International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 21, Issue 5 (May 2025), PP 61-66

Ergonomic Concern in Determination of Optimum Teaching Approach in a Primary School System

Ogochukwu C. Nwosu[1*], Victor M. Mbachu[1], Moses C. Uzochukwukamma[1], Nkemakonam C. Igbokwe[1], Ugochi C. Mbachu[2], Ifeoma L. Nwosu[3]
[1]*Department of Industrial and Production Engineering, Nnamdi Azikiwe University Awka Nigeria*
[2]*Department of Educational Management and Policy, Nnamdi Azikiwe University Awka Nigeria*
[3]*Department of Information and Communication Technology, Shanahan University Onitsha Nigeria*
**Corresponding Author: Ogochukwu Chinazaekpere Nwosu*

Abstract
Application of ergonomics in work systems and measurement of physiological cost of work helps to improve productivity in a work system. In the ever-evolving education system, determining the optimum teaching approach- whether generalist/class teaching or specialist/subject teaching using ergonomics and measurement of physiological cost of work is crucial in enhancing productivity of teachers, and fostering students learning and engagement. This paper analyzes the physiological cost of work,relative aerobic strain and energy expenditure among teachers involved in the two teaching strategies.The physiological cost of work of generalist teachers ranged from 17.5 to 23.5bpm while that of specialist teachers exhibited lower values with values ranging from 5.4 to 7. 4bpm.Moreso, the generalist teachers expended a higher amount of energy (5.5 to 6.7 kcal/min) compared to their specialist teaching counterparts. The research supports a transition to the subject teaching approach as a potential strategy in reducing teacher fatigue and improving teacher well-being.
Keywords: *Ergonomics, Energy Expenditure, Relative Aerobic Strain, Physiological cost of work, Heart rate, Oxygen Consumption, Teaching approach, Multivariate Analysis.*

Date of Submission: 01-05-2025 Date of acceptance: 09-05-2025

I. Introduction

Many of the tasks carried out by workers today require physical efforts that consume a lot of energy. In the school system, teachers, whether class teachers (generalists) or subject teachers (specialists) also expend energy while executing their teaching tasks. If this expending of energy by workers is not properly managed, it can lead to fatigue which affects the overall productivity of both the workers and the work system. The importance and significance of the wellbeing of the worker in man-machine system has led to the development of human factor engineering, which includes ergonomics.

Ergonomics is the science of making jobs or product fit the worker's or the user's anthropometric and physiological specifications. The international Ergonomics Association cited in Karwowski and Zhang (2021) defined ergonomics as the scientific discipline concerned with interactions among humans and other elements of the system and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and performance. Guerrettaz (2021) also mentioned that ergonomics is an interdisciplinary field that seeks to understand purposeful human activity, including fields such as industry and office workplaces, medicine, energy systems, among others. The goal of ergonomics according to Naguib, El-Bayaa, El-Henawy and El-Bassuony (2023) is to optimize human wellbeing and overall system performance.

In an educational system, ergonomics can contribute to the effective and efficient delivery of education through preserving teachers' and students' health, creating a comfortable working environment, and making adjustments to procedure and processes based on teachers' and students' abilities. The teacher and teaching approach are instrumental in the achievement of positive learning outcomes in the learners. Also, the environment for teaching and learning must be created with recourse to the needs, limits, and capabilities of the users. In order to comply with educational ergonomics, school administrators must create a conducive learning environment and take into account the health and comfort of both teachers and learners(Uche and Fanny 2015). This has resulted to a debate between generalist teaching and specialist teaching approaches which continues to shape educational policies and practices worldwide (Ejesi, 2018; Lui, 2011; Mills and Bourke, 2020; Russo, Corovic, Hubbard, Bobis, Downton, Livy and Sullivan, 2022). Both approaches offer unique advantages and challenges, and their effectiveness depends on various contextual factors such as level of education, subject complexity, teacher training and school resources. Both approaches also involve the teacher's physical exhaustion of energy.

The generalist teaching approach encompasses a broad curriculum, allowing teachers to cover various subjects within a single classroom setting. This approach provides a holistic learning experience, catering to diverse student needs and learning styles. However, challenges may arise in maintaining focus and depth across multiple subjects, potentially leading to cognitive overload for both teachers and learners. Conversely, Yearwood (2011) explained that the specialist teaching approach involves focusing on a specific subject or area of expertise, allowing teachers to delve deeper into the intricacies of the topic. Interestingly, this approach can facilitate mastery learning, as teachers can dedicate more time and resources to a particular subject, promoting deeper understanding and retention. However, the risk of overspecialization and limited exposure to interdisciplinary concepts may hinder students' ability to make connections across various domains.

Teaching as a profession has received several changes and transitions with respect to policies and methodologies and such changes are usually challenging to the teacher. This can be seen during the pandemic period where school system switched from traditional classroom to distance learning and the transition led to the deterioration of teacher work-life balance, time management and other challenges associated with the use of computers (Yıldızoğlu and Cemaloğlu, 2023). Ergonomics plays a vital role in assessing the optimality of teaching approaches by considering factors such as cognitive load, physiological cost of work, exhaustion of energy by teachers, student engagement and relating them to learning outcomes.

II. Methodology

A total of eleven teachers was used for this study. Six were involved in generalist/class teaching, five were involved in specialist/subject teaching. The age of the participants ranged from twenty-eight to fifty years. A pulse oximeter was used to measure their heartbeat rates and oxygen intake at rest, before work, during work and immediately after work.All the participants were physically fit with no history of chronic pain or physical anomalies.

Calculation of Physiological Cost of Work

The energy expenditure(EE) per minute gotten from the heartbeat is gotten by the formula:

Energy Expenditure (Kcal/min) = 0.159 × Average heartbeat rate(bmin^{-1})-8.72

The relative aerobic strain (RAS) is given by:

$$\text{RAS} = \frac{\text{HBRwork} - \text{HBRrest}}{\text{HBR}_{\text{Max}} - \text{HBR}_{\text{Rest}}}$$

Where:

HBR_{work}= Heartbeat rate while working or immediately after work

HBR_{rest}= Heartbeat rate before work or resting position

HBR_{max}= Maximum expected heartbeat rate which is a function of age

HBR_{max}= 220- age of participant

The physiological cost of work (PCW) was gotten from the average of heartbeat during work and immediately after work subtracted by heartbeat rate at rest.

III. Results

The average PCW, RAS and energy expended for both teaching strategies are presented below

Table 1:Average Physiological Cost of Work(PCW) for both teaching strategies

DAYS	PCW for Mrs. A (Class Teaching)	PCW for Mrs. B(ClassTeaching)	PCW for Mrs. C(ClassTeaching)	PCW for Mrs. D (ClassTeaching)	PCW for Miss E (ClassTeaching)	PCW for Mrs. F (ClassTeaching)	PCW for Mrs. G (Subject Teaching)	PCW for Mrs. H (Subject Teaching)	PCW for Mr. I (Subject Teaching)	PCW for Mrs. J (Subject Teaching)	PCW for Mrs. K (Subject Teaching)
Monday	19.85714286	12.75	15.8571426	18.7	19.5	14.25	7.333333	4.625	4.166667	8.25	8.75
Tuesday	19.85714286	9.6666667	3.875	15.9166667	13.9	15.1666	5.83333	7.875	6	6.875	8.75
Wednesday	19.25	9.3	3.83333	20.6	15.625	13.4	5.75	5.666667	6	8.7	4.9
Thursday	22.642	7.833333	7.916666	17.25	17.416667	11.5	3.5	4.9166667	6.5	5.625	7.6667
Friday	19.8333	10.58333	8.33333333	13.28571429	17.7	14.25	4.6666667	5.375	6.16667	5.66667	7.125

Table 2: Average Relative Aerobic Strain(RAS) for both teaching strategies

DAYS	RAS For Mrs. A (Class teaching)	RAS For Mrs. B (Class teaching)	RAS For Mrs. C Class teaching)	RAS For Mrs. D Class teaching)	RAS For Miss E Class teaching)	RAS For Mrs. F Class teaching)	RAS For Mrs. G (Subject Teaching)	RAS For Mrs. H (Subject Teaching)	RAS For Mr. I (Subject Teaching)	RAS For Mrs. J (Subject Teaching)	RAS For Mrs. K (Subject Teaching)
Monday	20.3883495	13.8047	6.1011	8.541667	4.94791667	9.895833	4.5138889	4.6875	3.125	4.166667	2.8645833
Tuesday	20.7920792	10.76	4.296875	7.29166	5	10.416667	5.208333	4.1666667	4.16667	2.864533	0.78125
Wednesday	20.707	11.041	6.9444	8.958333	3.645883	9.166667	3.6458333	4.513888	5.555556	1.875	2.7083333
Thursday	23.055	9.1288	7.63889	7.638889	4.6875	9.375	4.5138889	5.208333	3.125	1.0416667	3.8914444
Friday	20.8333	12.152778	10.069	6.99404762	3.958333	8.85416667	4.4270833	2.8645833	3.47222	3.472222	1.0416667

Table 3: Average Energy Expenditure (EE) for both teaching strategies

DAYS	EE For Mrs. A (Class teaching)	EE For Mrs. B Class teaching)	EE For Mrs. C(Class teaching)	EE For Mrs. D(Class teaching)	EE For Miss E(Class teaching)	EE For Mrs. F(Class teaching)	EE For Mrs. G (Subject teaching)	EE For Mrs.H (Subject teaching)	EE For Mr. I (Subject teaching)	EE For Mrs. J (Subject teaching)	EE For Mrs. K (Subject teaching)
MONDAY	5.885285714	6.34525	5.449142857	5.8603	5.3515	6.10675	5.166	5.371375	5.1395	4.99375	4.91423
TUESDAY	6.203285174	6.332	5.252125	5.73575	5.2561	5.9345	5.4045	5.252125	5.272	4.954	4.59625
WEDNESDAY	6.42475	6.2737	5.5635	6.0034	5.053375	5.92125	5.07325	5.219	5.431	4.7473	4.9381
THURSDAY	6.646214286	6.1995	5.73575	5.78875	5.17925	5.9875	5.325	5.41755	4.99375	4.735375	5.06
FRIDAY	6.3585	6.4775	6.12	5.63542	5.0653	5.94775	5.272	5.013625	5.1395	5.06	4.655875

From the tables, it was observed that generalist teachers exhibit a higher PCW, RAS and EE against their specialist teaching counterparts. Increased physical strain due to multi subject delivery accounts for a higher PCW in generalist teachers. The RAS was below 30% for all participants showing that less than 30% of the maximum aerobic capacity was utilised for the work.

The values of PCW, RAS and EE were analysed further using principal component analysis (PCA) and multiple regression analysis to determine how factors like age, heartbeat rate and oxygen consumption relate with PCW, EE and RAS.

Table 4: Principal Component Analysis

Variable	PC1	PC2	PC3
Age	0.172	-0.517	-0.779
Heart Beat at Rest	-0.165	-0.701	0.328
Heart Beat during work	0.462	-0.131	0.183
Oxygen during work	-0.385	0.143	-0.418
PCW	0.402	0.421	-0.151
RAS	0.456	-0.010	-0.160
Energy Expended	0.460	-0.164	0.166

Table 4.1: Eigenanalysis of the Correlation Matrix

Eigenvalue	4.2825	1.6102	0.6847	0.3403	0.0791	0.0031	0.0003
Proportion	0.612	0.230	0.098	0.049	0.011	0.000	0.000
Cumulative	0.612	0.842	0.940	0.988	1.000	1.000	1.000

From the results of the principal component analysis shown in table 4 and 4.1, PC1 which is age captures the most variance at 61.2% and is strongly correlated to the physiological cost of work, relative aerobic strain and energy expended. This means that individuals with high PC1 have higher RAS, PCW and energy expenditure and higher heart beat rates during work with values at 0.456,0.402,0.460 and 0.462 respectively. Also, individuals with high PC1 values have lower oxygen intake during work. Therefore, it can be said that individuals with lower PC1 values have better oxygen efficiency. This is further indicated in the biplot graph below that shows that strongly correlated values points towards the same direction, whereas variables which are not strongly correlated, points to the same direction.

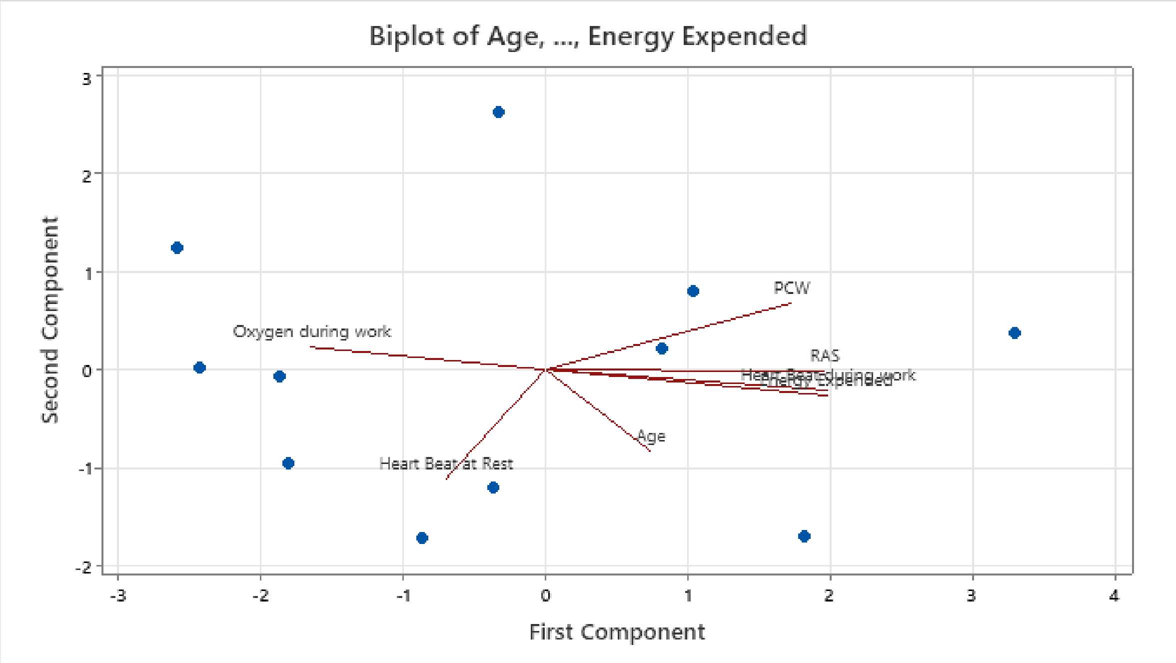

Fig 1: Biplot of age, heartbeat at rest, oxygen during work,PCW,RAS,energy expended and heartbeat during work

Table 4.2: Result of regression analysis for the dependent variable (Physiological cost of work) and the dependent variables

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-3.7	38.5	-0.10	0.926	
Age	0.0247	0.0201	1.22	0.260	1.25
Heart Beat at Rest	-0.9626	0.0293	-32.85	0.000	1.13
Heart Beat during work	1.0679	0.0610	17.52	0.000	2.61
Oxygen during work	-0.079	0.349	-0.23	0.826	2.41

Table 4.3: Model Summary for physiological cost of work

S	R-sq	R-sq(adj)	R-sq(pred)
0.405466	99.69%	99.52%	99.14%

Table 4.4: Result of regression analysis for the dependent variable (Relative Aerobic Strain) and the dependent variables

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-283	273	-1.04	0.334	
Age	0.198	0.143	1.39	0.208	1.25
Heart Beat at Rest	-0.420	0.207	-2.03	0.082	1.13
Heart Beat during work	1.848	0.431	4.28	0.004	2.61
Oxygen during work	1.51	2.47	0.61	0.560	2.41

Table 4.5: Model summary for relative aerobic strain

S	R-sq	R-sq(adj)	R-sq(pred)
2.86956	88.42%	81.80%	74.57%

Table 4.6: Result of regression analysis for the dependent variable (Energy Expenditure) and the dependent variables

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-7.59	3.02	-2.51	0.040	
Age	0.00294	0.00158	1.86	0.105	1.25
Heart Beat at Rest	0.00250	0.00230	1.09	0.312	1.13
Heart Beat during work	0.16576	0.00478	34.70	0.000	2.61
Oxygen during work	-0.0234	0.0274	-0.85	0.421	2.41

Table 4.7 Model summary for energy expended

S	R-sq	R-sq(adj)	R-sq(pred)
0.0317765	99.79%	99.67%	99.59%

The multiple linear regression analysis shows that heartbeat rate during work is a strong predictor for the dependent variables(PCW,RAS and energy expended). Also, the model summary shows a high coefficientvalues of 99.69%,88.42% and 99.79% for physiological cost of work, relative aerobic strain and energy expenditure respectively

IV. Conclusion

This research recommends that specialist or subject form of teaching should be incorporated in primary schools as can be seen from results gotten from the physiological cost of work, relative aerobic strain and energy expenditure. Also, from an ergonomic point of view the specialist form of teaching will help to reduce fatigue experienced by teachers and also fostering learner's success and academic achievements as well as the teacher's wellbeing.

References

[1]. Abubakar M, Ademuliyi YS, S. A. (2022). Ergonomic Assessment of Power Tiller Operators during the Testing of System of Rice Intensification Practices at Bakolori Irrigation Scheme , Zamfara State , Nigeria. Journal of Applied Scienceenvironmental Management, 26(12).

[2]. Ardzejewska, K., McMaugh, P. & Coutts, A. (2010). Delivering the primary curriculum: The use of subject specialist and generalist teachers in NSW Australian College of Physical Education, Sydney/Macquarie University. Issues in Educational Research, 20 (3),

203,
[3]. Banibrata Das, Tirthankar Ghosh, S. G. (2015). Assessment of Ergonomic and Occupational Health-Related Problems Among Female Prawn Assessment of Ergonomic and Occupational Health-Related Problems Among Female Prawn Seed Collectors of Sunderbans , West Bengal , India. 3548. https://doi.org/10.1080/10803548.2012.11076949
[4]. Baruah, M., Ali, N. F., & Bhattacharyya, N. (2021). Ergonomic intervention for digging in tea gardens. 10(6), 378–383.
[5]. Borah, R., & Kalita, M. (2016). Ergonomic evaluation of weaving activity and ergonomic intervention for drudgery reduction of weaver. 7(2), 239–244. https://doi.org/10.15740/HAS/ARJSS/7.2/239-244
[6]. Choudhary, M. K., Pareek, C. M., Meena, S. S., & Mehta, A. K. (2018). Ergonomics Assessment of Pedal Operated Maize Dehuskar-Sheller for Male Agricultural Workers. 14(6), 1–5. https://doi.org/10.9734/AIR/2018/40268
[7]. Ejesi, N. S. (2018). Relative effectiveness of the use of subject specialist and generalist teaching teaching approaches on academic achievement of pupils in primary schools in Anambra state, Nigeria. Journal of Guidance and Counselling Studies. 2(2), 116-134.
[8]. Garg, A., Hagglund, G., & Mericle, K. (2007). A Physiological Evaluation of Time Standards For Warehouse Operations as Set by Traditional Work Measurement Techniques. 37–41. https://doi.org/10.1080/07408178608974700
[9]. Gayatri, M., Deepa, V., & Nidhi, C. (2011). Research Article COST ASSESSMENT OF ERGONOMIC RISK : A PRACTICAL APPROACH REDESIGNING OF WORKSTATION FOR Address for Correspondence.
[10]. Guerrettaz, A. M. (2021). Materials-in-action: Pedagogical ergonomics of a French as a foreign language classroom. The Modern Language Journal, 105(S1), 39-64.
[11]. Jabeen, R., & Hussain, N. (2022). Teachers' awareness and practices on school ergonomics in Karachi, Pakistan. Journal of Humanities, Social and Management Sciences (JHSMS), 3(1), 366–381. https://doi.org/10.47264/idea.jhsms/3.1.26
[12]. Karwowski, W., & Zhang, W. (2021). The discipline of human factors and ergonomics. In G. Salvendy and W. Karwowski (eds.), Handbook of human factors and ergonomics, 3-37. John Wiley & Sons, Inc. https://doi.org/10.1002/9781119636113.ch1
[13]. Kulkarni, M., & Khakare, P. (2021). Assessment Physiological Cost of Selected Carpentry Tasks. 10(01), 2687–2694.
[14]. Liu, F. (2011). Pre-Service Teachers' Perceptions of Departmentalization of Elementary Schools. International Journal of Whole Schooling, 7(1), 40-52.
[15]. McGrath, M. (2008). Mathematics Specialist and Mathematics Coaches: What does the teacher say? Journal of Instructional Psychology, 29 (1), 40-45
[16]. Mbachu and Okonkwo. (2018). A physiological Assessment and Analysis of Stairs Climbing : Using the RAS and Efficiency of work done Corresponding Author ' s E -mail : profvictor2000@yahoo.com. Journal of Engineering and Applied Sciences, 12(March 2010), 76–86.
[17]. Mills, R., & Bourke, T. (2020). Primary specialisation in Australian education: Pre-service teachers' lived experiences. In J. Fox et al. (eds.) Teacher Education in Globalised Times: Local Responses in Action. Springer Nature. https://doi.org/10.1007/978-981-15-4124-7_2
[18]. Naguib, R. M., El-Bayaa, M. S., El-Henawy, W. M. & El-Bassuony, J. M. (2023). Using ergonomics based instruction in teaching English langage integrated skills. Port Said Journal of Educational Research (PSJER), 2(1), 105-131. DOI: 10.21608/PSJER_2023.181595.1013
[19]. Russo, J., Corovic, E., Hubbard, J., Bobis, J., Downton, A., Livy, S. L., & Sullivan, P. A. (2022). Generalist Primary School Teachers' Preferences for Becoming Subject Matter Specialists. Australian Journal of Teacher Education, 47(7). http://dx.doi.org/10.14221/ajte.2022v47n7.3
[20]. Singh, A., Gautam, U. S., Singh, R., & Paliwal, D. (2014). Ergonomic study of farm women during wheat harvesting by improved sickle. 9(18), 1386–1390. https://doi.org/10.5897/AJAR2013.7956
[21]. Uche C.M, O. F. C. (2015). Educational Ergonomics in Higher Education institutions in Nigeria. Makerere Journal of Higher Institution, 7(2).
[22]. Yearwood, C. (2011). Effects of departmentized versus traditional settings on fifth graders, maths & reading achievements. A doctoral thesis. School of Education, Liberty University, USA.
[23]. Yıldızoğlu, H., & Cemaloğlu, N. (2023). Examination of the Relationship Between Teachers ' Organizational Change Fatigue Levels and the Organizational Resilience Levels of Secondary Education Institutions Öğretmenlerin Örgütsel Değişim Yorgunluğu Düzeyleriyle Ortaöğretim Kurumlarının Örgütsel D. 31(2), 186–201. https://doi.org/10.24106/kefdergi.1271471
[24]. Zunjic, A. (2017). A NEW DEFINITION OF ERGONOMICS Aleksandar. IETI Transactions on Ergonomics and Safety, 1(1.), 1–6. 10.1093/nq/s6-II.51.486-d
[25]. Zunjic, A., Papic, G., Bojovic, B., Matija, L., Slavkovic, G., & Lukic, P. (2015). The role of ergonomics in the improvement of quality of education. FME Transactions, 43(1), 82–87. https://doi.org/10.5937/fmet1501082Z