

## Distinguishing characteristics of junior high school classroom interior design in Bali with ergonomics principles consideration to optimize students' performance

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(Abstract) The main goals of this paper is to promote the model of Interior design of Junior High School classroom in Bali, which is designed by ergonomics principles consideration to optimize students' performance during the learning activities. The condition of interior design of classroom has plays an important role to optimize the students' performance, has been aware by the Government of Bali. But, unfortunately, untill for this time being they never go to persue the interior design of the classroom with ergonomics principles consideration to optimize the students' performance. Although International Ergonomics Association (IEA) was recognized that ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system and the profession that appllies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

**Practitioner Summary:** Ergonomics problems were collected from 167 female and male students in Junior High School of Badung and Gianyar Regency of Bali Province, from Monday to Friday on 7.30 am to 12.30 pm. By regarding that problems, proposed junior high school classroom interior design with ergonomics principle consideration that provide: (1) locker to store for each students' school bag that settled over the lenght of the wall in front of the classroom; (2) facilities for placing books and stationaries on every students' desk; (3) the edges and corners of each desk and chair must made curve and blunt; (4) flexible whiteboard that hung on over the lenght of the front wall of the classroom for covering visual objects and a number of accessories; (5) personal students' circulation to prevent the tendency to mount onto the chair or even the desk; (6) most of the accessories in order to place in the classroom must be hung at the rear wall of the classroom; (7) translucent ceiling to allow sunlight for increasing the intencity of illumination thus saving electrical energy; and (8) spreading of air circulation to accelerate the movement of air in order to reduce the interior relative humidity so that the classroom condition of interior design was comfortable.

**Keywords:** junior high school, classroom, students' performance, interior design, ergonomics.

### 1. Introduction

Interior design of classroom has been awareness plays an important role in an effort to optimize students' performance during learning, in order to increase the quality of learning outcomes. This awareness is also has been owned by the Government of Bali, especially after the Minister of National Education of Indonesia (MNEI) issued a regulation no: 24/2007 on school infrastructure. This regulation requires that any school management arrange the class at each school, so that learning activities can running well. Its has a simple contents, complete and general but its implementation has not been evaluated thus no one know about the effectiveness. Moreover, after the MNEI is issued a 12-year compulsory education policy that requires all of a public schools, as the only one in a village and residents are was categorized as well a compulsory school age must be accepted as a student that all Indonesian citizens to education.

Therefore, class has been built with size of 64 m<sup>2</sup> should be used by 40 to 45 students, whereas in the regulation declared to be used only by 32 students. An area of 2 m<sup>2</sup> is provided for each student has not met again, due the class is extent size of 64 m<sup>2</sup> must be added of 8 to 13 pieces of desk and chair so that all students can learning in the class. By doing so, the remaining area for each student only 1,6 to 1,42 m<sup>2</sup> and crowded enough to learn with concentration requirement. Fortunately, the wet and dry interior temperatures when measured by sling thermometer around 26° and 29°C. But, when this figure was converted to the pshychrometric chart, the interior relative humidity around 82%. Interior lighting intensity that measured by lux

meter only 199 lux, whereas the air movement measured by anemo meter of 0.013 m/sec and sound intensity measured by sound level meter is 55 dB (Ardana, et al., 2013). Subjective assessment was also conducted twice through filled of five questionnaires by 167 students, before the start and after completion of the learning activities. Filling questionnaire of eye complaints, Nordic Body Map, 30 items subjective fatigue, boredom and comfort generate data as shown in Table 1. These data support the results of objective measurements, which prove the need for ergonomic solutions on the interior design of learning in Junior High Schools in Bali to optimize students' performance in order to improve the quality of learning outcomes.

**Tabel 1**  
**Results of Difference Test (n = 167)**

Variables	Eye Strain			Musculoskeletal Complaints			Fatigue			Boredom	Comfort		
	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.		Pre	Post	Diff.
Mean	9,27	13,18	3,91	29,84	43,12	13,28	31,77	43,55	11,78	116,55	136,14	122,80	13,34
SD	0,46	0,59	0,65	0,71	2,45	2,60	0,60	0,93	0,81	7,14	3,80	3,41	2,30

n = Total samples SD = Standard Deviation

To improve the quality of learning outcomes should pay attention to five key indicators are: (1) teacher; (2) student; (3) facilities; (4) process; (5) budget (Marmai, 2001). Most of teacher have university degrees, even master and received special training. Students are selected strictly and the budget has been further enhanced. But, conditions of the student body and the design of the facilities have not received serious attention. Awareness of the important role of the student body condition is virtually non-existent, due to improve the quality of learning outcomes is always only associated with treatments in teaching methods and learning materials alone. Increasing the quality of learning outcomes have not believed to be obtained through optimal learning activities, which is affected by students' body conditions while learning at class. The stability of the student body condition during learning in the class, can be influenced by the design of the conditions of facilities which is used because it can cause physical and mental complaints. In doing so, is needed to look for solutions in order to improve the quality of learning outcomes to be realized if additional spacious room is impossible nowadays. Students' performance while learning at class can be optimized, if physical and mental complaints can be prevented. By doing so, ergonomics principles should be applied to this interior design of class due the theory of interior design are less able to solve this problems.

Important factors in achieving the quality of learning outcomes, are the optimalisation of the students' performance and the quality of facilities arrangement in the class (Marmai, 2001). Interior design of class analysis is also needed in order to optimize students' performance, not just focus for implementing the optimal function and aesthetically all components of the interior. Concurrently, ergonomic analysis should be carried out for the purpose for optimizing students' performance due may be could decrease of eye strain, musculoskeletal complaints, subjective fatigue, boredom and increase of the students' comfort. In order to really achieve optimize of the students' performance at Junior High School in Badung and Gianyar Regency, it is important that interior design of class for learning with ergonomics principles consideration should be applied right away at any school.

Most of investigation on ergonomics that has been carried out in learning, has succeeded to reduce 54.03% musculoskeletal complaints and increase the average value from 6.5 to 7.0 (Sutajaya, 2004). Learning process based on ergonomic principles, in order to improve learning outcomes from the mean value of 58.71 in the first cycle to 62.06 in the second cycle or has been increased about 5.7% (Sutjana et al., 2004). Lighting of interior on learning with ergonomic consideration was also able to increase the speed and accuracy and learning constancy about 70.46%, 56.36% and 90.95% respectively (Partadjaja, 2004). Redesign of desk and chairs with ergonomics consideration which is it use in the classroom of learning could be reduce fatigue is 73.76%, musculoskeletal complaints about 99.88%, boredom 26.40% and 65.81% increase learning motivation in addition to learning achievement of 33.70% (Wijana, 2008).

## **2. Students' problem in the existing of classroom interior design**

Students learn on a desk with a flat surface and height of 74 cm, whereas elbow height is 67 cm when sitting. When write, read, draw and put both arms on desk, shoulder is automatically lifted. When put a forearm on the desk edges and corners of a rectangle and taper shaped, body structures under the skin depressed. If foot should be placed on the footrest of desk, thigh's surface pressed by the bottom drawer under the desk which is also rectangle formed. If the foot placed on the surface of the floor, popliteal part pressed by the front edge of the seat is a rectangle shaped with height is 45 cm and student popliteal high only 39 cm (Ardana, et al., 2013). Student also must seat on a chair with no armrest but erect backrest, arms and back can not relax when learning with sitting. Dynamic body postures when learning with sitting, only when the body in upright position and bent to perform activities or put both arms on desk surface. All these conditions, tends to lead musculoskeletal disorders.

Students learning for 320 minutes with sitting, to attend four different topics of lessons. The first one lasted 120 minutes, the second and third on 80 minutes each and the last one is 40 minutes. Among that topics, there is a time leg for waiting a substitute teacher who will provide the next of lesson and rest breaks for 30 minutes after the end of the second lesson. At rest breaks of class, there are a number of students still sitting in class thus increasing the amount of time to sit around 30 minutes again (Ardana, et al., 2013). As was described by Storr-Paulsen and Aagaard-Hansen (1994), while at school children spend a lot of time sitting. They remain seated for long periods of time with no opportunity to take breaks. In the case of children at school, static and forward-leaning sitting postures were associated with neck pain and low back pain (Murphy et al., 2004). Children are seated for long periods of time at school, which imposes a daily strain on their growing backs (Motmans, 2006). Due to the lack of understanding of ergonomics, then no one to stretch a muscles when there is a time leg and rest breaks of class to prevent musculoskeletal disorders. Whereas the principles of ergonomics is already and always published in Bali by Professor Adnyana Manuaba since 1976 but still considered not important may cause it already has its own way to solve the problem.

The lighting in the class in the higher priority using sunlight for electricity energy saving policy, whose condition is stable and the intensity can be adjusted according to need than natural light that is unpredictable fluctuation. Therefore, each ceiling only fitted by four units fluorescent lamp with 20 watt capacity to help lighting of the room when considered dark. The intensity of light that only 199 lux, obtained from nine pieces of glass windows and ventilation laid on the right and three on the left side of walls of class. The right side of the class to obtain a direct reflection of sunlight, but the left side protected by canopy and a number of trees that grow in the school yard. As a result of 199 lux light intensity, regulator muscles of pupil size can not contraction and relaxation in turn so one must contraction and relaxation in a longer period of time according to the rules of physiology. Prolonged muscle contraction can run out of energy, cause fatigue, if the lactic acid as a metabolic waste is not successfully removed from the muscle cells then cause eye complaints. Eyes need accommodation in order to avoid fatigue what's more to cause disorders, can be realized through the provisions of opportunities to look far and close alternately. Nerve of eye regulator has works prolonged time, can cause fatigue synapses resulting eye strains. Another factors that causes eye strains, glare experienced by students who sat stuck the glass window that lined the right wall of class.

Students experiencing subjective fatigue, due wearing learning equipment that does not fit with their preference of anthropometric characteristics, lack of movement and displacement of the body because they must learn with sitting even some had to sit clamped among friends and/or wall of class. This is due to an additional 8 to 13 pieces of desks, circulation path must be wide thus desk laid out in a row of three so that the personal circulation which should amount to six lanes reduced to three lanes only. This conditions can lead to complaints with no sound, by students who must sit wedged, because school administrators have absolute authority and must be obeyed. For students who are reserved and/or shy and behave positively, tend to be constrained to or out from where they sat. They had to resist to urge to next friends to understand their needs, so that the learning concentration of both impaired. Students who are naughty and negative behavior, tend to mount onto friends' chair even desk to immediately be able to and/or out of the chair and never thinking of the disturbance. Negative and selfish behavior is disturbing student learning concentration so the performance less than optimal.

Concentration impaired due to visual objects are numerous and colorful, hung on the left and right of the whiteboard which hang on the wall in front of the class. Photos of national hero, prominent educator and placards of motto or maxim also hung in every part of the empty classroom wall so that always affect the students' interest to watch. Consequently, students are less focused on the teacher and whiteboard as a provider of information media it is used by teachers to explained their content of the lesson. Moreover, if

teachers still using the methods of teaching and learning materials that have been boring, causing a tendency to distract the more interesting objects or playing games in the class. Challenges that are not in accordance with the student's capabilities, but must be addressed while learning in the class tend to lead boredom. Design of class is too simple, walls and ceilings without variations and white color only even wooden elements colored with brown that sounded naturally but instead absorb more light intensity has been less so that it becomes less attractive to be enjoyed and is unable to cultivate empathy. If the stimulus from various senses comes together and must be distributed simultaneously by synapses to the processing of information, can cause fatigue synapses that eventually resulted subjective fatigue. Psychological factors such as mental disorders, finally can also lead to physical complaints (Manuaba, 2000).

Students experiencing physical discomfort, mental, visual and also thermal. Physical discomfort caused by using desk and chair is not in accordance with the anthropometry, thus affecting students' mental condition who needed to perform concentration and demonstrate their intellectual capabilities but also must be in class that does not have a personal circulation path. Lack of accommodation causes visual complaints, when there is an opportunity to stretch the muscles in a systematic way but not utilized. Thermal complaints caused by learning in the class with 82% interior relative humidity and air movement only 0,013 m/sec and filled with CO<sub>2</sub> although wet and dry temperatures are 26° and 29°C. Low of air movement by the less of holes in the walls of class, whereas the class is in good position of air circulation.

### **3. Ergonomics concept for designing interior of classroom**

Learning is an activity that involves a lot of more mental than physical factors, therefore mental workload analysis becomes more vital to be used as guidelines to design a type of equipment required (Patel and Salvendy, 2002). Design is a wonderful thing; it can change people's lives. Ergonomics is the same; it is also a wonderful thing, and it can also change people's lives (Chong, 2010).

Ergonomics solution is scientifically and practically, hence there is no reason for rejecting its application in various sectors for the sake of improving the quality of human life as a whole and completely. IEA was recognized that ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Rodahl (1986) asserts that we are, like all higher animals, basically designed for mobility which is the basic requirement for the performance of any kind of physical work. Consequently, our locomotive apparatus, i.e. the neuro-muscular-skeletal system, constitutes the majority of our total body mass. The muscle, which is the basic instrument of mobility, is a very old tissue. Yale University (2005) also said, the muscles, tendons, ligaments, joints, bones, cartilage and discs in the spine make up the musculoskeletal system. An injury or illness to these parts is called musculoskeletal disorder (MSD). To understand these injuries, it is necessary to understand the structure and function of various parts of the body. According to Rodahl's theory, Anderson (2009) explained that a teacher in Minnesota is convinced children learn better if they are free to move around. With the help of a local ergonomics company, she has designed a desk that makes it easier for pupils to be active.

According to the theory of ergonomics, human body should be given the opportunity to move and rest. Muscles that were contracted can already relax, in order to gain new energy for the next contraction. Muscle which relaxation already had to be immediately contraction to perform their duties because it has the energy, so in accordance with the laws of physiology. According to that mechanism, so the improvement of students' performance should be a pay attention to the important indicators such as: physical, mental and environmental conditions (Dimiyati and Mudjiono, 2002). An optimal involvement of physical and mental factors while learning at class, is a representation of the optimization of students' performance. An effort to optimize the students' performance, must pay attention to the physical and mental characteristics that can be used as a guideline to enhance the harmonized interaction among children with the condition of the facilities and class environment. Sudharmanto and Slameto hope growing attention to the physical health consideration (particularly eye) even the students' brain capabilities, in order to optimize the performance due it affects the increasing of quality of learning outcomes (Marmai, 2001).

Ergonomics tend to effort for improving performance through harmonized tasks demands, capabilities, ability and limitation of human being. Physical and mental condition of human being also considered in designing all of the elements which is a part of work system, in order to make up the quality of work results and productivity will increase. Excellent performance can be achieved from a healthy body condition, fresh,

efficient and productive (Manuaba, 2000). Therefore, important role of ergonomics in design must be known by the public, that the realization of any design components must be real (Wilson and Corlett, 2005; Chong, 2010). Yale University (2005) also claimed, whether standing or sitting there is a neutral position of the back, neck, arms and hands. This is the position that puts the least amount of strain on a given part of the body. Postures that differ from the neutral position increase stress on the body. Thus, student anthropometric data are used as a guidelines to design desk and chair and personal circulation path. Physiological body postures can minimize disorders, fatigue, boredom and enhanced the feeling of students comfort. Anthropometric data are the measurements of the human body form used by designers to represent the human shape and size in designing the fittings and features of the workplace. The Australian Safety and Compensation Council Chairman, Bill Scales, needs more accurate Australian anthropometric data and tools will help our designers make workplace safer (Anderson, 2009a). Anthropometric data, commonly applied according to 95 percentil and the rest used by 5 percentil, because based on the principles of space of movement flexibility or space geometric (Panero and Zelnik, 2000).

Human body also have capabilities, abilities and limitations because the internal conditions has a narrow tolerance when different with a physiological requires. Important factors that play a role to maintain a healthy body still fresh: postures must be dynamic even sitting; at a certain period any position should be replaced with the opposite position, driven and moved; physical environmental must keep homeostasis concepts is not impaired (Rodahl, 1989; Dul and Weerdmeester, 1993; Sherwood, 2001; Pinel, 2009; Guyton and Hall, 2008). There are a fundamental fact that can be used to guide design process, so that people can always be prosperous in any activity, such as: (1) different body shapes and sizes, need anthropometric place for activities; (2) different motor capabilities, then the reaction time and strenght and sensories capability as well as different; (3) cognitive or mental capabilities to store and process information differently so the results of accurate decisions are also different; (4) experience, motivation, culture background and persepition of risk is different so the same man to be different at different times; (5) man is not enough to have just been briefed let alone appeal, because not sure willing to change behaviour then the system should be made to authomatically change the behavior even without an appeal; (6) human oriented in the end product, through fault repairs as already experienced; and (7) man ready to face the risk or takes risk in order to obtained better results and right as well as maximum (Pulat and Alexander, 1991). Conclusion, ergonomics do not expect human to experience a disaster but still must remain aware that, however, they must survive and productives and lives with prosperity.

Improper placement of learning materials on the desk is also a common cause of neck problems. Repeatedly bending the head downward to look at a paper flat on the desk and then tilting the neck backwards to see another visual objects that are straight forward position can cause pain and stiffness in the neck. When the physical learning conditions are uncomfortable or inappropriate, the student must doing something to adapt to the unsuitable conditions. The effort to cope with that factual conditions is added to the already existing demands on the learning characteristics, thereby increasing the level of stress. Stress is not only feelings; it causes changes in body functions (physiology) such as the realese of a variety of hormones, increased breathing, quickened pulse and the production of more stomach acid. Workers suffering from repeated, prolonged or continuous job stress may experience: (1) frequent headaches; (2) sleeplessness; (3) loss of appetite; (4) depression; (5) short temper; (6) backache and stomach problems; (7) ulcers; (8) high blood pressure; or (9) heart disease. Stress can also increase the risk of being injured on the job, weaken the body's resistance to disease, lead to substance abuse and contribute to martial and other social problems (Yale University, 2005).

Yale University (2005) also wrote, that conditions which cause stress (stressors) can divided into two general categories, the work environment and the organization of work. Environmental factors that lead to stress include: uncomfortable temperatures, humidity and poor air quality; improper lighting; noise; and equipment and furniture that are not the right shape and size. The organization of work involves the manner in which work is done. Numerous organizational factors can make more stressful, such as: repetitive tasks; a lack of participation in decision-making and control over how to do your job; lack of breaks or work not requiring; excessive overtime; and unreasonable pace of work. The criteria are generally used ditermined the success of the lighting of interior design, is the persentage of productivities increasing and comfort and user satisfaction. If not succeeded in realizing the common criteria, then illumination design is declared failed although recognized artistic. Excessive ilumination design is important to gain attention so as not to affect the frequency of headaches, stress and increased blood pressure. Beside that, glare or excessive light decrese the work efficiency and productivity (DiLouie, 2006).

Staining of learning class, need to consider the nature of performance which is more focused on the concentration and accuracy of learning outcomes. In that regard, Anderson (2009b) stated, experts say colors may affect cognitive performance because of the moods they engender. She also said, that red boost brain performance according to researchers at the University of British Columbia (UBC) that was conducted by Juliet Zhu and Ravi Mehta (UBC Ph.D candidate). Red boosted performance on detail-oriented tasks such as memory retrieval and proofreading. Zhu says, that red can make people's work more accurate, were associate with danger and mistakes and caution. The avoidance motivation or heightened state that red activates make us vigilant and thus help us perform tasks where careful attention is required to produce a right or wrong answer. The findings, could contribute to the design of ergonomically-enhanced work environments.

#### **4. The models of junior high school classroom interior design with ergonomics consideration**

The human body is designed for mobility, it must always moved but must be provide an opportunity to stretch the muscles. Then, each student is given a locker to put school bag that must not be taken to the seat. Locker styled stick over the length of class wall, below the whiteboard that hung on the front wall of the class (fig.1). Twice time out for waiting of substitute teacher come must be used to walk from the chair to the locker to put school supplies the completed worn and take on new learning materials for the next lesson, so it is not necessary to provide a special times let alone to take the time of lesson that already limited. Provision locker also to foster empathy, because it was already granted as an owner, class area can function optimally and more attractive even fun because in contrast to the class in general. Student body while seated can be dynamic, because the backrest tilted about  $105^\circ$  and at the front end of the desk are provide holes to put school supplies (fig.3) were brought to the chair. These conditions encourage occurs lean body movement, erect and leaning forward with a wider angle than before. There is at least a distance of 100 cm from the backrest to the holes desk, to pick up learning supplies by way of reach when sitting upright and lean (fig.3). Dynamic postures, prevent musculoskeletal disorders in order to learn with the optimal concentration.

Student anthropometric data use for designing the dimensions of desk and chairs, to manifest physiological postures. So, desk are designed with dimensions of 50 x 65 x 69 cm (fig.3) according to the width of the shoulder and both hand movement and as well as student elbow height when seated is 69 cm. And that's just in front only 15 cm wide, while the remaining width of 35 cm decrease by  $5^\circ$  thus students elbows remain higher than the height of desk surface despite being seated. The slope of surface desk cause elbow angle more larger than  $90^\circ$ , to prevent earliest disorders because the position is physiological. Desk are not equipped with drawer, because it takes leg room is wider so that students can freely leg movement and prevent used to hide the trash even prohibited items. Smaller desk dimension, generated personalized circulation path which must be provided in between the desk and at the desk with the interior walls. Provision six circulation path prevent students mount onto a chair even the desk, thereby eliminating the negative behaviors and reduces subjective complaints and increasing learning concentration because there is no more interference from friends.

The chairs are designed with dimensions of 41 x 41 x 39 cm, according to the width of the hips and buttock to popliteal and student popliteal height (fig.3). The design of chair seat height is 39 cm with summing high popliteal and 3 cm shoes height when sitting, so that both feet flat on the floor but popliteal untouched periphery seat holder. Beside that, chair also designed to have armrest that the height according to the student elbow height when seated. Thus, arms can placed on top of the thigh or the armrest and on the desk even hung on the side of armrest. Each of the edges and corners of desk even chair in touch with the body surfaces, designed curve and blunt to avoidance any pressure. Stress on the skin surface which wraps muscle, blood vessels, nerves and bones inhibit blood that carries oxygen and glucose as the energy required by muscles to be able to contraction. Pressure experiences on body surface, causing uncomfortable feelings because the flexibility to place a part of body was limited.

Avoiding eye strain, obtained by increasing the light intensity without neglecting of energy-saving policies. Then, sunlight should be used optimally and use energy-saving lamp so that the class becomes more attractive. Due to the plane of the wall is no longer a part that can be perforated, then there is only a ceiling that can be processed. Therefore, a massive tile must be replaced with a glass roof and perforated ceiling in six sections with each breadth of  $1 \text{ m}^2$ . Holes in the ceiling covered with acrylic material, so that sunlight has penetrated tile also directly penetrate the ceiling to increase the light intensity of class. Holes are made in the ceiling also used for the disposal of carbon dioxide in the class, because the addition of air hole

can increase the acceleration of air movement (fig.2) beside to opening a number of glass windows that were installed permanently previously.

Boards of class administrative, information boards and other board of class equipments which may not be moved to another wall, but it needs only at certain times then it must be hidden so as not to be a visual objects to disturbing learning concentrations. In doing so, installed two new sliding whiteboard among the whiteboard mounted permanently (fig.1). interior accessories that are needed in class to add the beauty and attractiveness, but it does not have to be the object who enjoyed when learning in ongoing must be mounted on rear wall of class (fig.2). Interior and a number of other class equipments stained reddish yellow, so that the atmosphere become more bright and attractive and grow higher learning motivation.



Fig.1. Interior design of classroom



Fig.2. Design of ceiling and accessories



Fig.3. Design of desk and chair

## 5. Conclusion

The distinguishing characteristic of junior high school classroom interior design with ergonomics principle consideration intended to foster a new horizon, about the quality of education that can not be improved only to intellectual-achievement oriented but must also pay attention to the student physical and mental condition during learning at class. Minimize of physical and mental disorders, certainly help the students to concentrate more better making it easier to understand the lessons given by any teacher. Interior class should be designed to increase motivation, discipline, sincerity and positive behavior in order to improve the quality of learning outcomes. This interior design of class encourage the growth of empathy, due students already feel entitled as an owner. It's time to develop the mind, that any problems can be solve perfectly if the various of disciplines given participating offer solution.

The problems facing by mankind in increasingly complex, then one discipline is no able longer to solve it completely. Ergonomics provides solutions to obtain a more perfect results, with no having to create a new problems as well. Regarding by that, Budnick (2010) statement should be observed: that ergonomists apply a hierarchy of methods when they are attempting to control a hazard or other process failures. Engineering controls are always the most effective, because they either remove the hazard at it's root or at least reduce or isolate the hazard so that exposures are controlled through design. Unfortunately, in practice, many companies and industries turn to administrative and personal protective equipment control methods that appear easier and cheaper to administer, yet end up costing far more in the long run simply because they are not effective and never solve the underlying root problems in a process.

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