

Sounding Board

Ergonomics for schools

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Abstract. Ergonomics in Schools has focused on micro-ergonomics issues such as mismatch between student body sizes and their desks and chairs, the weight of schoolbags and the prevalence of musculoskeletal disorders amongst school students. Very little of this has been turned into practice. Although advances in this context are being made by the International Ergonomics (IEA) Technical Committee (TC) on Ergonomics for Children in Educational Environments (ECEE), the UK Ergonomics Society Special Interest Group on Ergonomics for Schools and the New Zealand Ergonomics Society Ergonomics/Human factors in Education (EHFIE) Special Interest Group, there has been less focus on macro-ergonomics issues such as learning environments, ergonomics pedagogy and curriculum content/structure. This commentary reviews micro-ergonomics aspects of 'Ergonomics in schools' and argues in favour of a new direction: macro-ergonomics *for* schools, or educational ergonomics in which ergonomists seek to integrate ergonomics into national educational curricula in concert with Ministries of Education and also via inclusion of ergonomics modules in teacher training.

Keywords: Education, human factors, learning, curricula

1. Ergonomics 'in and for' Schools

There has been considerable activity worldwide on 'Ergonomics in schools' (see [22]) but very little on 'Ergonomics for schools'. It is differentiated from previous literature on 'Ergonomics in Schools' (see [22]) as its emphasis is 'for' – not 'in' schools. It is the tenet of this article that the emphasis on Ergonomics 'for' rather than 'in' schools may help to play a significant and meaningful role in shifting the emphasis from the physical environment in schools by changing worldwide societal views and practices in favor of integrating ergonomics/human factors within national school educational curricula.

The people in schools are mostly children/youths/students and teachers, but there are some other 'stakeholders' such as principals, caretakers, govern-

ing boards (or Boards of Trustees), government department officials (inspectors), equipment and learning resource providers and, last but not least, parents. The 'system' within schools contains many different 'elements', ranging from micro to macro-ergonomic in nature. These can include school equipment (e.g. desks, chairs, computers, laptops, books, schoolbags, pens, uniforms, and equipment used for sport and in the gymnasium and playground), work – (e.g. learning, teaching and playing) – spaces (e.g. desk/chair/workspace arrangements, lockers), school facilities/environments (e.g. classrooms, laboratories, libraries, corridors, playgrounds staffroom, physical factors such as heating, cooling, lighting, noise, building design and the internet) and school organisation (e.g. subjects/topics, curricula, learning/teaching methods and pedagogy, school-day length and timing, study durations, timetable, rest breaks, physical activities, departmental structures, governance, school rules, personal security, human rights, school and national poli-

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cies, educational priorities, internationalization, globalization).

2. Micro-ergonomics in schools

To date, only a moderate volume of research has been undertaken on a limited number of these different elements. It has mainly focused on micro-ergonomics issues such as the mismatch between the anthropometrics of students and their desks and chairs [5,11,2,31,33]. Saarni et al. [36] report what several previous studies [5, 11,2,31,33] have shown - "a mismatch between . . . anthropometrics of schoolchildren and . . . school furniture" and that "schoolchildren sit in disadvantaged postures for a substantial part of school lessons" (p. 1561). The latter is also reported by Geldhof et al. [10] and by Breen et al. [2] and is implied in Tuttle et al. [45,46] which focuses on buttock anthropometry for seat pan design.

Savanour et al. [38] and Acosta et al. [?], both suggest that the mismatch ("the lack of conformity . . .") between school furniture dimensions and schoolchildren's body sizes also occurs in developing countries. The former also points out what is also common worldwide: national and international standards for school furniture have not yet addressed the need for better matching. Savanour et al. [38] suggest that a range of furniture sizes need to be provided in classrooms to match pupils' body sizes. Koskelo et al. [18] in a controlled intervention study show that better matching in the form of adjustable school desks and chairs promote better sitting and standing postures, decreased tension in the upper and lower back muscles, alleviate pain and appear to be associated with better overall academic grades. The latter point is important. Koskelo et al. [18] do not actually provide evidence of 'improved academic performance', and do not claim to do so. Their study merely suggests a relationship that needs further investigation. It is poignant to note that it is the approach adopted by Saarni et al. [18] that will help in the examination of this important question. Saarni et al.'s data was collected as a baseline for a longitudinal intervention study which could shed some light on the effects of improved seating on learning.

Dockrell et al. [7] report that computer use in school classrooms is extensive. This phenomenon was also described in a keynote address at the IEA 2003 Seoul Congress [43] and is a worldwide phenomenon mirroring adult life. Dockrell et al. [7] also report that school teachers consider their training (if

any) in computer ergonomics as lacking and point out a need for ergonomics education for teachers. In this case, however, their meaning is for teacher training in ergonomics that is synonymous with computer workstation design, seated postures and avoidance of risk factors for musculoskeletal discomfort, pain, injury, and disorders (MSDPID). A user friendly and focussed pupil/teacher/parent learning tool for achieving part of this goal has recently been developed by the New Zealand Ergonomics Society Ergonomics (NZES) in Schools Special Interest Group (recently re-branded as the NZES Special Interest Group for Ergonomics/human Factors in education (EHFIE)) in the form of an interactive website: www.moveit.org.nz [3] A similar tool (MouseWise) has recently been developed in parallel in the Netherlands: www.mousewise.org [6]. The efficacy of neither of these tools has, however, been properly evaluated.

There are many other issues associated with micro-ergonomics in schools. The weight of schoolbags is one example. Mackie and Legg [28] is one of many articles in the literature in recent years [1,4,24,27,29, 30,32,34,47,48] that examined the perennially topical issue of heavy schoolbags, but is unique in its examination of the temporal pattern of schoolbag use in real-life situations over 24 hour periods. Like many others however, it does not address the long term consequences, if any, of carrying loaded schoolbags, let alone the combined effects of mismatched seating. One major such consequence is postulated to be an unacceptably high prevalence of MSDPID both among adolescents and into adulthood [?]. Although the evidence for this causality is still unproven, Jones et al. [16] show that a rehabilitative exercise program can reduce the incidence of non-specific low back pain among children [12,25, 39] and children working with computers [13]. A fundamental review of some of these issues was recently published [?]. Other micro-ergonomics issues include Havenith [14], who reports on energy expenditures and clothing insulations among adolescents at school, which can be used for development of climate control systems.

Despite their recognized challenges, longitudinal case-controlled ergonomics intervention studies are needed if the musculoskeletal discomfort, pain, injury and disorders (MSDPID) problems experienced by schoolchildren identified in epidemiological studies are to be addressed. Very little of this has yet been turned into practice, although excellent advances to help redress this are currently being made through the recent development of electronic

web sites by the IEA Technical Committee on Ergonomics for Children in Educational Environments (ECEE) (<http://www.iea.cc/ergonomics4children/>) and the United Kingdom (UK) and New Zealand Ergonomics Societies' Special Interest Groups on Ergonomics for Schools (www.ergonomics4schools.com and www.moveit.org.nz). A recent example is of 'Ergonomics in Schools' being a highly prominent focal theme in the New Zealand Ergonomics Society Conference [3,8,15,17].

3. Macro-ergonomics for schools

Very little research (and even less practical application) has focussed on macro-ergonomics issues such as classroom environments, and more particularly on ergonomics pedagogy, curriculum content and structure i.e. Ergonomics *for* schools. The current state of knowledge about ergonomics *for* schools is limited. There is insufficient knowledge of the interactions between the people in schools and the systems comprising school environments to claim that we have an adequately 'fundamental understanding' of 'Ergonomics *for* Schools'. In the pedagogy of school curricular design, ergonomics as a discipline in its own right has received very scant attention despite the pioneering reports about this by K.U. and M.F. Smith [40] and more recently by T.J. Smith [41,42] in the USA and Andree Woodcock [49–52] in UK.

The recently published special issue of Ergonomics [22] was a start in redressing this paucity of knowledge. Most – but not all – of the papers in the special issue were concerned with micro-ergonomics issues. A notable exception was that of Guercin [?], who suggested that adoption of an ergonomics approach through child-centred design of a road safety education programme could reduce the risk of pedestrian accidents amongst children. Road safety around schools is a 'hot' topic in which more research is needed [23,28].

Two papers [41,42,49] were seminal, in that they addressed fundamental macro-ergonomics issues in teaching, learning, curriculum, school and classroom design. Smith points to proven benefits of ergonomics applications in industry and identifies the need to extend this to educational systems and learning – "... which design characteristics in the learning environment have the greatest influence on variability in learning performance?" and challenges us to apply this to "... ergonomics interventions directed at design improvements of learning environments to benefit learning".

Woodcock also identifies the fundamental importance of education and of applying ergonomics principles in the design of curricula.

The most recent development in ergonomics *for* schools was a workshop held at the Nordic Ergonomics Society Conference in Reykjavik, Iceland [20]. It focussed on identifying the ways in which each of the Nordic countries could encourage the integration of ergonomics into the national educational curricula for school aged children. Although Denmark already had some legislation and an 'Information Centre' on this, it was generally agreed by the workshop participants that it was necessary for ergonomists to pro-actively engage with their respective Ministries of Education and to encourage the introduction of ergonomics educational modules within teacher training colleges. None had, however, actually tried this. However the Ministry of Education in Norway was in the process of establishing a joint project with the Norwegian Ergonomics Society to identify optimal school and classroom designs (personal communication, K.-I. Fostervold 2008). It is interesting to note that there is already considerable information about this in the USA (www.edfacilities.org) and that the initial response of the New Zealand Ministry of Education to a similar approach by the NZES Ergonomics/Human factors in Education Special Interest Group was very similar – little interest in integration of ergonomics into the national curriculum but considerable interest in applying ergonomics in the design of the physical environment of classrooms and schools (www.minedu.govt.nz/goto/performingclassrooms). Lastly, considerable efforts are being made in Latvia to integrate ergonomics into teacher education (personal communication, J. Gedrovics 2008). **Overview, future activity and conclusion.**

A more complete contemporary overview of the status of research and practice in Ergonomics in Schools may be obtained from the following sources: Trevelyan, F. C. and Legg, S. J., 2006, Back pain in school children – where to from here? *Applied Ergonomics, Special Issue: Fundamental Reviews*, 37 (1), 45–54; Brackley, H. M. and Stevenson, J. M., 2004, Are children's backpack weight limits enough? A critical review of the relevant literature, *Spine*, 29, 2184–2190; the IEA Technical Committee Ergonomics for Children in Educational Environments (ECEE) sessions in IEA2003, 15th Triennial Congress of the International Ergonomics Association, Ergonomics in the Digital Age, August 24–29th, South Korea – including a plenary keynote presentation by Straker, L. and Pollock, C. 2003, 'Delivering the power of computers

to children, without harming their health' (subsequently published (*ibid* 2004) as 'Optimising the interaction of children with information and communication technologies' in *Ergonomics*, 48, 506–521) and in *IEA2006, 16th World Congress on Ergonomics, Meeting Diversity in Ergonomics*, Maastricht, The Netherlands, 10–14 July, 2006 – including a plenary keynote presentation by Legg, S.J., 2006, *Ergonomics in Schools*, p 53 and which can be found on the IEA ECEE website (<http://www.iea.cc/ergonomics4children/>).

Two future special issues of journals will also deal with ergonomics amongst adolescents and youth: Legg, S. J. and Bennett, C. (Co-guest editors), 2009, *Concerns for the Next Generation Workforce, International Journal of Industrial Ergonomics*, and; Sommerich, C. (Guest editor), 2009, *Ergonomics Issues Concerning Children, Youths, and Students, WORK: A Journal of Prevention, Assessment and Rehabilitation*.

What should 'Ergonomics for Schools' seek to achieve? The focus for 'Ergonomics for Schools' should shift from micro- to macro-ergonomics issues such as the creation of greater knowledge about school facilities and educational curricular design to optimise learning and teaching – and then to apply this knowledge, and how to have ergonomists actively interacting with the education community to effectively communicate and action the potential benefits of embracing the principles and techniques of ergonomics for schools – in short Educational Ergonomics'.

References

- [1] H.M. Brackley and J.M. Stevenson, Are children's backpack weight limits enough? A critical review of the relevant literature, *Spine* **29**, 2184–2190.
- [2] R. Breen, S. Pyper, Y. Rusk and S. Dockrell, An investigation of children's posture and discomfort during computer use, *Ergonomics* **50**(10) 2007, 1582–1592.
- [3] B. Buchanan, L. Gardner Wood, S.J. Legg, S. Jones, M. Kaye, T. Hovey and N. Donaldson, MoveIT: a New Zealand interactive web based game/tool for educating intermediate schoolchildren and their teachers and parents about computer workstations and workspace re-design, *Proceedings of the New Zealand Ergonomics Society Conference, Waiheke Island, New Zealand, 7–9 November, 2007*, ISBN 0-9582560-1-2, 2007, 75.
- [4] S. Bygrave, S.J. Legg, S. Myers and M. Llewellyn, Effect of backpack fit on lung function, *Ergonomics* **47** (2004), 324–329.
- [5] J.W.Y. Cheung and T.K.S. Wong, Anthropometric evaluation for primary school furniture design, *Ergonomics* **50** (2007), 323–334.
- [6] H. de Kraker, M. Formanoy and E. de Korte, The effect of a healthy computing educational program on knowledge, attitude and computer behaviour in middle school children, *Proceedings of the 40th Annual conference of the Nordic Ergonomics Society* (NES2008), Reykjavik, Iceland, 11–13 August, 2008, 225.
- [7] S. Dockrell, E. Fallon, M. Kelly, B. Masterson and N. Shields, School children's use of computers and teachers' education in computer ergonomics, *Ergonomics* **50**(10) (2007), 1657–1667.
- [8] R. Dykes, A. Noble and S.J. Legg, Ergonomics in the New Zealand National Curriculum, and understanding and knowledge of ergonomics amongst New Zealand Secondary School Teachers, *Proceedings of the New Zealand Ergonomics Society Conference, Waiheke Island, New Zealand, 7–9 November*, ISBN 0-9582560-1-2, 2007, 65–69.
- [9] G. Garcia-Acosta and K. Lange-Morales, Definition of sizes for the design for the design of school furniture for Bogotá schools based on anthropometric criteria, *Ergonomics* **50**(10) (2007), 1626–1642.
- [10] E. Geldhof, D. de Clercq, I. de Bourdeaudhuij and G. Cardon, Classroom postures of 8–12 year old children, *Ergonomics* **50**(10) (2007), 1571–1581.
- [11] M.K. Gouvali and K. Boudolos, Match between school furniture dimensions and children's anthropometry, *Applied Ergonomics* **37** (2006), 765–773.
- [12] P. Grimes and S.J. Legg, Musculoskeletal disorders (MSD) in school students as a risk factor for adult MSD: a review of the multiple factors affecting posture, comfort and health in classroom environments, *Journal of the Human Environment System* **7** (2004), 1–9.
- [13] C. Harris, L. Straker, C. Pollock and S. Trinidad, Musculoskeletal outcomes in children using information technology – the need for a specific etiological model, *International Journal of Industrial Ergonomics* **35** (2005), 131–138.
- [14] G. Havenith, Metabolic rate and clothing insulation data of children and adolescents during various school activities, *Ergonomics* **50**(10) (2007), 1689–1701.
- [15] A. Hedge, Children and computers – past, present and future, *Proceedings of the New Zealand Ergonomics Society Conference, Waiheke Island, New Zealand, 7–9 November, 2007*, ISBN 0-9582560-1-2.
- [16] M.A. Jones, G. Stratton, T. Reilly and V.B. Unnithan, Recurrent non-specific low-back pain in adolescents: the role of exercise, *Ergonomics* **50**(10) (2007), 1680–1688.
- [17] P. Kane and S.J. Legg, Ergonomics design of school furniture systems must match student, staff, curriculum and classroom management needs, *Proceedings of the New Zealand Ergonomics Society Conference, Waiheke Island, New Zealand, 7–9 November, 2007*, ISBN 0-9582560-1-2, 60–64.
- [18] R. Koskelo, K. Vuorikari and O. Hänninen, Sitting and standing postures are corrected by adjustable furniture with lowered muscle tension in high school students, *Ergonomics* **50**(10) (2007), 1643–1656.
- [19] S.J. Legg, Ergonomics in Schools – Plenary keynote address, in *IEA2006, 16th World Congress on Ergonomics, Meeting Diversity in Ergonomics*, Maastricht, The Netherlands, 10–14 July, 2006, Programme Book, p. 53 and in <http://www.iea.cc/ergonomics4children/>.
- [20] S.J. Legg, Ergonomics for Schools in the Nordic countries: workshop, *Proceedings of the 40th Annual conference of the Nordic Ergonomics Society* (NES2008), Reykjavik, Iceland, 11–13 August, 2008, 207.
- [21] S.J. Legg, Ergonomics in schools, Special issue of ergonomics: Guest editorial, *Ergonomics* **50**(10) (2007), 1–6.
- [22] S.J. Legg and C. Bennett, Co-guest editors, Special Issue Ergonomics in Schools, *Ergonomics* **50**(10) (2007).

- [23] S.J. Legg, E. Laurs and D.I. Hedderley, How safe is cycling with a schoolbag? *Ergonomics* **46**(8) (2003), 859–869.
- [24] J.X. Li and Y. Hong, Age difference in trunk kinematics during walking with different backpack weights in 6- to 12-year-old children, *Research in Sports Medicine* **12** (2004), 135–142.
- [25] S. Limon, L.J. Valinski and Y. Beb-Shalom, Children at risk: risk factors for low back pain in the elementary school environment, *Spine* **29** (2004), 697–702.
- [26] G. Panagiotopoulou, K. Christoulas, A. Papanikolaou and K. Mandroukas, Classroom furniture dimensions and anthropometric measures in primary school, *Applied Ergonomics* **35** (2004), 121–128.
- [27] H.W. Mackie and S.J. Legg, Measurement of the temporal patterns of schoolbag carriage using activity monitoring and structured interview, *Ergonomics* **50**(10) (2007), 1668–1679.
- [28] H.W. Mackie and S.J. Legg, Postural and subjective responses to realistic schoolbag carriage, *Ergonomics* **52**(2) (2008), 217–231.
- [29] H.W. Mackie, S.J. Legg and J. Beadle, Development of activity monitoring for determining load carriage patterns in school students, *Work* **22** (2004), 231–237.
- [30] H.W. Mackie, J.M. Stevenson, S.A. Reid and S.J. Legg, The effect of simulated school load carriage configurations on shoulder strap tension forces and shoulder interface pressure, *Applied Ergonomics* **36** (2005), 199–206.
- [31] S. Milanese and K. Grimmer, School furniture and the user population: an anthropometric perspective *Ergonomics* **47** (2004), 416–426.
- [32] R.R.E.E. Motmans, S. Tomlow and S. Vissers, Trunk muscle activity in different modes of carrying schoolbags, *Ergonomics* **49** (2006), 127–138.
- [33] C. Parcells, M. Stommel and R. Hubbard, Mismatch of classroom furniture and student body dimensions: Empirical findings and health implications, *Journal of Adolescent Health* **24** (1999), 265–273.
- [34] T. Pucktree, S.P. Silal and J. Lin, Schoolbag carriage and pain in school children, *Disability and Rehabilitation* **26** (2004), 54–59.
- [35] F.C. Trevelyan and S.J. Legg, Back pain in school children – where to from here? *Applied Ergonomics, Special Issue: Fundamental Reviews* **37** (2006), 45–54.
- [36] L. Saarni, C.-H. Nygård, A. Kaukiainen and A. Rimpelä, Are the desks and chairs at school appropriate? *Ergonomics* **50**(10) (2007), 1561–1570.
- [37] D. Saimbanes, J.W. Martinez, E.W. Butler and T. Haider, 2004, Influence of school backpacks on adolescent back pain, *Journal of Pediatric Orthopedics* **24** (2007), 211–217.
- [38] C.S. Savanur, C.R. Altekar and A. De, , Lack of conformity between Indian classroom furniture and student dimensions: proposed future seat/table dimensions, *Ergonomics* **50**(10) (2007), 1612–1625.
- [39] A.N. Sjolie, Persistence and change in non-specific low back pain among adolescents: a 3-year prospective study, *Spine* **29** (2004), 2452–2457.
- [40] K.U. Smith and M.F. Smith, *Cybernetic Principles of Learning and Educational Design*, New York: Holt, Rinehart and Winston, 1966.
- [41] T.J. Smith, *The Ergonomics of Learning: Educational Design and Learning Performance*, Presentation to the University of Minnesota Academy of Distinguished Teachers Conference 2007, ‘Enhancing Student Learning: Conversations About Research and Practice,’ (Minneapolis, MN: University of Minnesota College of Education and Human Development Center for Teaching & Learning), April 23, 2007.
- [42] T.J. Smith, The ergonomics of learning: educational design and learning performance, *Ergonomics* **50**(10) (2007), 1530–1546.
- [43] L. Straker and C. Pollock, Delivering the power of computers to children, without harming their health, Plenary Keynote presented at the 15th *Triennial Congress of the International Ergonomics Association, Ergonomics in the Digital Age* August 24–29th, 2003, South Korea.
- [44] L. Straker and C. Pollock, Optimising the interaction of children with information and communication technologies, *Ergonomics* **48** (2004), 506–521.
- [45] N. Tuttle, R. Barrett and E. Gass, Seated buttock contours: a pilot study of Australian senior high school students, *Ergonomics* **50**(10) (2007), 1593–1602.
- [46] N. Tuttle, R. Barrett and E. Gass, Preferred seat orientation of senior high school students, *Ergonomics* **50**(10) (2007), 1603–1611.
- [47] J. Whittfield, S.J. Legg and D.I. Hedderley, The weight and use of schoolbags in New Zealand secondary schools, *Ergonomics* **44** (2001), 819–824.
- [48] J. Whittfield, S.J. Legg and D.I. Hedderley, Schoolbag weight and musculoskeletal symptoms in New Zealand secondary schools, *Applied Ergonomics* **36** (2005), 193–198.
- [49] A. Woodcock, Ergonomics, education and children: a personal view, *Ergonomics* **50**(10) (2007), 1547–1560.
- [50] A. Woodcock and R.A. Bartlett, Enhancing the teaching and learning of ergonomics in schools through the development of web based Ergonomics Association, *Ergonomics in the Digital Age*, August 24–29th, 2003, South Korea.
- [51] A. Woodcock, E. Clarke, J. Cole, J. Cooke and C. Desborough, Teaching ergonomics to 4 to 6 year olds, in: *Contemporary Ergonomics*, P.T. McCabe, ed., Taylor and Francis: London, 2003, pp. 519–524.
- [52] A. Woodcock and H.G. Denton, The teaching of ergonomics in schools: What is happening? In: *Contemporary Ergonomics*, S. Robertson, ed., Taylor and Francis: London, 2001.