

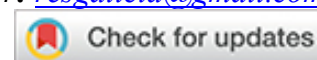
Ergonomic Redesign of Primary School Desk-Chairs in Panama: A Posture Health Approach Using the Theory of Constraints

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ABSTRACT

This study examines the relationship between school furniture design and long-term student postural health by evaluating the feasibility of redesigning the Panamanian primary school desk-chair to accommodate morphological and anthropometric variation among students in grades one through six. The proposed redesign aligns with the methodological requirements of constructivist learning, emphasizing the need for a physical environment that supports active, flexible pedagogical approaches.

An exploratory and descriptive research design was implemented in three General Basic Education Schools (GBES) in Panama. Schools were selected using a convenience sampling method, and approximately 10% of enrolled students (n = 198/1,970) were randomly sampled across grades one to six. Data collection methods included structured interviews with experts in medicine, ergonomics, architecture, education, and engineering, as well as student and classroom observations, questionnaires, and document review.

The methodological core of the study is the Theory of Constraints (TOC) Thinking Process, specifically the Process of Ongoing Improvement (POOGI). A Current Reality Tree (CRT) was constructed to identify Undesirable Effects (UDEs) across seven functional areas (posture and health, ergonomics and comfort, anthropometrics, procurement, flexibility, materials, and maintenance costs), and to define the core conflict driving poor furniture design. From this analysis, design criteria and specifications were derived for a new ergonomic desk-chair model.

The proposed design introduces height-adjustable, foldable armrests; adjustable seat depth and backrest height; an anatomically contoured seat with a waterfall edge; and a backrest aligned with a 37° thoracic kyphosis angle, all made from more sustainable materials (polyurethane, polypropylene, and cast iron). These features are intended to reduce soft-tissue and intervertebral disc pressure, improve blood circulation, and accommodate anthropometric variation while supporting constructivist classroom practices.

In conclusion, the TOC Thinking Process was effective in evaluating what to change, what to change to, and how to implement change in the context of school furniture. The resulting conceptual redesign provides a comprehensive approach to posture health and offers a replicable methodological framework for educational systems aiming to align school furniture with current ergonomic and pedagogical standards. Future research should focus on prototyping and empirically testing the redesigned desk-chair in actual classroom settings.

Keywords: ergonomics; school furniture; desk-chair; posture health; ischial tuberosities; Theory of Constraints; Panama.

INTRODUCTION

Jean Piaget's Theory of Constructivism, grounded in cognitive psychology, emphasizes the cultural and methodological processes through which learners build knowledge.¹ As educational methodologies evolve

toward more active and constructivist approaches, the physical learning environment—including desks and chairs—must adapt to support interaction, movement, and collaborative learning.

Prolonged sitting has been widely documented as hazardous to spinal health. Alibegović et al.² showed that extended seated posture reduces the lumbar and sacral angles of the spine by half, increasing intervertebral disc compression by at least 35% compared to standing. These findings align with several studies^{3–12} showing that long-term sitting can also alter hemodynamic responses, including impaired blood flow in the external iliac artery.¹³ Thus, improper sitting and inadequate furniture design expose children to relevant biomechanical and physiological risks.

One of the most influential and comprehensive studies on occupational sitting is the work of Akerblom¹⁴, who proposed foundational requirements for the design of proper desk chairs. These criteria, along with the international standard ISO 5970:1979¹⁵ (now withdrawn), which specifies functional dimensions for school furniture, remain highly relevant. Among the key requirements are: allowing posture changes; preventing seat pressure on the thighs and popliteal area; incorporating a backward seat angle of approximately 5°; providing lumbar backrest support at 115°–120°; matching table height to the student’s elbow height in the seated position; ensuring sufficient seat width; and providing adequate leg clearance and rounded edges.

Approximately 75% of the seated body weight is transmitted through the ischial tuberosities, generating pressures of 6–7 kg/cm² on the seat surface, as demonstrated by Sonenblum et al.¹⁶ and Rincón et al.¹⁷. These pressures contribute to discomfort and fatigue, prompting frequent posture changes and, when poorly managed, may affect circulation and tissue integrity.

In Panama, the school chairs used in General Basic Education Schools (GBES) are neither anthropometrically nor ergonomically designed. They lack height adjustability, do not provide adequate support for the seat or backrest, and are largely based on UNESCO guidelines from the 1970s. The current design promotes poor posture and poses medium- and long-term risks to spinal health, consistent with observations by Sarı and Şahin⁴ and others. Furthermore, the rigid, heavy structure and non-adjustable components are poorly suited to constructivist pedagogical strategies that require flexibility and reconfigurable classroom layouts. The existing desk-chair models used in Panamanian schools (Figure 1A and 1B) are therefore inadequate for contemporary educational and health needs.

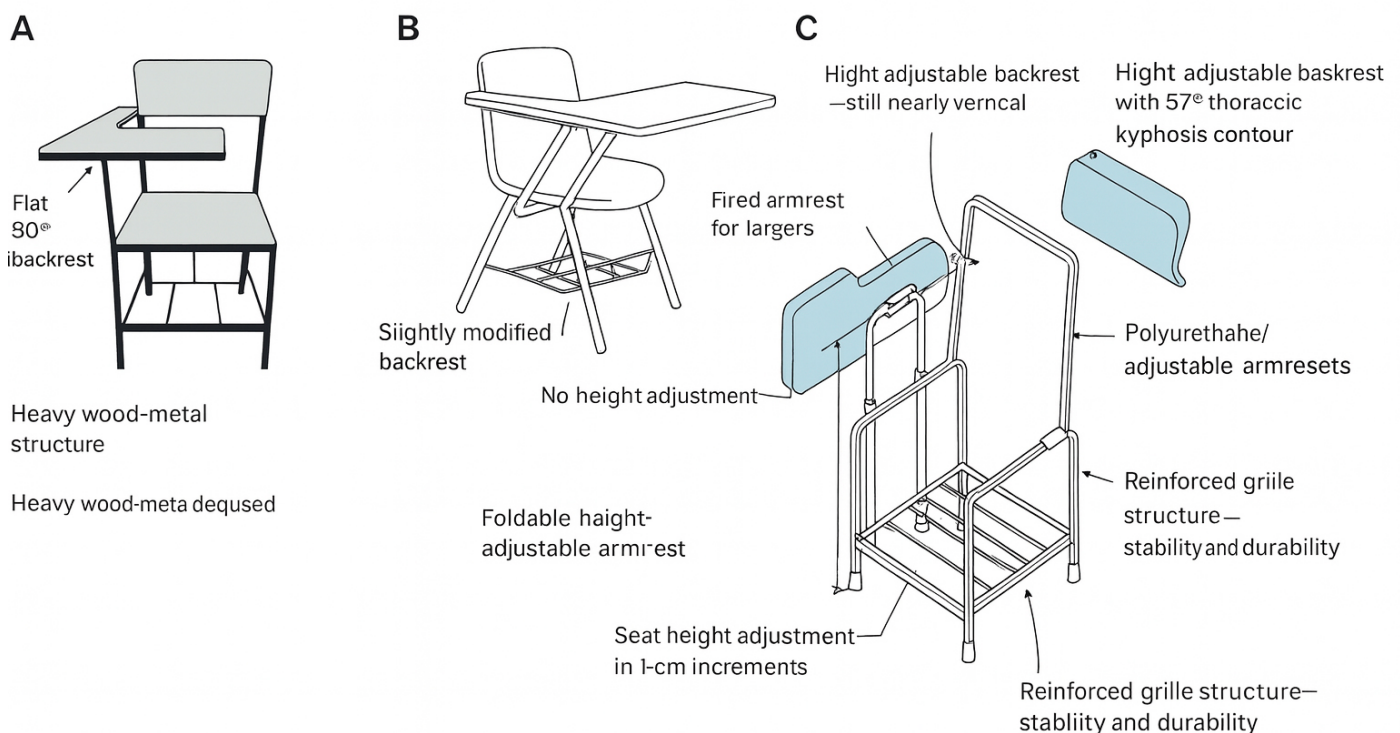


Figure 1. Desk–chair model for GBES according to the MEDUCA–UNESCO guidelines from the 1970s (A), MEDUCA’s desk–chair model from 1999 (B), and the proposed redesigned school desk–chair (C).

Given these circumstances, a critical need exists to redesign the standard Panamanian school desk-chair to address anthropometric variability, posture health, and the requirements of constructivist pedagogy simultaneously.

Objective

The primary objective of this study is to apply the cause-and-effect logic of the Theory of Constraints (TOC) Thinking Process to guide the ergonomic redesign of school desk chairs in Panamanian GBES, with a particular emphasis on enhancing postural health. The proposed redesign is based on criteria established by Akerblom, ISO 5970:1979, and recommendations from *Human Dimension & Interior Space*.

MATERIAL AND METHODS

Study design

This exploratory and descriptive research focuses on the use and performance of desk-chairs within the Panamanian General Basic Education system. The study compares existing chair designs with standard anthropometric specifications and ergonomic criteria for school furniture, integrating qualitative methods to establish design criteria and specifications that address students' morphological and anthropometric needs, particularly regarding seat and backrest contour and height adjustability.

The methodological approach is informed by *The Ultimate Student's Guide to Scientific Research*, integrating ergonomic criteria from industrial engineering with Goldratt's TOC philosophy. The process is guided by three fundamental questions: What to change? What to change to? How to create the change?

Setting and participants

The study was conducted in three General Basic Education Schools (GBES) in Panama: Escuela Omar Torrijos, Escuela República de Puerto Rico, and Escuela Ricardo Miró. School selection was based on convenience, with consideration of geographic location and the willingness of school principals to facilitate data collection.

A non-probabilistic sample of approximately 10% of total student enrollment (198/1,970 students) was randomly selected across grades 1–6 in each school: 62 of 612 students in Escuela Omar Torrijos, 24 of 235 students in Escuela República de Puerto Rico, and 112 of 1,123 students in Escuela Ricardo Miró. This sampling strategy yielded an estimated margin of error of 2.1%.

Data collection instruments and procedures

Data collection techniques included structured interviews, an observation guide, a questionnaire, and document review. Structured interviews were conducted with professionals in medicine (pediatrics, orthopedics, physiotherapy, and ergonomics), architecture, education, and engineering to capture expert perspectives on posture, ergonomics, and design requirements for school furniture.

Following standard qualitative research methodologies²⁰, conversations were conducted with students to understand their perceptions of comfort and discomfort, as well as their recommendations for design improvements. Classroom observations focused on how students sat, how they interacted with the furniture during typical activities, and how their bodies adapted to the fixed dimensions and angles of the existing desk-chairs.

The document review included analysis of MEDUCA–UNESCO guidelines for the GBES desk-chair models, internal technical documents related to procurement criteria, and international standards such as ISO 5970:1979.¹⁵

Theory of Constraints Thinking Process

According to *The World of the Theory of Constraints*²¹, the TOC Thinking Process (TOC-TP) served as the overarching methodological roadmap to address the central research question, following the three guiding questions above. This process is the basis of the Process of Ongoing Improvement (POOGI).

The analysis proceeded in several stages:

Identification of Undesirable Effects (UDEs)

A list of UDEs was compiled across seven functional areas:

1. Posture and health
2. Ergonomics and comfort
3. Anthropometrics
4. Procurement
5. Flexibility
6. Materials
7. Maintenance costs

These UDEs were identified from expert interviews, student feedback, classroom observations, and document review.

Generic Cloud and Evaporating Cloud

To define the core problem generating the system's UDEs, a Generic Cloud (GC) was developed. Subsequently, Evaporating Clouds (ECs) were constructed to represent the conflicts underlying specific groups of UDEs, particularly those related to posture and health (UDE 1), procurement (UDE 4), and materials (UDE 6).

The EC for the Ministry's desk-chair model captures the central conflict between maintaining outdated UNESCO-based criteria and integrating updated ergonomic and anthropometric standards.

Current Reality Tree (CRT) and Negative Reality Branch (NRB)

A Current Reality Tree (CRT) was built to validate the core conflict using cause-and-effect logic. The base of the CRT was developed using students' feedback on comfort and the Ministry of Education's capacity to establish evaluation policies for school desk-chairs. Undesirable Effects were then linked to this base to form causal chains.

A Negative Reality Branch (NRB) was also constructed to anticipate potential negative outcomes associated with maintaining the status quo or implementing partial or inadequate corrections.

The TOC-TP thus provided a logical and systematic framework to move from UDEs and conflicts to specific "Injections" (actions or ideas) that would transform UDEs into Desired Effects (DEs) and inform ergonomic design specifications.

It should be noted that no physical prototypes were constructed, and no pre- or post-ergonomic trials were conducted at this stage. This study is limited to a conceptual redesign based on TOC analysis and qualitative data.

RESULTS

Undesirable Effects by functional area

Across the seven functional areas, seven core UDEs were identified:

Functional area	UDE code	Description	Main sources*
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Posture and health	UDE 1	Current desk-chair design promotes poor posture and may lead to long-term postural deviations and spinal injuries; backrests do not accommodate the normal thoracic kyphosis range (30°–50°, mean 37°).	Students, medical and ergonomics experts
Ergonomics and comfort	UDE 2	Students experience discomfort due to high pressure on the ischial tuberosities; flat backrest and fixed armrest do not follow anatomical contours.	Students, teachers, and ergonomics experts
Anthropometrics	UDE 3	A single, non-adjustable chair size is used for all children aged 5–12, based on outdated UNESCO criteria that ignore current anthropometric variation.	Document review, experts
Procurement	UDE 4	Government procurement prioritizes low cost and quantity over ergonomic and health criteria, resulting in furniture that does not meet comfort or posture standards.	Policy and document review
Flexibility	UDE 5	Rigid structure and fixed armrests limit adaptability to new curricular activities and flexible classroom layouts required by constructivist pedagogy.	Teachers, observations
Materials	UDE 6	Wood–metal design is excessively heavy and noisy and raises sustainability concerns due to material choice and acoustic impact.	Document review, experts
Maintenance costs	UDE 7	Repair and routine maintenance costs are increasing due to material limitations and structural weaknesses of current models.	School administrators

*Main sources refer to the predominant origin of information for each UDE (student feedback, expert interviews, observations, or document review).

Table 1. Undesirable Effects (UDEs) identified in current GBES desk-chair models, grouped by functional area.

As shown in Table 1, posture and comfort problems are not isolated complaints, but reflect a consistent pattern of poor spinal support, flat seat geometry, and high pressure on the ischial tuberosities (UDE 1 and UDE 2). At the same time, a single non-adjustable chair size is used for all children aged 5–12, based on outdated UNESCO criteria, leading to a persistent anthropometric mismatch (UDE 3). This mismatch is reinforced by rigid structures and fixed armrests that do not support flexible classroom layouts or constructivist learning activities (UDE 5). Finally, systemic constraints related to procurement and materials (UDE 4, UDE 6, and UDE 7) favour low-cost, heavy wood–metal furniture with high acoustic impact and increasing repair costs. Together, these UDEs define the “current reality” that the Theory of Constraints analysis seeks to transform.

Evaporating Cloud and core conflict

The most urgent justification for redesign arises from UDE 1 (Posture and health), because the current design directly harms student well-being through poor ergonomics, leading to postural deviations, spinal strain, circulatory issues, and musculoskeletal risks.

At the systemic level, procurement policies (UDE 4) and material inadequacies (UDE 6) reinforce the persistence of outdated designs. The Evaporating Cloud (EC), constructed from these elements, reveals a core conflict between:

- The need to minimize short-term procurement costs, and
- The need to adopt ergonomically sound and adjustable furniture that supports long-term posture health and modern pedagogy.

The Generic Cloud, derived from reverse-engineering several ECs, confirms that adhering to outdated MEDUCA–UNESCO criteria and cost-driven procurement prevents the integration of updated ergonomic standards and anthropometric considerations.

Ergonomic design specifications based on TOC analysis

Using the CRT and ECs as analytical tools, the TOC Thinking Process identified the required changes and guided the development of ergonomic design specifications. The proposed redesigned desk-chair includes the following key features:

Component	Design specification	UDE(s) addressed	Ergonomic rationale
Backrest	Height-adjustable backrest with anatomical contour set at a 37° thoracic kyphosis angle.	UDE 1, UDE 3	Supports the natural thoracic curvature, reduces long-term spinal strain, and allows adaptation to different body sizes.
Seat	Anatomically contoured seat with a rounded waterfall front edge.	UDE 1, UDE 2	Redistributes pressure away from the ischial tuberosities, reduces soft-tissue compression, and improves blood circulation.
Seat height	Seat height is adjustable in 1-cm increments.	UDE 1, UDE 3	Matches seat height to children's lower limb dimensions, avoiding excessive knee and hip flexion and popliteal pressure.
Armrest / writing pad	Foldable, height-adjustable armrest and writing surface mounted on a seesaw-type mechanism with locking screws.	UDE 2, UDE 5	Facilitates access and egress for larger students, accommodates different activities and improves classroom flexibility.
Structure	Reinforced metal frame with a lower grille support.	UDE 5, UDE 7	Increases stability and structural strength, reducing deformation and long-term maintenance needs.
Materials	Cast-iron frame with polyurethane or polypropylene seat, backrest and armrest surfaces.	UDE 6, UDE 7	Lighter and more durable than wood, less noisy during movement and more environmentally sustainable.
Overall geometry	Desk and seat proportions aligned with updated anthropometric data and classical ergonomic criteria (Akerblom, ISO 5970).	UDE 1, UDE 3, UDE 5	Ensures adequate leg clearance, desk height near elbow level and sufficient seat width to accommodate wider hips.

Table 2. Ergonomic design specifications for the redesigned primary school desk-chair were derived from the Theory of Constraints analysis.

As summarized in Table 2, the redesigned desk-chair incorporates a height-adjustable, foldable armrest and writing surface that improve access for larger students and accommodate different classroom activities, directly addressing comfort and flexibility issues (UDE 2 and UDE 5). The seat is anatomically contoured, with a rounded waterfall front edge and adjustable height in 1-cm increments, which redistributes pressure away from the ischial tuberosities, reduces popliteal compression, and allows closer matching between seat height and children's lower limb dimensions (UDE 1 and UDE 3). The backrest is height-adjustable and

aligned with a 37° thoracic kyphosis contour, providing physiological spinal support and reducing long-term spinal strain (UDE 1).

At the structural level, the redesigned frame incorporates a lower grille support to increase stability and durability, addressing recurrent deformation and maintenance problems (UDE 5 and UDE 7). The use of a cast-iron frame combined with polyurethane or polypropylene surfaces for the seat, backrest, and armrest reduces weight and acoustic noise compared with traditional wood–metal models, while improving sustainability (UDE 6 and UDE 7). Finally, the overall desk and seat geometry is aligned with updated anthropometric data and classical ergonomic criteria (Akerblom, ISO 5970), ensuring adequate leg clearance, a desk height near elbow level, and sufficient seat width to accommodate wider hips (UDE 1, UDE 3, and UDE 5).

Overall, the redesigned desk-chair represents a shift from a model that requires students to adapt to the furniture to one that adapts to student morphology and anthropometry, thereby aligning with constructivist pedagogy and posture health requirements.

DISCUSSION

This study applied the Theory of Constraints Thinking Process as a methodological framework to diagnose and redesign primary school desk-chairs in Panama. The TOC-TP proved to be a flexible and effective tool for organizing Undesirable Effects, identifying core conflicts, and deriving targeted Injections (design changes) that transform UDEs into Desired Effects.

The CRT enabled a systematic linkage between student discomfort, poor posture, and long-term spinal risks (UDE 1) and structural limitations in procurement (UDE 4), material selection (UDE 6), and the absence of adjustability in the current design. This analysis demonstrates that poor posture health outcomes are not solely the result of individual behavior but are rooted in institutional and design decisions.

The ergonomic criteria embedded in the redesigned chair—adjustable armrest, adjustable seat depth, an anatomically contoured seat with a waterfall edge, and a backrest aligned with physiological thoracic kyphosis—are consistent with classical and contemporary literature on spinal biomechanics, sitting posture, and seat pressure distribution.^{2–9, 11, 12, 16, 17, 22} The incorporation of height increments and adjustable components addresses the widely documented mismatch between school furniture and children’s anthropometric dimensions in many countries.^{3–5}

From a pedagogical standpoint, the redesign supports constructivist learning by improving flexibility and ease of movement, which are essential for active learning strategies such as group work and project-based activities.¹ The foldable, height-adjustable armrest and the lighter, more sustainable materials facilitate classroom reconfiguration and student mobility.

The use of TOC-TP also contributes a methodological innovation: instead of addressing furniture problems as isolated technical issues, it frames them as part of a systemic conflict involving health, pedagogy, procurement, and sustainability. This systems-oriented approach can support administrative decision-making in ministries of education and school authorities by providing a clear cause–and–effect logic that links procurement criteria with measurable health and educational outcomes.²¹

Limitations and future directions

A key limitation of this study is the absence of prototype-based ergonomic testing and pre- and post-evaluations of posture, comfort, or musculoskeletal outcomes. The present work focuses on conceptual design based on qualitative and logical analysis, without yet implementing physical prototypes in classrooms.

Future research should therefore:

1. Develop and build physical prototypes of the redesigned desk-chair.
2. Conduct pilot usability and “ease of use” tests in real classroom settings;

3. Assess short- and long-term outcomes, including comfort, sitting behaviour, musculoskeletal symptoms, and student and teacher satisfaction;
4. Evaluate the cost–benefit implications of adopting ergonomic furniture at scale, including maintenance and replacement costs.

Despite these limitations, the study provides a robust methodological framework that combines ergonomics, anthropometry, and TOC and can be replicated or adapted in other Latin American and international contexts.

CONCLUSIONS

The Theory of Constraints Thinking Process provided a structured and effective methodology for identifying and analyzing the Undesirable Effects associated with current school desk-chair designs in Panamanian GBES, clearly linking student discomfort and health risks to systemic procurement and design decisions. The resulting conceptual redesign directly addresses critical posture health factors—such as spinal alignment, pressure on soft tissues and intervertebral discs, and blood circulation—while accommodating morphological and anthropometric differences among students in grades 1–6. At the same time, the proposed design aligns school furniture with constructivist pedagogical requirements by increasing flexibility, adjustability, and compatibility with active learning strategies, and by incorporating more sustainable and durable materials. Overall, this research contributes a novel methodological approach that integrates ergonomics, anthropometry, and TOC to resolve dilemmas in furniture design and procurement, offering ministries of education and school systems a logical roadmap for evidence-based improvements. Nevertheless, further empirical testing with physical prototypes is required to validate the ergonomic, health, and educational impacts of the redesigned desk-chair and to support its potential large-scale policy implementation.

Supplementary Materials

Not applicable.

Author Contributions

Conceptualization, R.E.S.G. and A.M.; methodology, R.E.S.G. and A.M.; validation, R.E.S.G. and A.M.; formal analysis, R.E.S.G. and A.M.; investigation, R.E.S.G.; resources, R.E.S.G. and A.M.; data curation, R.E.S.G.; writing—original draft preparation, R.E.S.G.; writing—review and editing, R.E.S.G. and A.M.; visualization, R.E.S.G.; supervision, A.M.; project administration, R.E.S.G. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest Statement

The authors declare no conflict of interest. The institutions with which the authors are affiliated had no role in the study design; data collection, analysis or interpretation; manuscript writing; or the decision to submit the work for publication.

Institutional Review Board Statement

The study was conducted in accordance with the ethical principles applicable to educational and social research in Panama. Authorization to conduct the study was obtained from the participating schools and the relevant educational authorities prior to data collection.

Informed Consent Statement

According to the authors, school authorization and parental/guardian consent were obtained before involving students in interviews, observations and questionnaires, and student assent was sought in age-appropriate terms. No personally identifiable information is reported in this manuscript.

Data Availability Statement

The qualitative and school-level data generated and analyzed in this study (interview transcripts, observation notes and internal school documents) are not publicly available due to confidentiality agreements with the participating schools. De-identified summary data may be made available from the corresponding author upon reasonable request and subject to institutional approval.

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AI-Assisted Tools Disclosure

No artificial intelligence system was used to generate, manipulate or analyze empirical data, figures or statistical results in this study. Generative AI tools were used only for minor linguistic refinement and formatting standardization of the manuscript, under full human supervision. No AI tool contributed to scientific interpretation, data generation, experimental design or the creation of original scientific content. The authors independently verified all results, analyses and conclusions, in accordance with BioNatura Journal's policy on AI-assisted content (see: <https://bionaturajournal.com/artificial-intelligence--ai-.html>).

REFERENCES

1. Erawati NK, Adnyana PB. Implementation of Jean Peaget's Theory of Constructivism in Learning: A Literature Review. *Indonesian Journal of Educational Development (IJED)*. 2024;5:394–401.
2. Alibegović A, Hadžimerović AM, Pašalić A, Domljan D. School Furniture Ergonomics in Prevention of Pupils' Poor Sitting Posture. *Drvna industrija*. 2020;71:88–99.
3. Araújo LGL, Rodrigues VP, Figueiredo IA, Medeiros MNL. Association between sitting posture on school furniture and spinal changes in adolescents. *Int J Adolesc Med Health*. 2020;34:469–475.
4. Sari Mİ, Şahin İ. Ergonomic Analysis Based on Digital Human Modelling: Adjustable School Furniture Design for Secondary School Students. *Politeknik Dergisi*. 2020;23:1097–1110.
5. Fidelis OP, Ogunlade B, Adelakun SA. Incidence of School Furniture Mismatch and Health Implications in Primary School Children in Akure, South-West Nigeria. *J Occup Ther Sch Early Interv*. 2021;14:90–102.

6. Zheng L-d, Cao Y-t, Yang Y-t, Xu M-l, Zeng H-z, Zhu S-j, et al. Biomechanical response of lumbar intervertebral disc in daily sitting postures: a poroelastic finite element analysis. *Comput Methods Biomech Biomed Engin.* 2023;26:1941–1950.
7. Cho M, Han JS, Kang S, Ahn CH, Kim DH, Kim CH, et al. Biomechanical Effects of Different Sitting Postures and Physiologic Movements on the Lumbar Spine: A Finite Element Study. *Bioengineering (Basel).* 2023;10:9051051.
8. Roman-Liu D, Kamińska J, Tokarski T. Differences in lumbar spine intradiscal pressure between standing and sitting postures: a comprehensive literature review. *PeerJ.* 2023;11:e16176.
9. Qin B, Baldoni M, Wu B, Zhou L, Qian Z, Zhu Q. Effect of lumbar muscle atrophy on the mechanical loading change on lumbar intervertebral discs. *J Biomech.* 2022;111120.
10. Bendix T. Low back pain and seating. In: *Hard Facts about Soft Machines.* 2020. p. 147–155.
11. Kou B, Han Y, Hao Y, Xu H, Wen W, Zhang Z, et al. Morphological changes and strain characteristics of lumbar intervertebral disc during sitting in forward flexion. *Chinese Journal of Tissue Engineering Research.* 2022;26:5792.
12. Zanolà RL, Donin CB, Bertolini GRF, Buzanello Azevedo MR. Biomechanical repercussion of sitting posture on lumbar intervertebral discs: A systematic review. *J Bodyw Mov Ther.* 2024;38:384–390.
13. Hou J, Li X, Li Z, Yin L, Chen X, Liang F. An in vivo data-based computational study on sitting-induced hemodynamic changes in the external iliac artery. *J Biomech Eng.* 2022;144.
14. Akerblom B. Standing and Sitting Posture, with Special Reference to the Construction of Chairs. *Phys Ther Rev.* 1949;29:486.
15. ISO 5970:1979. Furniture — Chairs and tables for educational institutions — Functional sizes. International Organization for Standardization; 1979. Available at: <https://www.iso.org/standard/12165.html>. Accessed 25 Nov 2025.
16. Sonenblum SE, Seol D, Sprigle SH, Cathcart JMK. Seated buttocks anatomy and its impact on biomechanical risk. *J Tissue Viability.* 2020;29:69–75.
17. Rincón O, Bernal ML, Salazar JJ, Zea CR. Relationship between seat surface shape and pressure distribution in school seat models. *Work.* 2020;66:161–171.
18. Panero J, Zelnik M, Diffrient N. Antropometría del asiento. In: *Human Dimension & Interior Space.* 7th ed. Barcelona: Editorial Gustavo Gili; 2017. p. 57–68.
19. Rubin SJS, Qvit N. *The Ultimate Student's Guide to Scientific Research.* 1st ed. 2025:1–140.
20. Taherdoost H. *Data Collection Methods and Tools for Research; A Step-by-Step Guide to Choose Data Collection Technique for Academic and Business Research Projects.* 2021.
21. Knop K. Using the Theory Of Constraints Thinking Process Tools to Solve Critical Problems in the Organization. *Scientific Papers of Silesian University of Technology Organization and Management Series.* 2024:305–331.
22. Stagnara P, De Mauroy JC, Dran G, Gonon GP, Costanzo G, Dimnet J, et al. Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. *Spine (Phila Pa 1976).* 1982;7:335–342.

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