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# BIOTECHNOLOGICAL TEACHING LEARNING PROCESS WITH SCIENCE TECHNOLOGY SOCIETY APPROACH ERGONOMICS-BASED INCREASES LEARNING OUTCOME AND LEARNING ACHIEVEMENT STUDENTS OF IKIP SARASWATI TABANAN

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## ABSTRACT

To identifying whether biotechnological teaching learning with Science Technology Society approach Ergonomics-Based (STMBE) could improve the learning outcome and the students' learning achievement. **Methods:** This is a randomized pre-and post-test control group design and involved 16 samples from the control group and another 16 samples from the experiment group. All data obtained was then statistically analyzed by employing *t group* test and *Mann-Whitney* at 5% significant levels. **Results:** The results showed that the biotechnological teaching learning using STMBE approach applied to the experimental group could increase the learning outcome viewed from the facts that the musculoskeletal complaint went down by 43.68% ($p$<0.05), that the exhaustion decreased by 34.90% ($p$<0.05), that boredom dropped by 22.64% ($p$<0.05), and that the learning activity went up by 42.72% ($p$<0.05), and that the students' achievement rose by 43.56% (p<0.05). **Conclusion:** It could be concluded that the biotechnological teaching learning using STMBE approach could increase the learning outcome and the students' learning achievement.

Keywords: Biotechnological, Teaching Learning, Science Technological Society, Ergonomics.

## INTRODUCTION

It is necessary to improve the quality of human resources in Indonesia in such a way that everybody can compete in the globalization era. To this end, it is necessary to improve the quality of learning process in such a way that the students' learning achievement/ achievement index will be better.[1] The improvement in the quality of learning process should be followed by the effective, comfortable, safe, healthy, and efficient learning atmosphere. The learning model applied by the lecturers is one of the factors which can contribute to the learning achievement.[1-3] There are many innovative learning models, one of which is Community Technological Science learning.[4,5] The results of the studies previously conducted showed that the learning process taking place at the Department of Biology, IKIP Saraswati Tabanan had neglected ergonomic aspects such as the facts that the learning facilities had not been adjusted to the students' anthropometry and that the learning environment in the class room had not been optimally prepared. These had been responsible for musculoskeletal complaint, exhaustion and boredom.

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It was necessary to apply ergonomic principles,[7] one of which is approach, hereinafter referred Ergonomics-Based Community Technological Science. It was necessary to adjust the students' ability and limitations to the environment where the learning process took place, the assignments which were supposed to be done by the students and how the learning environment was organized to minimize the musculoskeletal complaint, exhaustion and boredom as well as to make the learning process more human. Based on what was described above, it is necessary to improve the learning process by paying attention to the scales of priority such as a) the lighting intensity which was made to be between 350-700 lux for reading and writing;[8] b) the work terminal which was improved by adjusting the lecturing chairs to the students' anthropometry;[9-11] c) the position of the white board which was improved and the height of the LCD screen which was adjusted to the eyes of the students who were sitting behind in such a way that the head movement still remained within the range of $5^{o}$ above and $30^{o}$ under the horizontal era;[8] d) the addition and location of work board which were adjusted to the eyes of the students who were standing;[12] e) the learning media, especially the power point, which was fixed so that it was in accordance with the ergonomic principles;[13-16] and f) the learning process using ergonomic approach, which gave emphasis on more dynamic movement of muscles was applied, and in which active break was provided.[12] In this way, it was expected that the process input and the learning achievements of the students at the Department of Biology, IKIP Saraswati Tabanan could be improved.

**METHODS**

This study is an experimental one, using randomized pre- and post-test control group design.[17] The subjects were randomly divided into two groups; the first group was referred to as control group which was provided with biotechnological learning using Community Technological Science, and the second group was referred to as experimental group which was provided with Ergonomics-Based Community Technological Science. The former involved 16 samples and the latter involved six samples as well.

The Nordic Body Map questionnaire was used to obtain the data related to the musculoskeletal complaint, 30 Items of Rating Scales were used to obtain the data related to exhaustion, questionnaire was used to obtain the data related to the students' boredom, assessment format was used to obtain the data related to the students' learning activity, and the learning achievement assessment was used to obtain the data related to the students' learning results.

The normality of the data obtained was tested using Shapiro-Wilk test. The data which fulfilled the normality test were analyzed using parametric analysis with t group test, and the data which did not fulfill the normality test were analyzed using non parametric analysis with Mann-Whitney test with a 5% degree of significance ($p$ = 0.05).

**RESULT AND DISCUSSION**

**Condition of the Subjects**

The height of the students of the Department of Biology of IKIP Saraswati Tabanan, who were involved as the subjects of the study and belonged to the control group, averaged 159.16±5.365 cm; and the height of the students, who belonged to the experimental group, averaged 158.63±6.371 cm. The weight of the students, who belonged to the control group, averaged 53.13±2.498 kg., and the weight of the students, who belonged to the experimental group, averaged 53.16±2.498 kg. From the result of the comparability test, it was found that the heights and weights of the students who belonged to the control group and the heights and weights of the students who belonged to the experimental group were comparable (p>0.05), meaning that their heights and weights did not significantly differ and that the variables of height and weight did not affect the results of the study. Such an almost similar condition was also reported by another researcher that the weights of the students of AKPER PPNI who belonged to the control group averaged 49.17±4.67 kg, and that the weights of the students who belonged to the treatment group averaged 50.50±5.43 kg. Furthermore, he reported that the heights of the students of AKPER PPNI who belonged to the control group averaged 156.08±3.61, and that the heights of the students who belonged to the treatment group averaged 158.16±4.68 cm.[18] Similarly, Ariati (2008) also reported that the weights of the students of the Nutrition Department of the Polytechnics of Health Denpasar ranged from 46-58 kg and averaged 51.92±4.14 kg. Moreover, she reported that their heights ranged from 157 to 166 cm and averaged 160.88±3.27 cm.[19]

The subjects involved in this present study were 32 and their body mass index ranged from 19 to 23 kg/m$^2$ and averaged 21.08±1.041 kg/m$^2$ (appendix 13). The average IMT showed that the subjects' nutritional status was normal, meaning that their physical condition was healthy, that they had no problem with nutrition, and that they could do their learning activity optimally. Both successive and insufficient weight affected the students' achievement, making them become tired and have musculoskeletal complaint. This was in accordance with what was stated by Adiatmika (2007) that physical mass index showed the balance between nutritional intake and its use. If someone's physical mass index were abnormal he/she would suffer from various kinds of diseases more easily.[20]

The ages of the students of the Department of Biology of IKIP Saraswati Tabanan who belonged to the control group averaged 21.13±0.806 years, and the ages of the students who belonged to the experimental group averaged 20.69±0.704 years. The fact that the subjects' ages ranged from 20 to 25 was in accordance with the inclusive criteria already determined. Such an average of ages was within the range of productive ages, when the subjects could do their physical activities optimally. From the result of the comparability test, it was found that the ages of the students who belonged to the control group and the ages of those who belonged to the experimental group were comparable (p>0.05), meaning that the variable of ages between the control group and experimental group did not significantly differ, and that the variable of ages did not affect the results of the study. Such a similar condition was reported by several other researchers. Tirtayasa (2003) reported that the ages of the students of AKPER PPNI Denpasar in 2003 were between 19 and 20 years. Similarly, Adiatmika (2003) reported that the students of SPK Kesdam were between 21 and 25 years, meaning that their ages averaged 23±1.36 years.[18,20] Antari, another researcher, reported that the ages of the students of Department of Guidance and Counseling of IKIP Negeri Singaraja ranged from 19 and 22 years, meaning that their ages averaged 20.69±0.79 years.[19] Dewantari reported an almost similar thing that the ages of the students of the Department of Nutrition of the Polytechnics of Health Denpasar in 2006/2007 academic year who belonged to group I, averaged 19.27±0.65 years, and that the ages of the students who belonged to group 2 averaged 19.27±0.47, and that the ages of the students who belonged to group 3 averaged 19.18±0.60. Based on what was described above, it could be stated that the average age of the students used as the subjects of the studies implied that they were about to end their adolescence and to start their early adulthood, meaning that they had maximum mental and physical capacity. This was in accordance with what was stated by *Badan Litbang Kemhan RI* (2011) that excellent physical capacity was needed to do activities. Physical capacity was directly comparable to particular limits of ages and the age of 25 was the climax. Getting older meant getting less capable of doing activities. This implies that, from the age point of view, the subjects of the present study were physically capable of being optimally involved in the learning process.[26]

**Environmental Condition in the Lecturing Room**

Comfortable environment could affect work productivity. The comfort was determined by the wet temperature, dry temperature, relative humidity, noise, weather movement, and the lighting intensity.

The wet temperature in the present study was found to average 24.00±0.93$^{o}$ C for the control group, and for the experimental group it was found to average 24.33±1.41$^{o}$C. From the result of the comparability test, it was found that the wet temperature for the control group and experimental group was comparable (p>0.05), meaning that the wet temperature between the control group and experimental group did not differ significantly. As a result, the wet temperature did not affect the results of the study. Similarly, Dewantari (2007) reported that the average wet temperature on the campus of the Department of Nutrition of the Polytechnics of Health Denpasar ranged between 24.2 and 25.0$^{o}$C, meaning that the environment was comfortable to do activities.[26]

The dry temperature also contributed to the microclimate of the lecturing room. It turned out that it exceeded the limit of comfort. In the control group it was 28.22±1.00$^{o}$C and in the experimental group it was 28.11±1.05$^{o}$C. However, the result of the comparability test showed that the dry temperatures in the control group and experimental group were comparable (p>0.05), meaning that the dry temperature did not affect the results of the study. Similarly, Wijana (2008) also reported that the dry temperature in the classroom of Elementary School 1 Sangsit for the control group averaged 29.50$^{o}$C and in the class room for experimental group it averaged 29.40$^{o}$C. The subjects felt that the dry temperatures in the class room for the control group and in the class room for the experimental group were comfortable.[37]

The relative humidity in the lecturing room for the control group was 76.67±2.00% and in the lecturing room for the experimental group it was 77.11±2.02%. The result of the comparability test showed that the relative humidity in the control group was comparable to that in the experimental group (p>0.05), meaning that the relative humidity in the control group did not significantly differ from that in the experimental group, and that the relative humidity did not affect the results of the study. Likewise, Ariati (2008) reported that the relative humidity in the class room for the control group averaged 79.33.5±2.08% and that the relative humidity in the class room for the intervened group averaged 79.67±2.52%, implying that such a relative humidity was in accordance with what was recommended by Manuaba (20004b), that is, between 70 and 80% for learning activities. Similarly, the relative humidity measured by Antari (2004) was 73.00±2.46% for the control group, and for the treatment group it was 73.03±2.77%, implying that such a relative humidity was in accordance with what was recommended by Manuaba (2004b) for learning activities.[6,7,19,23]

Noise would disturb the listening and communication processes when the learning process was taking place. In this present study, it was found that the noise in the lecturing room for the control group was 61.83±0.54dBA and it was 62.06±0.51 dBA in the class room for the experimental group. From the result of the comparability test, it was found that the noise in the control group was comparable to that in the experimental group (p>0.05), meaning that the noise in the control group did not significantly differ from that in the experimental group, and that the noise did not affect the results of the study. The score of noise recommended for education was 45 dBA. However, the extent of noise in the present study did not result from the voice coming from outside the lecturing room, but from the voice made by the lecturer and the students when they were having discussions, meaning that the noise was still within normal limits. Likewise, Wijana (2008) reported that the noise in the control group averaged 68.63 dBA and in the experimental group it averaged 63.13 dBA, implying that the condition was still within quiet limits.[37]

The weather movement or the wind speed in a room could affect the temperature someone felt. In this present study, the weather movement in the lecturing room for the control group was 0.16±0.02 m/second, and in the lecturing room for the experimental group it was 0.15±0.02 m/second. The result of the comparability test showed that the weather movement in the lecturing room for the control group was comparable to that in the lecturing room for the experimental group (p>0.05), meaning that the weather movement did not affect the results of the study. Likewise, Sutajaya (2006) reported that the weather movement in the lecturing room for the control group was 0.17 m/second and that in the lecturing room for the experimental group it was 0.18 m/second, implying that the weather movement was still within the comfortable condition for teaching and learning process. This also meant that the weather movement in the present study was still within the normal limits, as, as recommended by Manuaba (2004b) the weather movement should not exceed 0.2m/second.

Good lighting was highly important; otherwise, nothing could be well done and comfortable situation would not be created. In addition, good lighting could also make the object clearly and quickly visible, meaning that the eye muscles would not get tired. In the present study, the lighting intensity in the control group was found to average 179.53±12.75 lux and in the experimental group it was found to average 440.78±57.25 lux. However, it was recommended that the learning intensity should be between 350 and 700 lux for reading and writing, meaning that the lighting intensity in the control group was not comfortable for reading and writing as it could cause the eyes to be tired and could be responsible for boredom. However, the intensity of the experimental group was already in accordance with what was recommended for reading and writing, meaning that it was under the category of being comfortable. The result of the comparability test showed that the lighting intensity in the lecturing room for the control group significantly differed from that in the lecturing room for the experimental group (p<0.05). The reason was that the lighting intensity in the lecturing room for the experimental group had been intervened. A similar thing was reported by Sutajaya (2006) that the lighting intensity in the class room for the control group averaged 345.78 lux and in the class room for the experimental group it averaged 376.22 lux, meaning that it was under the category of being comfortable for reading and writing. This was in accordance with what was stated by Kroemer and Granjean (2000) which implied that it would be better if the lighting intensity in the class room was between 350 and 700 lux for reading and writing.

It was necessary to design the microclimate in the lecturing room by paying attention to the ergonomic principles in order to achieve as high learning achievement as possible, meaning that the energy was entirely used for learning activities; none was wasted to cope with the room condition which was not comfortable. The less optimal microclimate condition, as illustrated by the less maximum lighting, could make the eyes tired and could also lead to boredom and cause concentration to decrease. The too hot lecturing room could make the body sweaty; as a result, the body would have less moisture, the electrolyte would be imbalanced, and the body would get tired quickly. In addition, the students' performance would decrease, and their thoroughness in completing the learning assignments would get affected. However, the too cold lecturing room could cause restlessness and unpreparedness, and could disturb concentration especially when completing mental assignment. This was in accordance with what was stated by Tarwaka et al. (2004) that in the event that the microclimate in the class room were not paid attention to, then it would be hot and lead to physiological responses such as exhaustion, an increase in heart beat and blood pressure, a decrease in the digesting organ, a rise in the nucleus body temperature, a rise in the blood circulation to the skin, and an incerease in the sweat production. The knowledge of the microclimate in the lecturing room could be used as a reference for designing the lecturing room as the students needed comfortable environment; otherwise, they would not be able to make any progress and would show unexpected physiological responses.

**Musculoskeletal Complaint in the Learning Process**

The musculoskeletal complaint for the control group after the learning process averaged 51.19±1.25, and that for the experimental group averaged 42.29±0.46. The result of the differing test showed that they were significantly different (p<0.05).

The data showed that there was a 43.68% difference in regard to the musculoskeletal complaint between the control group and the experimental one, meaning that the musculoskeletal complaint decreased by 43.68% for the experimental group. The reason was that the learning facilities and learning technique had been improved. The subjects could well adapt to the new lecturing room; the lighting intensity in the lecturing room had been made maximum, the lecturing chairs had been adjusted to the students' anthropometric; the positions of the white board and LCD screen had been adjusted to the students' eyes in sitting position; the work boards, whose positions had been adjusted to the height of the students' eyes in standing position, had been added; the learning media, especially the power point, had followed the ergonomic principles; the learning process using ergonomic approach, which could make the muscles more dynamic, had been applied; and active breaks had been given. Such improvements enabled the students to study comfortably, safely and healthily. In addition, they also became more motivated to make progress. The natural position caused the muscles to contract optimally. The active breaks provided during the learning process enabled the muscles to contract and relax, and to quicken recovery. The physiological movements of the body needed little energy; as a result, exhaustion and musculoskeletal complaint could be minimized. Similarly, Adiputra (2008b) stated that the working attitude which contrasted with the natural attitude of the body would be responsible for exhaustion and muscle complaint. Such an unnatural attitude of the body might lead to so many non physiological muscle movements that there would be a waste of energy and musculoskeletal complaint. In the learning process using ergonomic approach, the static muscles became the dynamic ones, which, supported by the active breaks provided, would enable the blood to circulate optimally. In addition, the oxygen, nutrition, and energy intakes would be optimal; as a result, exhaustion and musculoskeletal complaint would take place more slowly. This was almost the same as what was stated by Guyton and Hall (2000) that isometric contraction accelerated exhaustion and the accumulation of lactate acid, which, in the end, was responsible for a sharp pain felt as musculoskeletal complaint. The same thing was reported by Wijana (2008) that there was a 99.88% decrease in regard to musculoskeletal complaint as a result of the fact that the table and chairs were used in accordance with the subject's anthropometry. The results of the other studies which could be used as references to strengthen the present study were as follows. Purnomo (2007) in his study concluded that work system using totally ergonomic approach could decrease the musculoskeletal complaint by 87.8%. Adiatmika (2007) reported that the improved work condition using totally ergonomic approach could decrease the musculoskeletal complaint in the waist by 23.41%. Principally, the decrease in the musculoskeletal complaint reported by Purnomo (2007) and Adiatmika (2007) resulted from the fact that the non physiological work system was improved. Apart from that, the work method and work equipment were also improved.

**Exhaustion in the Learning Process**

After the learning process, the exhaustion averaged 80.46±0.80 for the control group, and for the experimental group it averaged 68.96±2.07. The result of the differing test showed that the exhaustion for the control group significantly differed from that for the experimental group ($p<0.05$).

The data showed that there was a 34.90% difference in regard to the exhaustion between the control group and the experimental group, meaning that there was a 34.90% decrease in regard to the exhaustion for the experimental group. The factors contributed to such a fall in exhaustion were as follows. The microclimate in the lecturing room had been maximized; the lighting had been made between 350 and 700 lux for reading and writing. The learning facilities and infrastructure had been adjusted to the students' anthropometry, making their attitude physiological. The ergonomics-based learning emphasized that the muscles should be made more dynamic and that active breaks should be provided. The two factors could overcome exhaustion during the learning process. By the same token, Purnomo (2007) reported that there was a 29.25% fall in exhaustion resulting from a change in work system; the non physiological work system was improved, the time for break was arranged, and additional menu was provided to the workers of *gerabah* (earthenware vessels) industry at Kasongan, Bantul. Likewise, Adiatmika (2007) reported in his research that the change in working attitude, consumption of alternative drinks, distribution of information, the use of masker, and table propping could decrease the exhaustion of the metal painters at Kediri, Tabanan.

The lecturing chairs which were adjusted to the students' anthropometry, the learning infrastructure and facilities which were located based the ergonomic principles could cope with the non physiological working attitude. The learning process taking place in the experimental group gave opportunity to the students to move dynamically, causing the muscles, which used to be static, to be dynamic. The physiological working attitude and the dynamic muscles could minimize exhaustion. The boring learning situation in the control group could be changed into the comfortable learning situation in the experimental group. Such a change could also minimize exhaustion. It turned out that the active break provided to the experimental group could also cause exhaustion to go down. The reason was that active break could decrease the pile of lactate acid; therefore, musculoskeletal exhaustion could be recovered. In addition, the environmental condition should be maximized so that exhaustion could be avoided earlier. The early exhaustion reflected the learning load, identifying that the learning process needed much alternative energy. It needed a lot of energy to cope with the non optimal environmental condition. This was in accordance with what was stated by Ndha (2010) that the unhealthy learning environment and working attitude would additionally burden the students' bodies as exemplified by the fact that the non ergonomic learning media (not in accordance with the body size) would cause the students to become exhausted quickly; that the insufficient lighting in the class room could cause the eyes to get exhausted; and that noise could disturb concentration and memory. In addition, they were also responsible for any psychological exhaustion. The disharmonious working climate or relationship could lead to boredom and no interest in studying; as a result, achievement went down.

**Boredom in the Learning Process**

The boredom in the control group averaged 70.37±8.41 and in the experimental group it averaged 54.44±6.21. The test showed that the boredom of the control group significantly differed from that of the experimental group ($p<0.05$).

The data showed that there was a 22.64% difference in regard to the boredom between the control group and experimental group, meaning that there was a 22.64% fall in regard to the boredom in the experimental group. The reason was that the students in the control group were less motivated in learning. Being less motivated in learning resulted from the non optimal environmental condition and the non ergonomic learning infrastructure and facilities. In addition, the lecturer was less capable of managing the class effectively, making the students' activities static and monotonous. Such factors led to boredom, as, in general, they reflected unpleasant feeling, restlessness and exhaustion which exploited a lot of energy. Similarly, Sutajaya (2006) stated that learning through SHIP approach decreased the boredom of the students of the Department of Biology of IKIP Singaraja by 19%. The reasons were that the working condition in the control group was not physiological and active break was not provided. Wijana (2008) also reported that ergonomic approach could decrease the boredom of the elementary school pupils. In the control group the learning process took place without using ergonomic approach; however, in the experimental group ergonomic approach was used. The boredom went down by 18.73 (26.40%). The reasons were that the working condition in the control group was static, monotonous and no active break was provided. This finding was strengthened by Kroemer and Grandjean (2000), stating that boredom could be coped with by making the assignments vary, giving short or active break, changing the static working condition into the dynamic one, and modifying the working environmental condition.

It was true that biotechnological learning using STMBE could cope with boredom as the working environmental condition was modified; the learning infrastructure and facilities were improved, and the lighting intensity in the lecturing room was maximized. The learning process in the experimental group gave opportunities to the students to move more dynamically; as a result, the contraction of muscles, which used to be static, became more dynamic; and in addition, active break was also provided. The learning situation in the control group could be changed into a pleasant one in the experimental group by making the assignments vary. For example, the students were supposed to have a discussion group, each group was supposed to move to the working board, appreciation was given to those who were successful.

**The Students' Learning Activity**

The students' learning activity in the control group averaged 2.41 and in the experimental group it averaged 3.44. The data showed that there was a 42.72% difference between the control group and experimental group, meaning that the students' learning activity in the experimental group rose by 42.72%. This also meant that there was a 42.72% increase in regard to the learning activity for the experimental group. The reasons were that there were interactions among the students during the teaching and learning process, they got motivated and patient during the teaching and learning process, they participated in the teaching and learning process, they were brave enough to give their opinions, the learning time was effectively used. The reason was that STMBE learning could make the students study comfortably, safely, healthily, effectively and efficiently. In addition, the students were the center of the learning process. They could learn cooperatively; as a result, their learning activity was getting improved. This was in accordance with what was stated by Sanjaya (2009); Arends (2007); and Trianto (2007) that the student-centered learning and cooperative learning could increase the students' learning activity.

**The Students' Learning Result**

The biotechnological learning using STMBE approach could improve the students' learning result. This could be proved from the result of the study that the students' learning result in the control group averaged 70.63±12.29 and in the experimental group it averaged 86.15±10.77. The test showed that the students' learning result for the control group was significantly different from that for the experimental group ($p<0.05$). The data showed that the students' learning result for the control group was different from that for the experimental group by 43.56%. Therefore, it could be stated that the comfortable lecturing room condition could improve the learning process output as could be seen from the facts that the musculoskeletal complaint decreased, exhaustion went down, boredom fell, and the learning activity improved. Similarly, Wijana (2008) reported that ergonomic approach could improve the learning achievement of the elementary school pupils in science. The control group did not use ergonomic approach in the learning process but the experimental group did. The pupils' learning achievement in science increased by 12.72 (33.70%). The reason was that the working condition improved using ergonomic approach; there was cooperation among the students and they worked and solved their problems more actively and effectively. The other finding was reported by Ariati (2008) who stated that the students' learning achievement in the intervened group increased by 2.52% compared to that in the control group. The reason was that nutrition was given to the intervened group.[19]

The ergonomic condition of the classroom of the experimental group was safe, comfortable, healthy and effective for doing learning activity. Such a condition was certainly followed by an increase in the students' learning result. This was in line with what was stated by Kroemer and Grandjean (2000) that principally the classroom which was comfortable, safe, and healthy could increase the students' learning achievement. The materials of biology in general and the material of biotechnology in particular would be highly accurate if the learning process were applied using STM, as the materials of biology were closely related to the daily life and technology available in the community.[8]

**CONCLUSION**

That the biotechnological learning using STMBE approach could improve process input could be seen from the facts that the students' musculoskeletal complaint, exhaustion and boredom went down, and that the process input and learning activity of the students went up. Apart from that, it could also increase the students' learning achievement.

**SUGGESTION**

It is suggested to the lecturers and teachers who directly interact with the students in any educational institution that they should understand, be familiar with and be able to apply the ergonomic principles to the educational world in general and to the learning process in particular.

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