionals we could stimulate ergonomic considerations when implementing computer technology into schools, and ensure the quality selection and adequate use of computer equipment.

The education of teachers and school leadership in connection with ergonomic implementation of computer technology into educational settings should include:

- ergonomic aspects of quality computer hardware,
- elements of ergonomically constructed computer software,
- work with computer from an ergonomic point of view,
- information about ergonomically shaped workspace,
- understanding of ergonomic burdening on children's school work.

2.2 Ergonomically shaped workspace and computer technology

A lot of research on ergonomic aspects of computer use in school environments is associated with studies of computerized classrooms. In studies that concentrate on investigating ergonomic features of computerized classrooms, it is typically adults

that are used as research subjects, and this is why we are making a mistake if we apply the findings directly to children /**6**/. We can add that caution and a good degree of critical reflection is also necessary in other areas (e. g. design of user interfaces in computer software, compliance of certain computer devices). Harris and colleagues introduced the framework for a model of ergonomic computer use by children and therefore encouraged the use of such models in educational settings. However, authors also indicate that further, more extensive research needs to be undertaken. Computerized classrooms present a central place of intense, educationally guided interaction between students and computers. Therefore it is important to ensure their flexibility, their ability to be adjusted to suit different users and the placement of objects within the workspace enabling rational engagement in school related activities. Zandvliet and Straker found that two typical room layouts are prevalent for computerized classrooms in schools. The most popular room layout was arranged as a peripheral laboratory, where computers are placed along the peripheral walls of a classroom with students facing away from the center of the room to work. If the work demands that the student is mainly faced towards the computer screen then this set up is reasonable, because teachers can move around the classroom easily and monitor activity on each student's screen. The second typical layout was a linear arrangement of objects, which had students and computers in rows with students facing the front of the classroom. When Zandvielt and Straker investigated a great number of computerized classrooms, they did not report on noteworthy problems with the arrangement of objects in the room, but rather emphasized drawbacks associated with students' individual workstations. They highlighted the importance of providing adequate space for non-computer related work (e. g. writing in textbooks) and more adjustable workstations (adjustable height seating and the provision of variable viewing heights for computer monitors). Consequences of discrepancies between school furniture and anthropological characteristics of students, and those regarding unsuitable posture when using computers, are partly known. Milanese and Grimmer /**7**/ were trying to determine the relationship between reported spinal symptoms in an adolescent student population, and the match between their individual anthropometric dimensions and their school furniture. It turned out those students who were too large for school furniture, had most problems with the occurrence of certain spinal symptoms. Briggs and colleagues /**8**/ provided some evidence that the posture of school children is significantly influenced by the type of information technology they use. Results showed that children reading from books had more head and neck flexion, and a greater gaze angle than when using a desktop computer. Comparison of laptops and desktop computers showed more curved posture at first, which is most probably a consequence of inseparability of keyboard and screen that cannot be adapted suitably. It is interesting, that the age of the child also significantly affects the posture adopted when using information technology. The poses of younger children were less curved than the posture of older, which is probably the result of differences in their physical constitution. The disadvantage of the study is the short exposure of subjects to interaction with different kinds of informational technology. Certain elements of unsuitable posture are likely to occur over longer periods of time. Tervelyan and Legg /**9**/ provide a comprehensive overview of the research literature on back pain in school children and emphasize the need for new studies that will allow more detailed understanding of problems. They also introduce a research model for further investigation of back pain in children, which includes properly structured research with extended time frame on comparable schools.

In schools there is a strong negative association between the quality of computer equipment and number of computer workstations, which means, in order to provide the necessary number of computers, educational institutions with limited funds are forced to compromise the quality of equipment /**10**/. This raises some important questions: Are schools, which are constructing computerized classrooms with 30 or more machines, allowed to risk poor quality of computers and are they prepared to face the consequences that this decision would have for students? Is it possible to adapt some didactical approaches and also suitably and effectively work on smaller number of computer workstations (e. g. learning in pairs)? The answer is easier if we know the ergonomic characteristics of certain computer components and eventual long-term consequences of their inappropriate use.

2.3 Ergonomic use of computer hardware with consideration of some physiological and anthropological analysis

The speed with which technology develops in the field of computer equipment, and the novelty placed on new developments by the market, create the risk that every debate concerning this theme will be out-of-date. Therefore we will mainly concentrate on typical products, which represent the core tools for computer related activities.

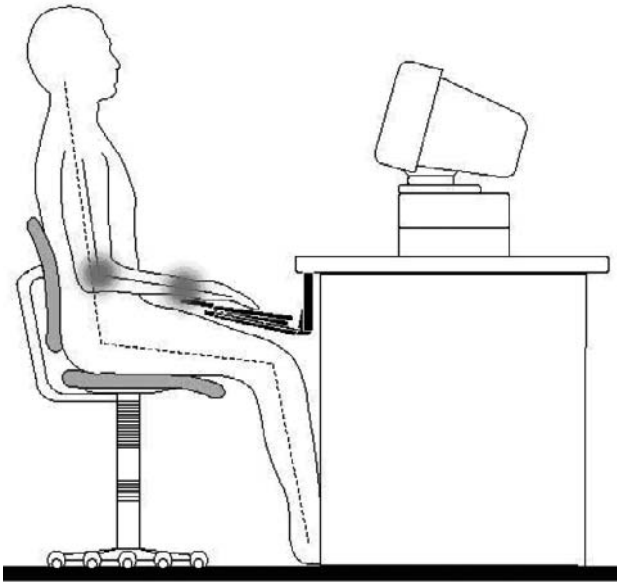

Figure 2: Ideal position at computer use (source: http://ergonomics.about.com)

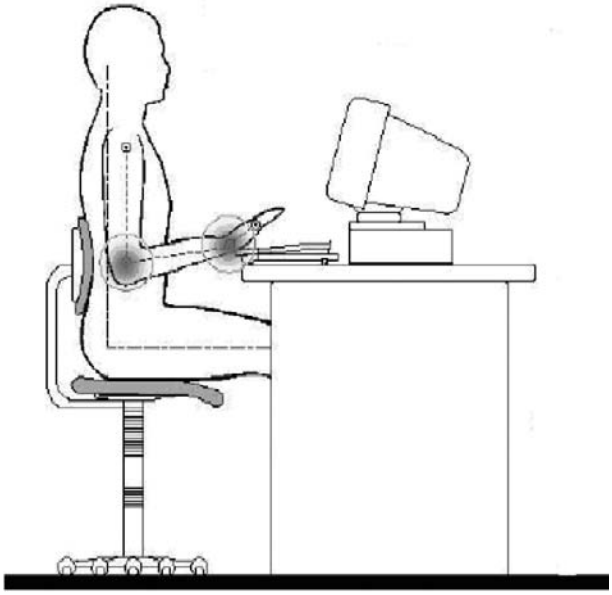

Figure 3: Usuitable hands position (source: http://ergonomics.about.com)

A short examination of what is on offer on the market showed that the basic keyboard design, whose shape was first developed some hundred years ago, still prevails. So-called traditional QWERTY keyboards (the name refers to the first six alphanumeric keys on the top row) hold a solid position among other more expensive, alternative, ergonomically formed solutions. According to Amel and Kumar /**11**/ the primary reason for this fact may be due to initial costs as well as an unwillingness to change. The authors also emphasize that lately we are witness to some instant ergonomic solutions (e. g. ergonomic keyboards with quick fix aids such as 'wrist rests'), but such products only cloud the need for more sophisticated designs that would embrace and resolve a wider spectrum of problem related to keyboard use.

Problems caused by the design of traditional keyboards are usually associated with unfavorable positioning of the forearms whilst typing with the fingers, which in certain cases leads to an increased pressure in the carpal tunnel and tonic tension of the arm and hand musculature. Besides this, reactive force that is generated when pressing keys in a direction along the axis of gravity, causes even additional tonic tension of arms and neck musculature /**12**/. Support of the forearm and wrist during keyboard use alleviates some of the listed problems. Cook and colleagues /**13**/ examined the effect of forearm support, wrist support and floating posture (no support) during keyboard use. They found that in comparison with the floating condition, the support of forearm resulted in significantly less ulnar deviation. The wrist support condition without forearm support resulted in less trapezius and anterior deltoid muscular activity.

Some problems that arise during keyboard use can be solved by keyboard designs which allow the wrist and forearm support. But if we want to address a broader scope of risk factors in the future, we will have to adopt more radical keyboard designs. Van Galen and colleagues describe two solutions. The first is to split the keyboard tray between the 5-T-G-B and the 6-Y-H-N and rotate the left and right halves clockwise and counter clockwise. The second option is to lift the front edges of the two halves of the keyboard to create a descending slope so that a less awkward alignment of the hand is required. The most noticeable problem with vertical keyboards is that key identities become less visible.

None of the described keyboard designs are widely accepted on the market, besides price of such ergonomic solutions is relatively high. However, when purchasing computer equipment, schools are advised to buy keyboards that allow at least wrist and forearm support.

The move from antiquated user interfaces that were based on entering word commands with a keyboard, to graphical user interfaces, encouraged development of new entry devices for interaction with computers. The computer mouse embodied the most elegant solution, one which was quickly welcomed by a wide circle of users and soon became standard for effective computer work.

Ergonomic use of the computer mouse is related with (1) its design, (2) the type of task that certain

computer activity requires (e. g. longer moves of the cursor due to the distance between icons), and (3) some control settings of the mouse. Sandfeld and Jensen evaluated the effect of motor and visual demands on the ability to control motor output in terms of performance and muscle activation during computer mouse use. Comparison between young and elderly groups of experienced computer users was made. Subjects were performing multidirectional pointing tasks with computer mice, during which three different levels of mouse gain and tree levels of target size were tested. All participants demonstrated a reduced working speed and hit rate at the highest mouse gain (8:1) and smallest target size. The combination of high mouse gain and small targets had most effect on the elderly group. Both groups were sensitive to decreasing target size despite the fact that motor demand was kept constant. In connection with muscle activation a study showed that forearm muscle activity was not significantly influenced by mouse gain, indicating that stability of the forearm is of significance during computer mouse use. Authors pointed out that physical demands associated with computer mouse use involve motor demands as well as visual demands. The level of the motor demand is influenced by movement amplitude in combination with demands for precision of the hand movements. On the other hand, the visual demands are connected with the size of the targets and their inter-distance on the monitor.

In spite of the fact that ergonomic use of computer mice depends to large extend on the type of task that computer activity demands, there are some elements of quality computer mouse, which should be of great importance to schools when upgrading computer equipment. Woods and colleagues /**14**/ highlighted some of the factors that are considered to be of great importance when designing a quality computer mouse:

- comfortable position for hand and finger,
- sufficient control,
- intuitive and easy to use,
- ease of device, button and trackball movement,
- good interaction with computer software,
- provision of different suitable accessories.

Figure 4: Renaissance vertical mouse and adjustable ergonomc keyboard (source: http://www.fentek-ind.com)

Prices of computer screens decreased notably in past years and, in addition, their quality rose significantly, so nowadays large liquid crystal displays (17 inches or more) are already accessible for reasonable prices. With suitable sizes and reduced radiation, liquid crystal displays in comparison with CRT (Cathode Ray Tube), screens do not represent a serious threat from an ergonomic point of view. Because of the retreat of CRT screens from the market, schools that still own them will, in the long run, be forced to replace antique equipment with more quality LCD screens. Therefore, necessitated discussion in this field is not so much associated with the types and sizes of monitors, but rather with some questions concerning the adequate positions and overall use of display devices.

It is interesting that against already established ergonomic guidelines about the correct positioning of computer screens, there still exist some inconsistencies. According to Burgess-Limerick /**15**/ the optimal location of the computer display is at least 15 degrees below horizontal eye level (at distance of approx. 750 mm). However, different experts present certain arguments that are in favor of other display positions /**16**/.

Considering the fact that the majority of computerized classrooms have lighting similar to other ordinary classrooms (with a tendency to optimal luminosity), let us mention a study that was aimed to determine the recommended luminance level surrounding the computer display. Sheddy and colleagues /**17**/ found that surround luminance

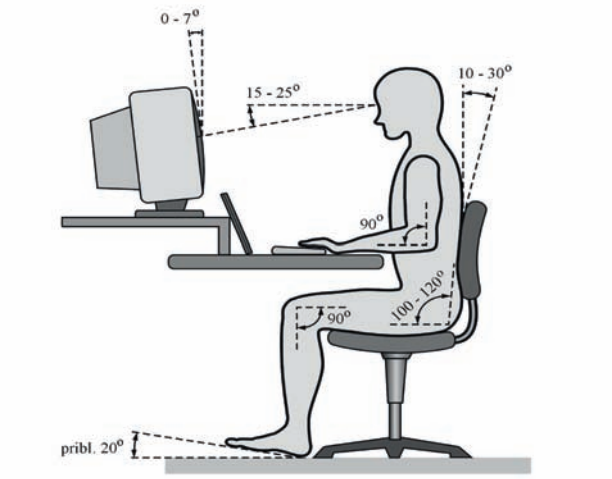

Figure 5: Suitable body position at computer use with cetain ergonomic degrees

levels at or slightly below that of the central task are preferred for optimal work. Where this is not the case there is a possibility of discomfort glare, which consequently leads to eye strain.

2.4 Ergonomic construction of computer software

Ergonomic aspects of software user interface include navigation inside certain computer applications and means by which, for instance, different multimedia content reacts to users' actions /**18**/. User interfaces of computer applications have changed their image through years of development and have become more and more efficient and user-friendly. However, although visual dimensions of some user interfaces more often than not fascinate a broad variety of users, mere functionality often straggles behind the general evolution. As an example, Olson and Olson /**19**/ mention the World Wide Web, which, regardless of its wealth of facts, can present a noticeable problem even for the more experienced user wishing to find specific information and having to navigate through large databases. In order to better organize this huge information basket, some designers are borrowing principles from library science and gradually trying to form a well-organized base of information, connected to a rationally created user interface. However, due to exponential growth of data, this may still be an enormous issue in the future. Cheng and Patterson /**20**/ argue that we can reduce the complexity of user-system interaction with the proper use of iconic interfaces, but unfortunately, because of the web's short history, lack of research on the subject and carelessness, the icons used on web often are ambiguous.

Olson and Olson claim that early research work into the frame of development of software user interfaces concentrated little on individual differences. Therefore creation of interfaces was targeted at office workers without disabilities or special needs, who were using computers solely to fulfill job obligations. Children, for example, do not have adequate knowledge from which to build metaphorical interfaces and they also lack sufficient motor skills. Authors highlighted the importance of attractive, appealing interfaces for young users, because the nature of children's interest calls for new, unsubtle changes in their environment. Durin and Solomon /**21**/ emphasized that software interfaces adapted for children should include colorful visual appearance, heavy use of animation and explanatory material using speech rather than text.

Johnson and Wiles /**22**/ point out that knowledge, which is used within the creation of appealing computer games, could be utilized for making effective educational software. Positive emotions that authors associate with playing computer games are satisfaction, a sense of progress and achievement, amusement and excitement. Motivation behind repeated experiences of positive emotions is the key element of quality computer games. Games could therefore contribute to the creation of educational software by presenting some ideas for effective design that promote positive effect and flow on the part of the users.

We should also elaborate on the problem, which is especially important in smaller countries like Slovenia. Efficiency of quality computer software is often reduced due to certain cultural barriers. Most computer applications are based on North American language and other characteristics which are inherent to American culture. Translating the content seems to be reasonable solution, but cultural disparities often require changes more fundamental than simple surface corrections /**23**/.

3. Conclusion

Development of information and communication technology presents schools with an obligation to prepare students for life in an unclearly defined future. We can assume that, due to effective functioning in modern society, a way of life connected with static work in front of computer screen will be intensified. The latter does not only emphasize the need for ergonomic knowledge within school communities, but also the necessity for successful dissemination of some ergonomic principles to younger generations, whose interaction with computers technology is not only school-related.

Straker and Pollock describe many cases of intensive inflowing of information and communication technology into children's everyday life. They highlight the importance of seriously exploring transformation in the lives of young generations and of deeply investigating the consequences of some upcoming changes. Ergonomics has to modify some of its integral parts, if it wants to seriously comprehend challenges that are produced by modern existence. In the 20th century ergonomics mostly aided technological development in reducing heavy physical exertion and thus helped lessen negative health impacts and their effects on productivity for heavy industry. At the present time, problems that demand the attention of ergonomics are quite different. Due to the mechanization and computerization of different processes, human work is based increasingly more on sitting behind computerized devices, which brings up issues related to insisting in monotonous, awkward body positions.

In this article we presented a model of ergonomic implementation of computer technology into the school environment. We concentrated on different areas that are generally related to this process. In the context of suitable school workspaces we underlined the inappropriateness of individual workstations in computerized classrooms for different kinds of school work and incongruence with students' anthropological characteristics. We should search for solutions that would enable more flexible workstations (e. g. adaptive chairs and tables) and ensure more space for computer-unrelated work, such as writing in textbooks. Problems of luminosity in computerized classrooms are also mentioned. Luminance of surroundings in classrooms should not surpass the average luminance of computer screen (around 800 cd/m^2). Therefore it would be reasonable to consider installation of lighting with adaptive luminosity.

We also studied some important elements of computer hardware and shed a light on ergonomic aspects of computer applications. An overview of the keyboard market showed that there are no noticeable products which would implicate a broader scope of ergonomic solutions. The recommendation for schools is to insist on purchasing keyboards that allow support of the wrist and forearm. When selecting the appropriate mouse, schools have to pay attention to adequate design and different control settings (e. g. selection of the most effective mouse gain). Because the market already offers suitably large and high-quality computer screens for relatively favorable prices, we especially emphasized the importance of correct positioning of the screen and a suitable level of surrounding luminance. Ergonomic constructions of educational computer applications should include logical and rational navigation through application menus, avoidance of monotonous tasks, and stimulation of students' excitement and curiosity.

After examination of some ergonomic aspects of computer equipment, we can more easily find an answer to the question regarding sacrificing the quality of computer equipment in favor of quantity. When buying new computer hardware, we have to consistently strive for quality products, since the use of unsuitable devices may have negative consequences for users in the long run. Besides, schools should strive to set a positive example and therefore warn students not only to consider the basic aspects of functionality of the product that they are buying, but also to reflect on certain design, comfort and safety issues.

School environments need ergonomic knowledge to successfully control even those factors of the educational process which are not recognizable at first sight. Desire to possess some of the ergonomic information is evident between educational experts, it is therefore important to shape some clear ergonomic guidelines that would be valuable to educational practice. The primary goal of so-called educational ergonomics is to create an extensive and reliable base of research findings, which could be used as a solid foundation for transmitting ergonomic knowledge to school communities and consequently into the value system of entire society.

References

/1/ Legg, S. (2007). Editorial: Ergonomics in Schools. *Ergonomics, 50* (10), 1523-1529.

/2/ Smith, T. J. (2007). The ergonomics of learning: educational design and learning performance. *Ergonomics, 50* (10), 1530-1546.

/3/ Woodcock, A. (2007). Ergonomics, education and children: a personal view. *Ergonomics, 50* (10), 1547-1560.

/4/ Fošnarič, S. (2001). Učenci in šolsko delovno okolje: Nekateri uporabni vidiki ergonomije v vzgoji in izobraževanju. Maribor: Pedagoška fakulteta.

/5/ Sušnik, J. (1995). Ergonomsko sedenje šolarjev: testiranje vzorčnega šolskega pohištva – delovnega stola in mize. *Slovenska pediatria, 2* (1-3), 127-128.

/6/ Barrero, M. & Hedge, A. (2002). Computer environments for children: a review of design issues. *Work, 18* (3), 227-238.

/7/ Milanese, S. & Grimmer, K. (2004). School furniture and the user population: an anthropometric perspective. *Ergonomics, 47* (4), 416-426.

/8/ Briggs, A., Straker, L. & Greig, A. (2004). Upper quadrant postural changes of school children in response to interaction with different information technologies. *Ergonomics, 47* (7), 790-819.

/9/ Trevelyan, C. F. & Legg, S. J. (2006). Back pain in school children – Were to from here? *Applied Ergonomics, 37* (1), 45-54.

/10/ Zandvliet, D & Straker, L. (2001). Physical and psychosocial aspects of the learning environment in information technology rich classrooms. *Ergonomics, 44* (9), 838-857.

/11/ Amel, T. & Kumar, S. (2000). Cumulative trauma disorders and keyboarding work. *International Journal of Industrial Ergonomics, 25* (1), 69-78.

/12/ Van Galen, G. P., Liesker, H. & de Hann, A. (2007). Effects of a vertical keyboard design on typing performance, user comfort and muscle tension. *Applied Ergonomics, 38* (1), 99-107.

/13/ Cook, C., Burgess-Limerick, R. & Papalia, S. (2004). The effect of upper extremity support on upper extremity posture and muscle activity during keyboard use. *Applied Ergonomics, 35* (3), 285-292.

/14/ Woods, V., Hastings, S., Buckle, P. & Haslam, R. (2003). Development of non-keyboard input device checklists through assessment. *Applied Ergonomics, 34* (6), 511-519.

/15/ Burgess-Limerick, R., Mon-Williams, M. & Coppard V. L. (2000). Visual Display Height. *Human Factors: The Journal of the Human Factors and Ergonomic Society, 42* (1), 140-150.

/16/ Pollock, C. & Straker, L. (2003). Technical note: Excerpts from CybErg 1999 discussion on computer display height. *International Journal of Industrial Ergonomics, 31* (3), 207-214.

/17/ Sheedy, E. J., Smith, R. & Hayes, J. (2005). Visual effects of the luminance surrounding a computer display. *Ergonomics, 48* (9), 1114-1128.

/18/ Lopuck, L. (1996). *Designing Multimedia; a visual guide to multimedia and online graphic design.* Berkeley: Peachpit Press.

/19/ Olson, M. G. & Olson S. J. (2003). Human computer interaction: Psychological Aspects of the Human Use of Computing. *Annual review of Psychology, 54* (1), 491-516.

/20/ Cheng, H. & Patterson, E. P. (2007). Iconic hyperlinks on e-commerce websites. *Applied Ergonomics, 38* (1), 65-69.

/21/ Durin, A. & Solomon, C. (1996). *Designing Multimedia Environments for Children.* New York: Wiley.

/22/ Johnson, D. & Wiles, J. (2003). Effective affective user interface design in games. Ergonomics, 46 (13/14), 1332-1345.

/23/ Ibidem /19/

Literature

1. Dockrell, A., Fallon, E., Kelly, M., Masterson, B. & Shields, N.(2007). School children's use of computers and teachers' education in computer ergonomics. *Ergonomics 50* (10), 1657-1667.
2. Harris, C., Straker, L., Pollock, C. & Trinidad, S. (2005). Musculo-skeletal outcomes in children using information technology – the need for a specific etiological model. *International Journal of Industrial Ergonomics, 35* (2), 131-138.
3. Johnson, D. & Wiles, J. (2003). Effective affective user interface design in games. Ergonomics, 46 (13/14), 1332-1345.
4. Sheedy, E. J., Smith, R. & Hayes, J. (2005). Visual effects of the luminance surrounding a computer display. *Ergonomics, 48* (9), 1114-1128.
5. Woodcock, A. (2007). Ergonomics, education and children: a personal view. *Ergonomics, 50* (10), 1547-1560.
6. Woods, V., Hastings, S., Buckle, P. & Haslam, R. (2003). Development of non-keyboard input device checklists through assessment. *Applied Ergonomics, 34* (6), 511-519.
7. Zandvliet, D & Straker, L. (2001). Physical and psychosocial aspects of the learning environment in information technology rich classrooms. *Ergonomics, 44* (9), 838-857.
8. http://www.fentek-ind.com. Renaissance vertical mouse and adjustable ergonomic keyboard . Retrieved April 12, 2008.
9. http://ergonomics.about.com. Ideal position at computer use. Retrieved April 12, 2008.
10. http://ergonomics.about.com. Unsuitable hands position. Retrieved April 12, 2008.