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Indoor air problems and the perceived social climate in schools: a multilevel structural equation analysis

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Abstract

Indoor air problems in schools appear to influence learning outcomes and absence rates. However, previous research has not investigated whether indoor air problems influence the social climate of schools. Therefore, we studied whether indoor air problems observed in schools associate with students' perceptions of the teacher-student relationship and class spirit. The nationwide sample of Finnish schools (N = 194 schools/27 153 students) was analyzed using multilevel structural equation modeling. Data on the schools' social climate collected from students were merged with independently collected data on observed indoor air problems from school principals. We found that the teacher-student relationship was reported to be worse in schools with observed indoor air problems compared to those without observed indoor air problems. Furthermore, the reported class spirit was worse in schools with observed indoor air problems, but only among students with a high grade point average. Our findings indicate that indoor air problems may affect the student-perceived social climate.

Keywords (6): indoor air quality, social climate, teacher-student relationship, psychosocial effect, lower secondary school, class spirit

1. Introduction

Problems in schools' indoor air quality (IAQ) are widespread. For example, some 24% of schools in Finland, 20% in the Netherlands, and 40% Spain were estimated to have moisture problems, such as dampness or mold. [1] Furthermore, many studies have found that a large proportion of schools are inadequately ventilated. [2–4] Such problems can increase the risk to students' health, [5,6] absence rates, [7,8] and decreased academic performance (e.g., standardized test scores). [3,7,9]

Despite these findings, little is known about whether and how poor IAQ associates with the students' perception of *social* climate in schools. The social climate reflects, for instance, the goals, norms, interpersonal relationships and teaching practices, organizational patterns, and school facilities present in a specific school. [10,11] Poor student-perceived social climate associates with students' decreased well-being and academic performance, [10–13] lower self-esteem [14] and problems in their school adjustment [15,16], for example. Given that the perceived social climate plays an important role in students' psychosocial well-being and learning, it is essential to study how schools' IAQ problems relate to it. The need to study the effects of IAQ on the *social* climate in schools is acknowledged in the "indoor air research" literature as well. [17]

1.1. Student-perceived social climate and indoor air problems in schools

Although there is no previous research assessing whether and how schools' IAQ problems relate to the student-perceived social climate, some indirect evidence suggests that there may be an association between them. Previous research has associated schools' IAQ problems with increased rates of teachers' sick leave and decreased well-being, [18, 19] and it may induce interpersonal conflicts as well as anxiety and fear.[20] Furthermore, it has been shown that teachers, who perceive their school's physical environment unsatisfactory, report more negative attitudes and lower

moral toward their work and notice more problems in the school's social climate than teachers who perceive the environment as satisfactory. [21–23] Finally, also principals' perceptions of their school's physical environment has been associated with their understanding of the school's ability to deliver instruction.[24]

However, it is unlikely that IAQ problems influence only school personnel. First, given that school's organizational culture and teachers' well-being and attitudes relate to the student-perceived social climate, [25–28] it is plausible that also students in schools with IAQ problems report lower social climate than students in schools without such problems. Furthermore, previous research indicates that also students' perceptions of their school's physical environment associate with how they perceive the school's social climate. [11,29] Finally, students' absence rates have been found to be higher in schools with poor IAQ than in schools without such problems, [8] which may also reflect issues in the social climate, since the social climate associates with school absenteeism. [30] Based on the evidence, it appears that schools' IAQ problems may relate to factors which constitute the student-perceived social climate, such as perceived social support, discipline, and peer relationships, in many ways.

1.2. The present study

In this study, we focus on two highly relevant factors of the student-perceived social climate: perceived quality of teacher-student relationship and perceived class spirit (i.e., the classroom's emotional climate). [10,31] These factors are very influential for students' academic performance, school engagement, health, and health-related behaviors, for example. [32–34] Therefore, it is important to know whether and how IAQ problems in schools relate to these factors. Our first research question asks whether the perceived teacher-student relationship and class spirit among

lower secondary school students differ between schools with observed IAQ problems and schools without such problems. Based on the literature cited above, [18,20,22,26] we hypothesize that students in schools with IAQ problems report worse perceived quality of the teacher-student relationship and class spirit than students in schools without such problems (H1).

Our second research question asks whether the associations between *student-level characteristics* (e.g., gender) and the student-perceived social climate are different in schools with and without IAQ problems. The need to study this issue is based on previous research showing that students' perceptions of their school's social climate is associated with many student-level characteristics, such as gender, socioeconomic status, ethnicity, social support, and academic performance; [13,35,36] different students perceive the social climate of their school differently. Given that not only student characteristics but also contextual factors can have effects on the student-perceived social climate, [37] we also tested whether the association between *school-level characteristics* (e.g., school size) and the student-perceived social climate are different in these two school contexts. Analyzing these interactions was considered important since is provides information on whether there are certain types of students or schools that are especially susceptible to report poor teacher-student relationship or poor class spirit when facing IAQ problems. Given that there are no previous studies considering this issue, no hypothesis is posed.

2. Material and methods

2.1. Data and participants

The data were obtained from two sources: a) the School Health Promotion Study (SHP) 2013, focusing on comprehensive school students in grades eight and nine (14–16 years old) and b) the Benchmarking System of Health Promotion Capacity Building (BSHPCB) data collections from comprehensive schools in 2013 (for more details, see Finell et al., 2017). [38] The questionnaire of BSHPCB is usually filled in by the school's principals. Two variables from BSHPCB were used in the analysis. The first variable measured if and when the triennial inspection required by Health Care Act 1326/2010 had been carried out in the school. This regulatory inspection is done in co-operation with the representatives of the school (e.g., a principal), the health authorities, and authorities responsible for construction and maintenance of the school building. It includes a number of factors (not just IAQ related) which can influence the well-being of the school community. The inspection of the indoor environment includes review of existing documents, such as results from possible questionnaires on IAQ and health, IAQ measurements, and other building related reports as well as a building walkthrough focusing on areas where problems have been found or suspected (see Finell et al., 2017; Hietanen-Peltola and Korpilahti, 2015). [38, 39]

The second variable measured whether or not there were biological exposures observed in the school during this regulatory inspection (see 2.2.2.). BSHPCB questionnaire also asks about physical and chemical exposures. However, we focus only on the item measuring biological exposures here because these issues, especially dampness and mould ("mouldy schools") have been under intensive public concern since 1990's in Finland. In the future, it would be interesting to perform comparative analyses on the other two items to test whether the associations with schools' social climate would be different. For the analysis, we included only those schools where a) the inspection was carried out in

2012 or 2013 and b) where 1) biological exposures were identified during the inspection but the problems had not been remediated or 2) no indoor air problems were identified. This means that 73 schools (N=10181 students, 27%) were excluded from the group of schools where the regulatory triennial inspection was carried out in 2012 and 2013. In these schools a) the biological exposures were not included in the inspection, b) problems were found and they were already corrected or c) no information were provided (see Measures). Sixteen schools with fewer than 10 students were also excluded from the analysis (total of 66 students, 0.2%). In addition, respondents who reported their age as at least two years younger or three years older than the average age of their classmates were excluded from the analysis (n= 64, 0.2%). Two schools with 16 and 12 students were excluded, because they were considered to be school-level outliers (in the teacher-student relationship). The final data consist of 27153 students from 194 schools. About 63 per cent of the students were from schools without observed indoor air problems (17127 students from 127 schools).

2.2. Measures

2.2.1. Outcome variables

The perceived quality of the teacher-student relationship was measured by three items: "Teachers are interested in how I am doing", "Teachers treat us, the students, fairly", and "The opinions of students are taken into consideration in the development of school work". The response scale was 1 = fully agree, 2 = agree, 3 = disagree, and 4 = fully disagree. These items have been used in many previous studies as indicators of the teacher-student relationship. [27,40,41] We modeled teacher-student relationship as a latent factor with these three items. The standardized loadings of the confirmatory factor analysis are presented in Table 2. The fit indicators are reported in Result section (see also Supporting information). The Cronbach alpha was 0.63.

The *class spirit* was measured by three items: "The students in my class get along well", "The classroom discipline in my class is good" and "The mood in our class is such that I dare to express my opinion freely". The response scale was the same as above. These items have been used previously by Karvonen and colleagues [40] as an indicator of class spirit. As above, we modeled class spirit as a latent factor. The standardized loadings are presented in Table 2. The fit indicators are reported in Result section (see also Supporting information). The Cronbach alpha was 0.67. The data source of the outcome variables was the SHP.

2.2.2. Predictor

The BSHPCB survey item "Were the following issues evaluated in the most recent inspection: Exposure to biological agents (indoor air, mold, etc.)" had the following response options: no data available; not included in the inspection; inspected, no deficiencies detected; inspected, deficiencies detected but not yet corrected; inspected, deficiencies detected and corrected. In this study, we focus only on the following options: 0 = inspected, no deficiencies detected and 1 = inspected, deficiencies detected but not yet corrected. The resulting variable is referred to as "observed IAQ problems".

2.2.3. Background variables

Gender (0 = boy, 1 = girl), *age*, *perceived health*, *parental support,* and *education of the mother* were included only at the student-level (see Statistical analyses and Figures 1 and 2 below). *Perceived health* was measured by the item: "How is your health in general?" The response scale was 1 = very good, 2 = fairly good, 3 = moderate, and 4 = fairly or very poor The scale was categorized into two categories (0 = very good, 1 = not very good), because only a small proportion reported moderate or bad health. The similar kind of categorization has been used in

other indoor air studies. [42, 43] *Parental support* was measured by a single item: "Can you talk about things that concern you with your parents?" The response scale was 1 = hardly ever, 2 = every once and a while, 3 = fairly often, and 4 = often. The scale was reversed so that 1 indicated good support and 4 low support. *Education of the mother* was measured based on response options 1 = comprehensive school or primary school, 2 = upper secondary school or vocational education institution, 3 = occupational studies in addition to upper secondary school or vocational education institution, 4 = university, university of applied sciences, or other higher education institution, and 5 = no education. The responses were categorized into two categories: 0 = no university degree education, 1 = university, university of applied sciences, or other higher education institution (i.e., university degree). Parents' higher education has shown to relate strongly to many important factors in Finland such as their children's future participation in higher education [44] and school choice. [45]

Students' self-reported grade point average (GPA) and *ethnic background* were included both at the student- and the school-levels (see Statistical analyses and Figures 1 and 2 below). In Finland, grades range from 4 (low) to 10 (high). In the original data, GPA was categorized into eight categories (1 = < 6.5, 2 = 6.5–6.9, 3 = 7.0–7.4, 4 = 7.5–7.9, 5 = 8.0–8.4, 6 = 8.5–8.9, 7 = 9.0–9.4, and 8 = 9.5–10). These categories were recoded into three approximately equally sized categories: 0 corresponding to a GPA less than 7.5, 1 corresponding to a GPA between 7.5 and 8.4, and 2 corresponding to a GPA more than 8.4. *Ethnic background* was measured by two items: In which country were your 1) mother and 2) father born? The items were recoded so that the value 0 means that one or both parents were born in Finland, whereas the value 1 means that both parents were born outside Finland. Given that immigration on a larger scale started in Finland as late as in the 1990s, [46] it is very unlikely that second generation immigrants would have children of

the target age. No missing items were accepted. The data source of all the aforementioned background variables was the SHP.

The *school's size* (i.e., number of students) reported in the BSHPCB was used only as a school-level background variable.

2.3. Statistical analyses

Given that in our data, school children were nested within schools, we built and then analyzed a multilevel structural equation model (MSEM). MSEM makes it possible to decompose both the variance and the measurement error of the outcome variables at the student- and school-levels. [47,48] As previously, [38] we used full information maximum likelihood estimation (FIML) with robust standard errors as an estimation method. Mplus statistical software 7.0 was used in the analysis. [49]

First, we tested the model fit of each measurement model (see Figures 1 and 2). This was done by carrying out a two-level confirmatory factor analysis for both the teacher-student relationship and class spirit variables separately. The loadings were fixed equally at the student and school-levels [47] (see Table 2 and further information on measurement models in Supporting information). We used the Standardized Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA) as fit indicators in all the models. SRMR < 0.08, CFI > 0.95, and RMSEA < 0.06 indicates a good fit between the hypothetical model and the observed data. [50] Due to the large sample size, the chi-squared test was not used. After the two-level confirmatory factor analyses was carried out, we calculated the intraclass correlations (ICC) of the latent factors (i.e., teacher-student relationship and class spirit) and each predictor.[47]

Figures 1 and 2 here

In order to test whether observed IAQ problems associated with the teacher-student relationship and class spirit (H1), we estimated two random intercept models (see Figures 1 and 2). In the random intercept model, the intercept coefficients are allowed to vary across schools. To avoid biased results we used latent factors instead of aggregated variables in both level as recommended. [53] This method allowed us to decompose the covariates into two uncorrelated latent factors by Mplus. The first component represents the deviation of students' answers from their school mean (i.e. student level). The second component represents the school mean (e.g. the cluster mean of school-related stress) and it reflects the deviation of each school mean from the grand mean (i.e. school level). [54, 55] All predictors, except the dichotomous ones, were centered by their grand means.

The hypothesized random intercept models are presented in Figures 1 and 2. *First*, we used gender, age, perceived health, and parental support only as student-level variables because of their low intraclass correlations (ICC ≤ 0.01)[47]. We also included the mother's education only at the student-level because it had a high correlation with GPA at the school-level (r = 0.70). Furthermore, the univariate associations between mother's education and outcome variables were not significant at the school-level. *Second*, we included school size and observed IAQ problems only at the school-level. *Finally*, we included the ethnic background (ICC = 0.07) and GPA (ICC = 0.04) both at the student and school-levels. This was possible by decomposing each variable into two latent uncorrelated components (one at the student-level and one at the school-level) by Mplus as explained above. [49,54]

In the text we report the standardized estimates (i.e., when the predictor increases by one standard deviation, the outcome variable increases by the standardized estimate) as well as separate R^2 for both the student- and school-levels provided by Mplus.[56] *In the tables* we also report the unstandardized estimates. When necessary, we report the effect sizes. The effect size is calculated as follows: the unstandardized beta divided by the standard deviation of the factor in the measurement model. This index is equivalent to Cohen's d. [57] Finally, we checked the linearity of the main associations by including the quadratic terms of each variable (except the dichotomous ones) in the models. If the quadratic term was significant ($p < 0.05$), it was included in the final model and reported.

Next, we tested whether observed IAQ problems modify the associations between background variables and outcome variables. Two identical models were built for 1) schools with observed IAQ problems and 2) schools without observed IAQ problems. The models were tested simultaneously (i.e., multigroup two-level structural equation modeling). [58] All included background variables were the same as in Models 1a and 1b (see Table 2). The Wald-test was used to determine whether the associations between background variables and outcome variables in the two contexts (i.e., observed IAQ problems vs. no observed IAQ problems) differed significantly from each other ($p < 0.05$).

2.4. Missing values

Gender and observed IAQ problems had the lowest percentages of missing values (0%) and the mother's education had the highest (10%). Values were assumed to be missing at random (MAR).[59] In order to deal with missing data, we used a full information maximum likelihood (FIML)

estimation that produces unbiased values of parameters by determining the value that maximizes the likelihood function based on all available data. [560]

3. Results

Descriptive statistics of the observed outcome variables and background variables are presented in Table 1. Only one significant difference in background variables between schools were found: students reported significantly worse perceived health in schools with observed IAQ problems than in schools without such problems (see Table 1).

Table 1. Descriptive statistics of the full data by indoor environment context (outcome and background variables N = 24451–27153students/192–194 schools).

	No observed IAQ problems		Observed IAQ problems		
	N	% or Mean (SD)	N	% or Mean (SD)	p^f
Outcome variables					
Teachers are interested in how I am doing (%)					
Fully agree	632	4	337	3	
Agree	6725	40	3746	38	
Disagree	7902	47	4795	48	
Fully disagree	1697	10	1058	11	0.003
Teachers treat us, the students, fairly (%)					
Fully agree	1836	11	899	9	
Agree	10478	62	6000	61	
Disagree	3713	22	2386	24	
Fully disagree	897	5	629	6	0.000
The opinions of students are taken into consideration in the development of school work (%)					
Fully agree	962	6	426	4	
Agree	8877	53	5050	51	
Disagree	5885	35	3611	37	
Fully disagree	1173	7	786	8	0.000
The students in my class get along well (%)					
Fully agree	3645	22	1993	20	
Agree	9827	58	5684	57	
Disagree	2832	17	1815	18	
Fully disagree	646	4	426	4	0.000
The classroom discipline in my class is good (%)					
Fully agree	1424	8	709	7	
Agree	8464	50	4804	49	
Disagree	5500	32	3428	35	
Fully disagree	1562	9	972	10	0.000
The mood in our class is such that I dare to express my opinion freely (%)					
Fully agree	5046	30	2931	30	
Agree	8332	49	4787	48	
Disagree	2802	17	1705	17	
Fully disagree	785	5	500	5	0.176
Background variables					
Gender (female %)	8430	49	4990	50	0.382
Age (years)	16635	15.4 (0.6)[a]	9729	15.4 (0.6)[b]	0.639
Perceived health (very good %)	5915	35	3172	32	0.000
Parental support (%)					
Often	4528	27	2574	26	
Fairly often	5424	32	3278	33	
Every once and a while	5534	33	3201	33	
Hardly ever	1325	8	793	8	0.259
Grade point average (%)					
< 7.5	5556	33	3320	33	
7.5–8.4	6399	38	3731	38	
> 8.4	5054	30	2879	29	0.327
Education of mother (university degree %)	5727	37	3276	37	0.437
Ethnic background (both parents born outside of Finland %)	654	4	346	4	0.125
School size (students per school)	125[e]	332.7[c] (187.5)	67	379.7[d] (187.6)	0.099

[a] Min–max: 13.5–18.2
[b] Min–max: 13.5–18.1
[c] Min–max: 67–936
[d] Min–max: 53–933
[e] Missing information from two schools
[f] Age and school size: F-test. All other variables: χ^2 – test

3.1. The association between observed IAQ problems and the student-perceived schools' social climate

First, we tested the fit of each measurement model (see Figures 1 and 2) by carrying out a two-level confirmatory factor analysis for each variable separately. In order to do that we fixed the loadings equally at the student and school-levels. [47] The model fits were good both for the teacher-student relationship (RMSEA = 0.01, CFI = 1.00, SRMR: student-level = 0.00, SRMR: school-level = 0.08) and class spirit (RMSEA = 0.01, CFI = 1.00, SRMR: student-level = 0.00, SRMR: school-level = 0.05). The standardized factor loadings are presented in Table 2 (see further information on measurement models and the fit indicators in Supporting information).

Table 2. Standardized loadings of the teacher-student relationship and class spirit latent variables (student-level: N = 27018–27025/ School-level: N = 194).

Teacher-student relationship		Class spirit	
Student-level		*Student-level*	
	λ		λ
The opinions of students are taken into consideration in the development of school work.	0.65*	The students in my class get along well.	0.73*
Teachers are interested in how I am doing.	0.56*	The classroom discipline in my class is good.	0.54*
Teachers treat us, the students, fairly.	0.60*	The mood in our class is such that I dare to express my opinion freely.	0.63*
School-level		*School-level*	
The opinions of students are taken into consideration in the development of school work.	0.91*	The students in my class get along well.	0.87*
Teachers are interested in how I am doing.	0.67*	The classroom discipline in my class is good.	0.57*
Teachers treat us, the students, fairly.	0.71*	The mood in our class is such that I dare to express my opinion freely.[a]	1.00*

* $p < 0.001$

[a] The residual variance is set to zero at the school-level.

There was a statistically significant variability both in the latent teacher-student relationship - variable within ($\sigma^2_{W} = 0.204$, $p < 0.001$) and between schools ($\sigma^2_{B} = 0.010$, $p < 0.001$) and in the latent school spirit - variable within ($\sigma^2_{W} = 0.276$, $p < 0.001$) and between schools ($\sigma^2_{B} = 0.012$, $p < 0.001$). The ICC of the both latent variables were 0.05 and 0.04 respectively, meaning that about 4–5% of the variability occurred between schools. Although the ICCs were relatively small, they had strong design effects (DEFF;[61] teacher-student relationship: DEFF = 7.46; school spirit: DEFF = 6.76).

Then we estimated two random intercept models (i.e., Model 1a and Model 1b) in order to test whether the perceived teacher-student relationship and class spirit differed between schools with and without observed IAQ problems (see Table 3). The model fits were good both for the teacher-student relationship (Model 1a: RMSEA = 0.02, CFI = 0.97, SRMR: student-level = 0.01, SRMR: school-level = 0.07, see Table 2) and for school spirit (Model 1b: RMSEA = 0.02, CFI = 0.99, SRMR: student-level = 0.01, SRMR: school-level = 0.06, see Table 2). After all background variables were inserted into Model 1a, observed IAQ problems associated significantly with the teacher-student relationship. The effect size was 0.5, indicating a medium-sized effect [57]. However, after all background variables were inserted into Model 1b, observed IAQ problems did not associate significantly with school spirit (see further information on univariate associations in Supporting information) .

In Model 1a, the most important student-level background variables were parental support, perceived health, and GPA. The most important school-level background variables were ethnic composition (measured by students' self-reported ethnic background) and the school's average GPA. In Model 1b, the most important student-level background variables were parental support, gender, and perceived health. The most important school-level background variables were school

size and the school's average GPA (see Table 2). Model 1a explained 11% of the total variance at the student-level (R^2 = 0.114) and 22% at the school-level (R^2 = 0.222). Model 1b explained 8% of the total variance at the student-level (R^2 = 0.077) and 16% at the school-level (R^2 = 0.157), respectively (see Table 2).

Table 3. Parameter estimates for the teacher-student relationship and the classroom's social climate[1] as a function of student- and school-level variables: A random intercept model (N=27153 students/194 schools).

	Model 1a **Teacher-student relationship**		Model 1b **Class spirit**	
	B (SE)[a]	**β (SE)[b]**	**B (SE)[a]**	**β (SE)[b]**
Student-level				
Gender[c]	-0.06 (0.01)***	-0.07 (0.01)***	0.13 (0.01)***	0.13 (0.01)***
Age[d]	0.01 (0.01)	0.02 (0.01)	-0.02 (0.01)	-0.02 (0.01)
Age squared[e]	-0.06 (0.01)***	-0.06 (0.01)***		
Perceived health[f]	0.08 (0.01)***	0.09 (0.01)***	0.16 (0.01) ***	0.15 (0.01)***
Parental support[g]	0.12 (0.00)***	0.26 (0.01)***	0.07 (0.01)***	0.13 (0.01)***
Parental support squared[e]	0.03 (0.00)***	0.06 (0.01)***	0.02 (0.01)***	0.03 (0.01)***
Education of mother [h]	0.05 (0.01)***	0.06 (0.01)***	-0.02 (0.01)	-0.01 (0.01)
Grade point average[i]	-0.06 (0.01)***	-0.11 (0.01)***	0.01 (0.01)*	0.02 (0.01)*
Grade point average squared[e]	-0.02 (0.01)*	-0.02 (0.01)*		
Ethnic background[j]	-0.02 (0.03)	-0.01 (0.01)	0.08 (0.03)**	0.03 (0.01)**
School-level				
Observed IAQ problems[k]	0.05 (0.02)**	0.25 (0.08)**	0.02 (0.02)	0.08 (0.08)
Grade point average[d]	-0.22 (0.09)*[l]	-0.28 (0.10)**	-0.24 (0.09) **	-0.27 (0.10)**
Ethnic background	-0.36 (0.12)**	-0.19 (0.09)*[n]	0.03 (0.19)	0.02 (0.09)
School size [o]	0.01 (0.00)[m]	0.16 (0.08)*	0.01 (0.01)*	0.24 (0.09)*
σ^2_W	0.17 (0.01)	0.89 (0.01)	0.24 (0.01)	0.92 (0.01)
σ^2_B	0.01 (0.00)	0.78(0.07)	0.01 (0.00)	0.84 (0.08)

*$p < 0.05$, **$p < 0.01$, *** $p < 0.001$

[1] A higher value in the teacher-student relationship and the classroom's social climate means more problems.

[a] Unstandardized beta

[b] Standardized beta

[c] Scale 0–1 (0 = boy)

[d] Grand mean centered

[e] Quadratic term. Only if the quadratic term was significant ($p < 0.05$), it was included in the final model and reported. There were no significant quadratic terms at the school-level.

[f] Scale 0–1 (0 = very good health)

[g] Scale 1–4 (1 = good support, grand mean centered)
[h] Scale 0–1 (1 = university education)
[i] Scale 0–2 (0 = GPA less than 7.5, grand mean centered)
[j] Scale 0–1 (0 = one or both parents are born in Finland)
[k] Scale 0–1 (0 = no observed IAQ problems in the school)
[l] $p = 0.012$
[m] $p = 0.064$
[n] $p = 0.027$
[o] In these models the scale was changed as follows: school size/100.

3.2. The effect of the school's IAQ problems on the associations between the background and outcome variables

We tested differences on the associations between a) student-level characteristics and the student-perceived social climate and b) school-level characteristics and the student-perceived social climate in schools with and without IAQ problems. In order to test these differences we used multigroup two-level structural equation modeling and Wald-test. The association between student-level GPA and class spirit was moderated by observed IAQ problems (Wald-test = 6.04, $p = 0.014$). This association was stronger in schools with IAQ problems (standardized beta = 0.05, $p < 0.001$) than in schools where there were no such problems (standardized beta = 0.00, $p = 0.821$; see further information on univariate associations in Supporting information). In order to better understand this result, we ran three separate analyses. We tested students whose GPA was a) less than 7.5, b) between 7.5 and 8.4 and c) over 8.4. Except for GPA, the other background variables in these three analyses were the same as in Model 1b (see Table 2). Students with the highest GPA (i.e., over 8.4) perceived more problems in class spirit in schools with observed IAQ problems than in schools without such problems (standardized beta = 0.19, $p = 0.032$). The effect size is 0.4, indicating a small-sized effect. [57] There were no differences between schools among students in the lower GPA clusters (GPA 7.5–8.4: standardized beta = 0.12, $p = 0.193$; GPA < 7.5: standardized beta = 0.01, $p = 0.948$).

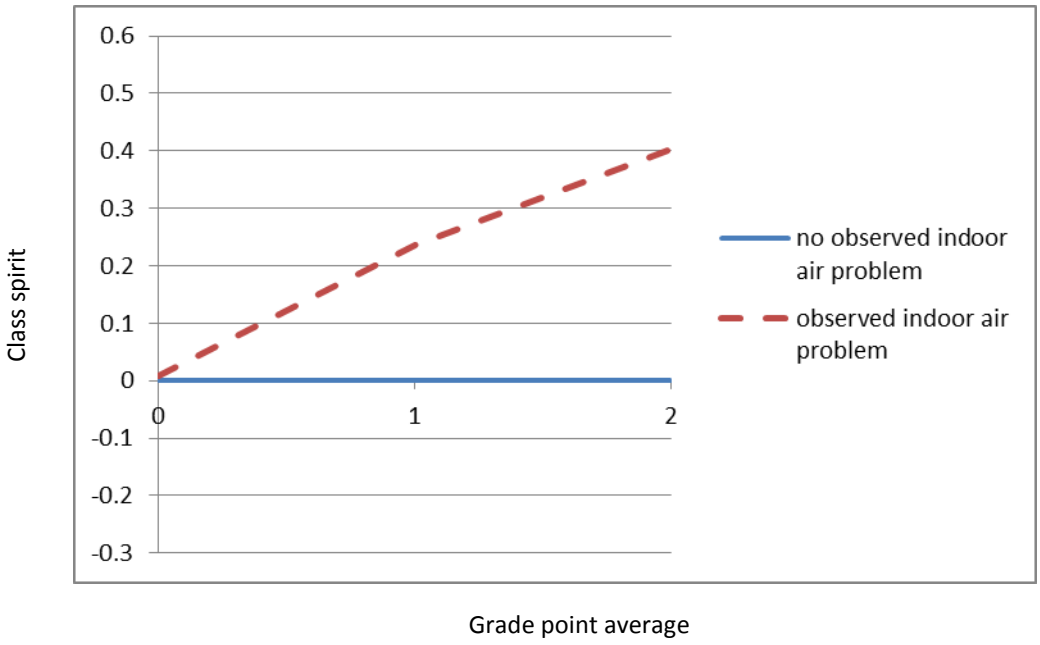

Figure 3. The mean difference of class spirit between schools with and without observed IAQ problems divided by the standard deviation of class spirit.
0 = GPA < 7.5, *p* = 0.948; 1 = GPA 7.5–8.4, *p* = 0.193; 2= GPA > 8.4, *p* = 0.032 (N = 193–194 schools).

Furthermore, the linear terms of the parental support and teacher-student associations were significantly different (Wald-test = 4.75, $p = 0.029$) between the two school contexts (no observed IAQ problems: standardized beta = 0.27, $p < 0.001$; observed IAQ problems: standardized beta = 0.23, $p < 0.001$; see further information on univariate associations in Supporting information). The Wald-test between quadratic terms was not significant (Wald-test = 0.50, $p = 0.479$). This small effect indicates that the difference in the perceived quality of the teacher-student relationship between the two school contexts was larger among students with high parental support than students with low parental support. In total, students with low parental support, however, evaluated their teacher-student relationship more negatively than students with high parental support.

4. Discussion

Our main finding was that on average, students in schools with observed IAQ problems reported worse teacher-student relationship than students in schools without such problems. Furthermore, we found that students with a high GPA reported worse class spirit in schools with IAQ problems than in schools without such problems.

Previous research has reported associations between poor IAQ in schools and both health and learning outcomes (e.g., respiratory symptoms, illness absence, and academic performance). [3,7,9,62] Our findings contribute to this research by showing that IAQ problems in schools may have an effect on the student-perceived social climate. To our knowledge, this is the first time when these effects have been assessed. Given that social climate is shown to influence various factors, such as academic performance, absence rates, and students' psychosocial well-being, [10,30,31] our findings are important. Furthermore, we found that a school's observed IAQ problems significantly modified the associations between student-level characteristics and the student-perceived social climate. Although these associations were weak, the findings supported the previous research by Finell and colleagues[38] by concluding that schools with and without IAQ problems may represent two different social contexts. They also suggest that the social and psychological consequences of IAQ problems in schools result from complex processes where both the students' and school personnel's characteristics play a role.

An important task for future research is to examine why IAQ problems in schools may influence the student-perceived social climate. Our results and the literature provide three potential intertwined paths. The first path relates to the impact of poor IAQ on *school personnel,* for example by decreasing their well-being, increasing sick leave, and causing possible problems in management and decision-making procedures. [19,20,26,28,63] The second path relates to the impact of

poor IAQ on *students*. The students' perceived health is associated with the student-perceived social climate, [10] as was also found in our study. The third path relates to the poor condition of the school facilities as well as anticipated remediation of the *school building.* [22,23] In Finland, school general management and facility management are independent from each other. In other words, school principals and staff do not have a direct role or oversight of the facility management. They can report any issues or concerns but the allocation of funds for school facility management and remediation decisions are made by the municipality technical board. However, remediation processes often result in disturbances (e.g., moving to temporal buildings and/or noise), which can be stressful both to school personnel and students, and may therefore influence the student-perceived social climate.

From a practical point of view, an important question is how it is possible to prevent the potential social consequences caused by IAQ problems in schools. The main task is naturally to investigate and properly remediate indoor air problems in the school building. However, these processes are often slow. In case the remediation is delayed, the prevention of health problems among teachers and students can involve source control (e.g., more frequent cleaning), enhanced ventilation, and exposure prevention (e.g., not using problematic areas). Furthermore, management and decision-making procedures should be developed in order to avoid conflicts inside the school organization and experiences of injustice.[64] Open communication and sharing up-to-date (regular, factual) information with school personnel, students, and parents should help to maintain trust between parties.

The strengths of the study include the large and representative sample. The use of multilevel structural equation models has many advantages, including better statistical power compared to models using aggregated school-level data and avoiding spurious findings from using student-level

data without taking the hierarchical data structure into account. [48] The limitations of the study include the cross-sectional design and the use of questionnaire data. Furthermore, we did not have physical measures. This means that we have to rely on principles report on the findings of triennial inspection on biological exposures and that we are cannot better distinguish schools based on the factors that have caused their IAQ problems. It is likely that there exists variation in the severity of schools' IAQ problems and their social consequences. We also do not know the degree teachers and students were aware of their school's IAQ problems. In the future, these issues should be further studied using longitudinal data and physical measures. Future research should also detect factors that can mediate the association between school's indoor environment and the perceived social climate. Also possible building-related confounders (e.g., poor sanitary conditions or unpleasant school environment) should be considered.

The present study is part of a larger project aiming to clarify associations between psychosocial factors and IAQ problems among comprehensive school students in Finland. In a previous study, we found associations between both the physical and psychosocial environment and subjective IAQ in schools. [38] In the present study, psychosocial factors are the outcome variables. Our study underlines the fact that the associations between the perception of IAQ problems and psychosocial factors are highly complex and are likely to influence each another in various ways.

5. Conclusions

Our study found that problems in a school's IAQ associated with the student-perceived social climate. Furthermore, we found that the school's observed IAQ problems significantly modified the associations between student-level characteristics and the student-perceived social climate. Our study points to a need to study schools' IAQ problems from a multidisciplinary perspective in order to better understand how IAQ problems influence students' psychosocial well-being. Furthermore, from practical point of view, when evaluating the urgency of remediation, also IAQ problems' possible social consequences should be taken into account. Fast and effective remediation process not only prevent adverse health effects but can also prevent problems in school's social climate.

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Figure 1

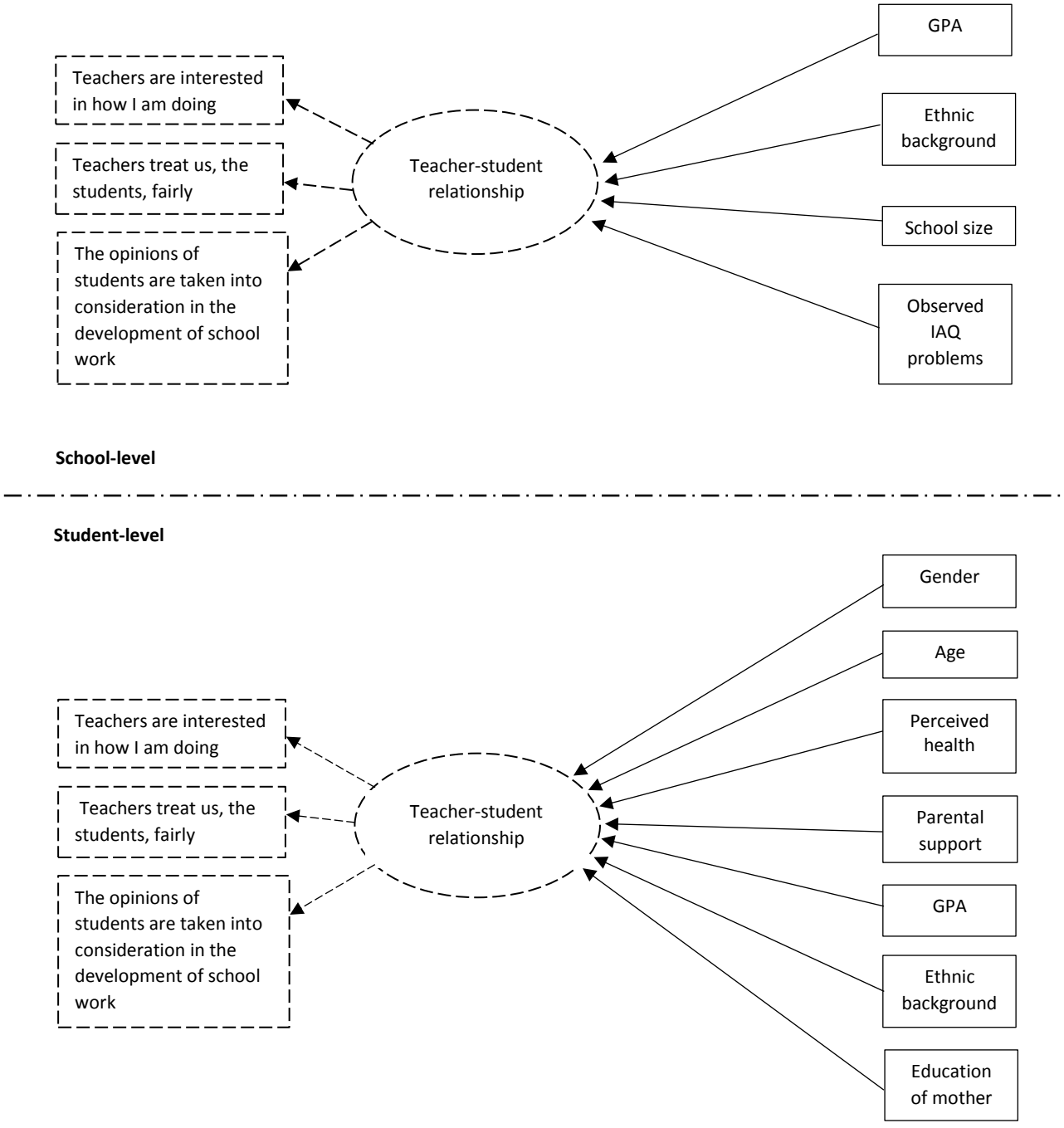

Figure 1. Hypothesized structural equation model: The teacher-student relationship as a latent outcome variable.

Figure 2

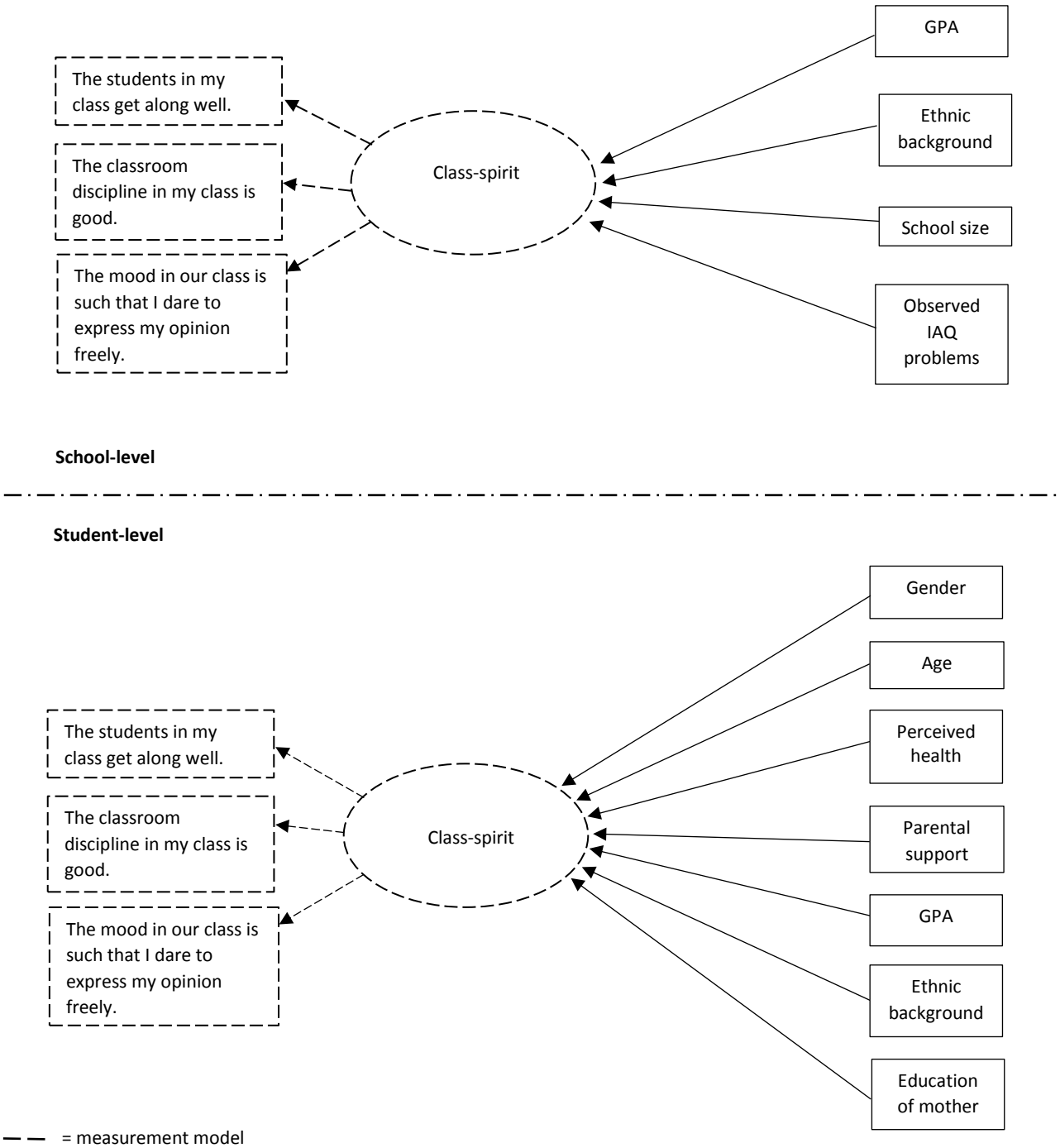

Figure 2. Hypothesized structural equation model: Class spirit as a latent outcome variable.