



Solutions to Improve IEQ in Classrooms



„Bildungsrepublik“ Deutschland (Republic of Education Germany)
... or is it?



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Who is it all about?

The three pedagogues ...



8,8 million.
pupils



820.353
teachers



32.758
general education schools

↑
> 10% of German
population

„The room is the third pedagogue“
Loris Malaguzzi (1920–1994)



pupils (2023/2024): <https://de.statista.com/statistik/daten/studie/1009802/umfrage/anzahl-schueler-in-deutschland/>
teachers: <https://de.statista.com/statistik/daten/studie/162263/umfrage/anzahl-der-lehrkraefte-nach-schularten/>
schools (2023/2024): <https://de.statista.com/statistik/daten/studie/235954/umfrage/allgemeinbildende-schulen-in-deutschland-nach-schulart/>

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In surveys, teachers and pupils criticize the quality of
buildings and the interior:

Noise, air quality, lighting, and
permanent sensory overstimulation ...



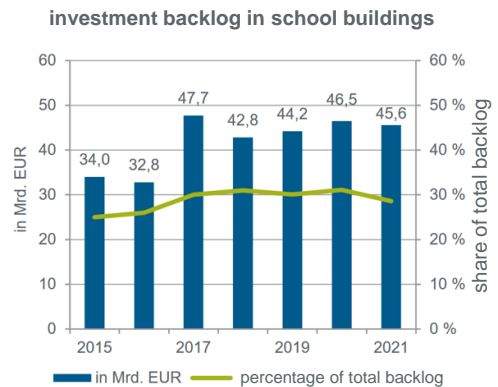
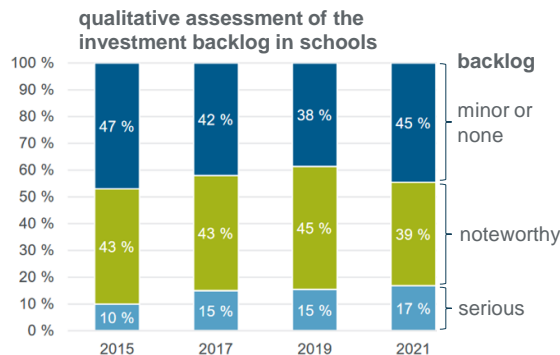
see forsa survey: <https://www.vbe.de/presse/pressendienste/pressendienste-2023/an-3500-schulen-fehlen-mehr-als-15-prozent-der-lehrkraefte>,
survey teacher health: https://www.schleswig-holstein.de/DE/landesregierung/ministerien-behoerden/III/Presse/PI/2018/Februar_2018/III_Lehrkraeftegesundheit.html,
<https://www.epochtimes.de/gesellschaft/bildung/immer-mehr-lehrer-quitzen-den-dienst-wenn-der-traumberuf-zum-albtraum-wird-a492465.html>

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What about the “third pedagogue“?

Figures from the KfW Municipal Portal



every second school in need of renovation

approx. EUR 45 billion investment backlog

→ Refurbishments offer opportunities for holistic improvement of classrooms



KfW municipal portal, different years, see <https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-2022/Fokus-Nr.-401-September-2022-Update-Schulen.pdf>

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What potential are we leaving behind?

Impact of IEQ on teaching and learning



- +15 % performance capability from 22 to 18 °C [König, 36]
- +2 % productivity per 1 K less (20–25 °C) [Wargocki, 37]
- performance capability max. around 22 °C [Drexler, 38]

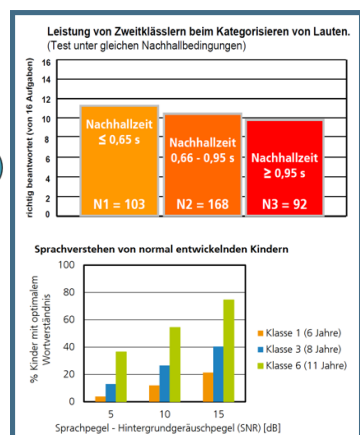


- ... with plenty of daylight availability
- + 23–26 % faster learnig (reading), +15–20 % (maths) [Herschong, 57]
- better results maths/logic [Baloch, 58]
- better concentration skills[Slegers, 59]

- ... with dynamic lighting [Schulte-Markwort, 60–62]
- +35 % reading speed, –76 % motoric restlessness, –45 % mistakes



- +15 % performance capability from 1200 to 700 ppm [König, 36]
- +12 % editing speed, +2 % quality from 2100 to 900 ppm [Wargocki, 45]
- +8 % speed with doubled ventilation rate (3–10 l/s) [Wargocki, 37]
- +5 % learning speed from 2300 to 900 ppm, +2,5 % concentration skills from 4000 to 1000 ppm [Wargocki, 45]



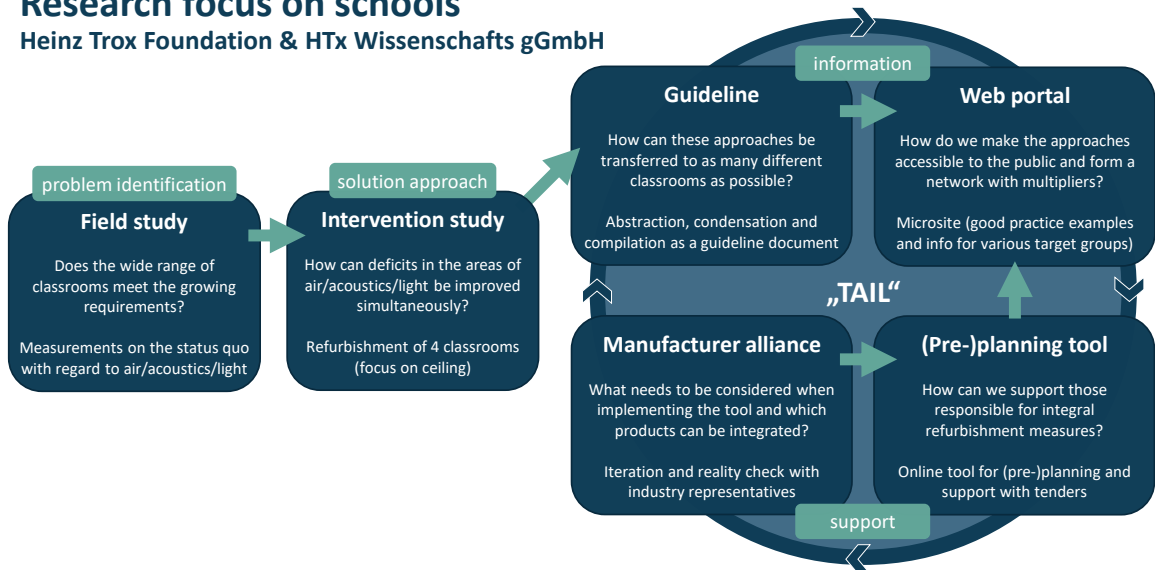
categorization of sounds: [816]
speech comprehension: [54]

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Research focus on schools

Heinz Trox Foundation & HTx Wissenschafts gGmbH

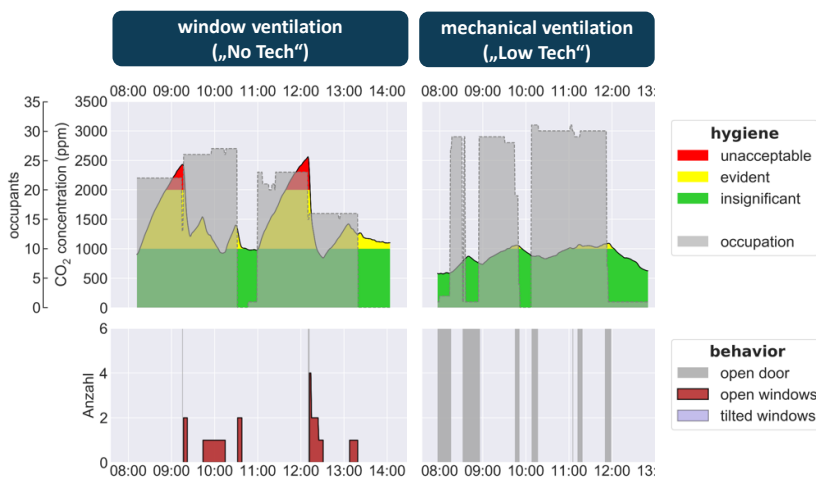


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Deficits in all areas

Results on the status quo (field study before the pandemic)



lighting requirements: Technische Regeln für Arbeitsstätten <https://www.baua.de/DE/Angebote/Regelwerk/ASR/ASR-A3-4>
 occupation density limit: SchulbauV <https://www.gesetze-bayern.de/Content/Document/BaySchulBauV-2>

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air quality (48 rooms)

- rarely consistent window ventilation behavior
- CO₂ peaks over 2700 ppm

acoustics (56 rooms)

- only one in five rooms meets inclusive requirements
- increased vocal stress due to reverberation/background noise

lighting (48 rooms)

- strongly dependent on seating
- locally below 300 lx in every other room

- ▶ occupancy density often close lower limit of 6 m³ per pupil
- ▶ deficits in all areas

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Old news ...
The deficits have been known long enough now!

So why is progress in Germany so slow?
(Scandinavia is doing a lot better ...)



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Courage to be 'good enough' – Pareto instead of best practice?

Practical and SMART refurbishment

current situation

- strong focus on individual flagship projects, but insufficient overall progress



- health-promoting classrooms are possible with sufficient resources, but: **every 2nd school in need of renovation**



33.000 schools – 33.000 Beacon projects?

- comprehensive (initiative for) classroom refurbishment would take forever!

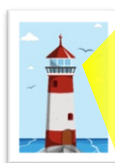


- **recognized and practicable concept is missing** ➡

Start with Good Practice or postpone Best Practice?

80%

100 %



What a practicable and SMART refurbishment concept should include ...

- S** Swift and without cancellation of lessons
- M** Modular, ability to flexibly position ventilation unit, acoustic elements and lighting according to the modular principle and combine them regardless of manufacturer
- A** Adaptable to a wide variety of spatial conditions
- R** Reduced pre-planning effort and a high degree of universality to enable nationwide implementation
- T** Temperature/air/lighting/acoustics addressed simultaneously to integrally improve the teaching and learning environment



beacon:
<https://de.vecteezy.com/vektorkunst/9576482-clipart-leuchtturm-im-flachen-stil-vektor-illustration>

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33.000 schools – one common denominator?

As different as classrooms may be,
the ceiling is usually free for refurbishments!

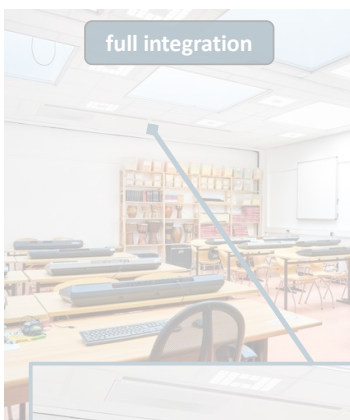


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One SMART approach, many possible solutions!

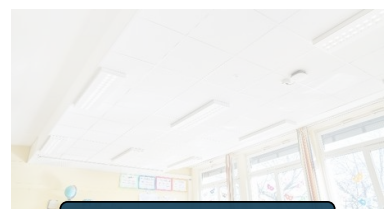
Air, lighting and acoustics always in a single step...



full integration



partial integration



suspended ceiling stripe



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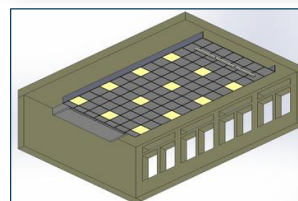
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SMART intervention

Ceiling ventilation unit + system ceiling upon



- ceiling ventilation unit with heating circuit integration
- suspended acoustic ceiling as longitudinal stripe
- LED lighting with daylight/presence detector



simultaneous addressing of all deficits via ceiling



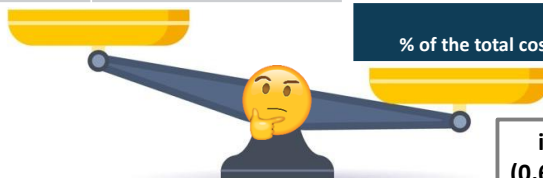
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SMART intervention

What did it do, what did it cost? (example: elementary school classroom)

	before	after (refurbished)
ventilation	natural ventilation peaks: > 2700 ppm mean: > 1000 ppm	decentral ventilation unit peaks: < 1500 ppm mean: < 1000 ppm
lighting	fluorescent tubes power: 464 W mean: 280 lx	LED inlay lights power: 328 W (-29 %) mean: 980 lx (+71 %)
acoustics (reverb.)	exposed concrete mean: 1.2 s	suspended ceiling mean: 0.6 s (desired: 0.5 s)



(relative) annual cost (for typical service life/maintenance)

	Per room	per person (n = 25)	per person (n = 34)
ventilation/heating + maintenance	1610 €	64.41 €	47.35 €
lighting	105 €	4.20 €	3.09 €
suspended acoustic ceiling	116 €	4.64 €	3.41 €
sum	1831 €	73.24 €	53.85 €
% of the total cost p. p (9500 €)	—	0.8 %	0.6 %

**investment/maintenance < 75 EUR
(0.6 to 0.8 % of total cost p. p. and year)**



scale: <https://www.istockphoto.com/de/vektor/symbol-skalierten-waage-isoliert-auf-wei%C3%9Fem-hintergrund-vektorillustration-gm1458798028-493306057> 14

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