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Understanding social wellbeing in classrooms: the influence of peer networks

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ABSTRACT

Background: The wellbeing of pupils is increasingly recognised as a key factor in education, with the role of schools in shaping it emphasised across the literature. Classroom peers are likely among the most influential social connections of individuals during their formative years, and while pupils' own peer relationships have been widely studied, the relation between classroom networks and pupil wellbeing remains underexplored.

Purpose: This study explored the relationship between structural features of pupils' classroom and individual networks and their social wellbeing (defined through four domains: *loneliness*, *belonging*, *acceptance*, and *prosociality*).

Method: Based on self-reported peer interactions among all pupils in 905 Danish classrooms (16,961 children aged 10–15), we identified individual (direct connections) and classroom networks (connections among all pupils in class). Using linear regression methods and controlling for key pupil characteristics and school-fixed effects, we analysed the importance of structural features of both types of networks for pupils' social wellbeing.

Findings: The findings revealed quantifiable and empirically significant associations between specific peer network structures and pupils' social wellbeing, suggesting that denser, more clustered, less reciprocated, and less centralised classroom networks were positively associated with social wellbeing, although the inclusion of pupils' individual networks reduced these associations. The study also found that larger and stronger individual networks were positively associated with social wellbeing outcomes.

Conclusion: The study's findings suggest that there is a role for future research studies in further distinguishing between varying levels and structures of peer networks, to explore their relationship with different domains of social wellbeing. The findings have relevance for teachers, helping them to broaden and nuance their understanding of peer networks, and their links to social wellbeing, and better equipping them to influence and improve peer relations in class.

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Introduction

Recent decades have witnessed increased academic and political interest in pupil wellbeing, and across countries there is an evolving consensus that schools play an important role in supporting such wellbeing (Currie et al. 2012; Osterman 2000). Despite this widespread interest, there is no single definition of the term that applies across existing work on the subject. In practice, it is a multidimensional construct entailing physical, psychological (or mental health), and social dimensions (Konu and Rimpelä 2002; Soutter, O'Steen, and Gilmore 2013). In the context of pupil wellbeing within schools, the physical dimension typically refers to the environment in and around the school – for example, noise levels and temperature; and pupils' ability to access resources such as computers, books, or school meals. The psychological dimension usually refers to pupils' experiences of 'being well' within school – for example, in terms of their levels of comfort or stress, and the presence of any anxiety or depressive symptoms.

The research reported in this paper focuses specifically on the social dimension of wellbeing, exploring pupils' subjective feelings about peer relations in school, and how these relate to structural features of their peer networks. Existing research has demonstrated that pupils' social wellbeing, such as feelings of belonging and acceptance, are strongly related to the ways in which they interact with peers in school. For example, studies of school belonging have demonstrated its association with peer support and low levels of ethnic discrimination (Allen et al. 2018; McDiarmid et al. 2023), while studies of acceptance show a relationship with (lower levels of) peer rejection, bullying and victimisation (Pakaslahti, Karjalainen, and Keltikangas-Järvinen 2002; Prinstein and Cillessen 2003). Although this research highlights the importance of pupils' peer interactions for their social wellbeing, it focuses primarily on individuals' subjective experiences of their interactions with peers rather than on objective or observable aspects of peer interaction, such as peer interaction networks. Where more objective studies do exist, these have primarily investigated how individual networks composed of peers directly connected to the individual, relate to pupils' academic, behavioural, or mental health outcomes (Lavy and Sand 2012; Ueno 2005), with fewer studies demonstrating how classroom networks composed of all pupils in the classroom, are associated with such outcomes (Ahn and Rodkin 2014; Almquist 2011; Gest and Rodkin 2011; Rimpelä et al. 2020; van Rijsewijk et al. 2018).

The association between peer networks and social wellbeing in school has, to the best of our knowledge, not yet been investigated; however, the literature gives us reason to believe that such a link exists. In this paper, we examine the association between structural features of both individual and classroom peer networks and pupils' social wellbeing, thereby contributing to the literature on social wellbeing in schools by investigating the significance of peer interaction as observed in self-reported peer networks. The study focuses on pupils in Denmark, analysing data from two large-scale surveys – *Klassetrivsel* (Classroom Wellbeing), a digital survey monitoring pupil wellbeing across 25 of 98 Danish municipalities; and the *Danish Student Wellbeing Survey* (DSWS) an annual student wellbeing survey administered to all pupils in Denmark aged 10–15.

Background

The literature on school-level peer networks has predominantly investigated how networks form, and the influence of various pupil characteristics. A common finding is that pupils' network formation is guided by homophily, i.e. that peers who are similar with respect to gender, age, racial or ethnic background, academic achievement, or behaviour tend to group together (An 2022; Bennett and Bergman 2021; Gest, Graham-Bermann, and Hartup 2001; Salmivalli, Huttunen, and Lagerspetz 1997; Vermeij, van Duijn, and Baerveldt 2009). Studies also show that some pupils with specific characteristics; for example, those with Attention Deficit Hyperactivity Disorder (ADHD), autism, or depression, have different – often restricted – access to peer networks (de Boer and Pijl 2016; Pachucki et al. 2015).

Although the main agenda of the social network literature continues to be to understand network formation, there is emerging research that is exploring how features of the networks themselves influence the lives of their agents. Several studies have investigated how features such as different aspects of network structure, relate to various pupil outcomes (Ahn and Rodkin 2014; Cappella et al. 2013; Falci and McNeely 2009; Gest, Graham-Bermann, and Hartup 2001; Gifford-Smith and Brownell 2003; Pachucki et al. 2015; Salmivalli, Huttunen, and Lagerspetz 1997; Ueno 2005). These studies generally find strong associations between individuals' networks and peer experiences, their social behaviour, and their school adjustment. Studies that include school or classroom networks in their analysis also demonstrate that certain structural features of these networks, such as classroom centralisation, clustering, and density are related to pupil outcomes (Almquist 2011; Crudgington et al. 2023; Rimpelä et al. 2020). However, most studies overlook classroom networks entirely. As a result, our understanding of the significance of the social context (in terms of the larger peer group structure) in classrooms remains limited.

Conceptual framework

To investigate how pupils' social wellbeing is related to peer networks, the research reported in this paper explores a range of structural features of both individual and classroom networks. Our selection, definition, and understanding of these structural features, and how they relate to social wellbeing, is based on existing social network theories as well as results from previous empirical analyses. Although social network analysis is a well-established field, the relation between network structures and social outcomes is under-theorised, and we have limited knowledge of how the different features of network structure should be interpreted. In this section, we present and define the structural network features that were selected for this study, and describe existing evidence and theories, indicating how these are relevant to our understanding of social wellbeing.

Social networks, in general, consist of connections between individuals. These connections can be outgoing (from one pupil to a peer or group of peers), incoming (from a peer or group of peers to that pupil), or reciprocated (bilateral). In the context of a classroom, a distinction can be made between individual networks (peers directly connected to the individual) and classroom networks (connections between all pupils in the class).

With respect to individual networks, there is a well-established positive relationship between the size and strength of an individual's network and their social outcomes (Gifford-Smith and Brownell 2003). In this study, we define two aspects of network size as relevant to pupil outcomes: 1) the number of incoming; and 2) the number of outgoing connections for the pupil. Similarly, we define two aspects of network strength as relevant: 1) how reciprocated the pupil's connections are (Baumeister and Leary 1995; Granovetter 1973); and 2) how connected the pupil's outgoing connections are (Bearman and Moody 2004).

With respect to classroom networks, the literature provides evidence of four structural features which may be related to social wellbeing: density; reciprocity; clustering; and centralisation. These are discussed in turn below.

Density captures how closely connected the classroom network is. For this reason, it is understood by some as indicating the degree of social cohesion of a particular network (Ahn and Rodkin 2014; Falci and McNeely 2009). Prior research indicates that denser networks are associated with lower levels of aggression and higher levels of perceived social support (Ahn and Rodkin 2014; Rimpelä et al. 2020). It is therefore expected that density will be positively associated with pupil social wellbeing.

Reciprocity reflects the proportion of connections in the classroom that are bilateral. While at the individual level, reciprocated connections are considered stronger and more supportive for the individual than unilateral (incoming or outgoing) connections (Granovetter 1973), reciprocity at the classroom level demonstrates 'balance or stability in social structure' rather than cohesion (Rao and Bandyopadhyay 1987, 141). The association between classroom reciprocity and pupil social wellbeing is, thus, theoretically ambiguous. On the one hand, stability can be positively related to social wellbeing because the classroom network structure is well known and easier to navigate for the pupils within it. On the other hand, highly stable networks can also constrain social dynamics, limiting opportunities for pupils to form new connections.

Clustering measures the extent to which pupils' connections are themselves connected, highlighting local patterns of connections, or 'small worlds' within the class. Social networks generally exhibit some degree of clustering since, over time, people either become connected to each other's connections or break the initial connection (Block 2015). Bearman and Moody (2004) argue that individuals within the same cluster are likely to share values and are therefore less exposed to the social stress associated with competing value systems. Clustering may therefore be positively associated with the social wellbeing of pupils in the same cluster. However, it is not obvious that other pupils in the classroom will benefit from clustering; for example, if the norms of competing groups outweigh the benefits of cluster norms. Rimpelä et al. (2020) found that clustering within pupils' school networks was positively related to school burnout. The relationship between clustering and social wellbeing should therefore be considered ambiguous.

Centralisation measures the extent to which connections in a classroom network are evenly distributed among pupils or concentrated around a few pupils. Networks with higher degrees of centralisation are often described as hierarchical and associated with lower levels of social support, while networks with lower levels of centralisation are viewed as more egalitarian and democratic (Gest and Rodkin 2011). Existing studies suggest that centralisation is negatively related to, for example, mental health and non-aggressive behaviour (Ahn and Rodkin 2014; Almquist 2011), and thus we also expect it to be negatively related to social wellbeing.

Together, these four structural network features and four individual network measures capture aspects of classroom social networks that – based on the existing literature – likely relate to the social wellbeing of pupils.

Purpose

The purpose of the study reported in this paper was to investigate the association between Danish pupils' social wellbeing and their peer networks in school. Based on the conceptual framework outlined above, and previous studies on peer networks in school, the study posed the following five hypotheses (H):

H1. Denser classroom networks are *positively* related to pupils' social wellbeing.

H2. Reciprocity in the classroom network is associated with pupils' social wellbeing, but the direction of this association is theoretically ambiguous.

H3. Clustering in the classroom network is associated with pupils' social wellbeing, but the direction of this association is theoretically ambiguous.

H4. More centralised classroom networks are *negatively* related to pupils' social wellbeing.

H5. Individual networks with more connections, any reciprocated connections, and/or any transitive connections, are *positively* related to social wellbeing.

Method

The study used a quantitative design to examine the association between structural features of peer networks in class, both at the classroom and individual level, and pupils' social wellbeing. The analysis was guided by the five hypotheses outlined above, linking network characteristics to four domains of pupil wellbeing: loneliness; belonging; acceptance; and prosociality. Drawing on data from two large-scale surveys – *Klassetrivsel* and the DSWS – linear probability models were used to estimate associations, with Model 1 including only classroom network features and Model 2 adding individual network controls. All models controlled for pupil demographics and school-fixed effects, with clustered standard errors at the classroom level to account for intra-class correlation. This design enabled systematic investigation of how peer network structures related to distinct domains of social wellbeing in school settings.

Ethical considerations

The study relied exclusively on existing pseudonymised datasets and involved no interaction with human subjects. It therefore did not necessitate approval from the Institutional Review Board at VIVE – The Danish Center for Social Science Research. The research team did not have access to the encryption key for the pupil survey dataset,

which meant that confidentiality was rigorously maintained throughout the project. Data from the 25 participating municipalities was disclosed under the Danish Data Protection Act, Section 10, which permits the use of de-identified personal information for research purposes without individual informed consent.

Data collection

The study combined data from two large-scale datasets, which together offered a unique framework for examining how pupils' social wellbeing in school related to both their individual networks and overall classroom network structure. The first was sociometric data from *Klassetrivsel*, a digital survey tool used by 25 of 98 Danish municipalities to monitor pupil wellbeing. This source provided pupil peer nominations within classrooms for various sociometric items, reflecting pupils' social connections in an educational setting. Specifically, we utilised pupil responses to the following item: 'Who do you spend the most time with during recess (breaks between lessons)?' for which the pupil's nominated up to three peers from their class. Data was obtained post hoc: In February–August of 2021, the research team obtained permission to analyse existing data from public schools in the 25 municipalities covering the four academic years, 2017/18 to 2020/21.

The second was the DSWS (Niclasen, Keilow, and Obel 2018), an annual nationwide survey administered to all state-funded public-school pupils in grades 4–9 (aged 10–15) since 2015. The DSWS systematically measures key domains of pupil wellbeing in school, including loneliness; belonging; acceptance; and perceived prosociality (hereafter referred to as *social wellbeing*). The DSWS is hosted by the Danish Ministry of Education. Our research team obtained permission to access the DSWS data in October 2021. For this study, we accessed survey data covering the academic years 2017/18–2020/21, which corresponded to the same period for which we obtained the *Klassetrivsel* data.

The *Klassetrivsel* data was available for 32,046 pupils aged 10–15 and for 1,543 classrooms in select public school cohorts that used the *Klassetrivsel* software. We restricted our data usage to surveys across the three school years 2017/2018–2019/2020 (excluding surveys conducted after the COVID-19 national lockdown in March, 2020) and to classrooms in which no more than two pupils had missing sociometric information. To avoid potential peculiar network characteristics of very small or large classrooms driving our results, we further excluded classrooms with fewer than 15 or more than 28 registered pupils (class sizes in Denmark are regulated and capped at 28 pupils per class, and the average class size in grades 4–9 in the sample municipalities was 22). Finally, we excluded 182 classrooms where more than half of the pupils had repeated survey observations. This exercise left 905 classrooms and 19,592 pupils in the sample. From this data, we were able to construct sociometric classroom peer networks based on the peers that pupils aged 10–15 reported spending most time with during lesson breaks.

Using individual, pseudonymised identifiers, we matched the sample pupils with information on pupil wellbeing in school in the same school year from the DSWS. In total 16,961 DSWS sample pupils from the 905 *Klassetrivsel* classrooms responded to all four social wellbeing outcomes measures of interest: loneliness; belonging; perceived prosociality; and acceptance. Finally, we linked the sampled pupils to the Danish administrative registers, which enabled us to add demographic information and school

Table 1. Descriptive statistics of sample and comparison analysis.

	Sample	General population of public-school pupils in the 25 sample municipalities	*p*-value, estimated difference
Register-based control variables			
Gender			
Boys	50.6%	50.4%	.476
Girls (ref.)	49.4%	49.6%	
Ethnicity by country of origin			
Minority pupils	7.5%	12.2%	<.001
Majority pupils (ref.)	92.5%	87.8%	
Age			
Young for grade (school start before age 6)	1.3%	1.3%	.931
School start at age 6 (ref.)	87.2%	85.6%	
Old for grade (school start after age 6)	11.5%	13.1%	<.001
Number of siblings			
No (ref.)	13.0%	14.7%	
1	50.6%	49.2%	<.001
2 or more	36.4%	36.1%	.233
Family structure			
Nuclear family	70.0%	66.8%	<.001
Single-parent family (ref.)	30.0%	33.2%	
Mother's age			
Average age at birth (Years)	30.21	30.16	.595
Mothers education:			
No tertiary degree (ref.)	17.0%	19.8%	
Vocational degree	34.7%	32.4%	<.001
Short/Medium-cycled degree	38.0%	35.5%	<.001
Long-cycled degree (Master's)	10.3%	12.3%	<.001
Grade level			
4th grade	27.1%	16.6%	–
5th grade	17.4%	17.5%	–
6th grade	17.6%	17.4%	–
7th grade	23.0%	16.9%	–
8th grade	10.6%	16.9%	–
9th grade	4.2%	14.8%	–
School year of observation			
2017/2018	47.6%	37.3%	–
2018/2019	35.3%	38.3%	–
2019/2020	17.1%	24.4%	–
Social wellbeing outcomes:			
Share of sample reporting feeling			
Lonely, seldom or never	82.0%	79.5%	<.001
Belong at their school, agree or highly agree	77.0%	75.2%	.001
Perceived prosociality of peers, agree or highly agree	81.6%	79.9%	<.001
Accepted by peers, agree or highly agree	78.0%	76.3%	<.001
Observations (*N*)	16,961	253,244	

Notes. All characteristics are summarised in percentages, except mothers' average age at birth measured in years. (ref.) denotes the omitted reference category in regressions. Social wellbeing was missing for some pupils in the full population: Not lonely ($N = 218{,}031$), Belonging ($N = 215{,}789$), Prosociality ($N = 217{,}968$), and Accepted ($N = 214{,}811$). The final column presents the *p*-value of a two-sided *t*-test for equal means of the row variable in the two samples adjusted for grade level and school year; tests for reference categories are not reported.

identifiers. Table 1 presents full details of the demographic composition of the sample, and its representation in relation to the general population of public-school pupils in the 25 municipalities from which we obtained peer network information ($N = 253{,}244$).

Table 1 indicates that the sample was balanced in terms of gender: Fifty-one percent of the pupils in the sample were boys. Grade 4 pupils (aged 10 to 11) were most prominent in the sample (27%) while only 4% were 9th graders (aged 15 to 16). This distribution reflected both our sample selection strategy (dropping repeat classrooms) and the tendency for the *Klassetrivsel* tool to be used less frequently in grades approaching graduation (grade 9). Almost half of the sample (48%) was surveyed in the school year 2017/2018, which, in addition to reflecting our sample selection strategy, suggests that the schools' use of the *Klassetrivsel* tool declined throughout the period. Together, these patterns highlighted the importance of adjusting our analyses for pupil age and school year, to ensure that results were not mechanically driven by the overrepresentation of younger pupils and earlier survey years. Compared to the public-school pupils in the 25 municipalities, the sample had a higher socio-economic background: they were significantly less likely to belong to an ethnic minority; significantly more likely to be from a nuclear family; and significantly more likely to have a mother with a post-secondary educational degree (with the exclusion of Master's level degrees).

On average, the sample pupils reported relatively high levels of social wellbeing along the four domains outlined above. These levels were significantly higher than the general public-school pupils in the 25 municipalities, likely reflecting a combination of differences in pupil characteristics and that schools using the *Klassetrivsel* tool may have already prioritised school wellbeing: Eighty-two percent reported that they seldom or never felt lonely (Not lonely), 77% agreed or highly agreed that they belonged at school (Belong), 82% agreed or highly agreed that their peers were helpful and kind (Prosociality), and 78% agreed or highly agreed that they were accepted by their peers (Accepted).

Measure development

Social wellbeing measures

From the DSWS, we extracted items on the four key domains of pupils' social wellbeing outlined above: loneliness; belonging; perceived prosociality; and acceptance. All four items originated from the internationally validated Health Behavior in School-Aged Children survey (Roberts et al. 2009) and were worded as follows: 'Do you feel lonely?', 'I feel that I belong at this school', 'Most of the peers in my class are kind and helpful', and 'Other pupils accept me as I am'. Pupils responded to each item using a 5-point Likert-scale where 1 indicated the least positive and 5 the most positive response. Very few pupils (only 1–2%) indicated a very negative response (= 1) to these items, while a substantial proportion indicated a positive (= 4, 35–45%) or very positive (= 5, 35–46%) response. To simplify the analysis, we recoded the Likert responses into binary indicators representing high levels of social wellbeing in each domain. This approach reduced the influence of rarely used response categories and avoided assuming that steps between scale points are evenly spaced (i.e. that the 'distance' in terms of wellbeing from 2 to 3 was the same as the distance between 4 and 5), while enabling us to examine how peer network structures related specifically to high social wellbeing. Correspondingly, a pupil was coded as *not lonely* if they responded with a 4 ('seldom') or 5 ('never') on the loneliness item; as *belonging* if they selected 4 ('agree') or 5 ('highly agree') on the item on belonging in school; with perceived *prosociality* if they selected 4 ('agree') or 5 ('highly

Table 2. Pairwise correlations of domains of pupils' social wellbeing in school.

	1	2	3	4
Domains of social wellbeing				
1. Not lonely	–			
2. Belong	0.40***	–		
3. Prosociality	0.31***	0.40***	–	
4. Accept	0.40***	0.45***	0.47***	–

Notes. The table shows the Pearson's correlation coefficients for indicators of high social wellbeing across four domains for 16,961 pupils in grades 4–9. Symbols denote level of significance, *** $p < .001$.

agree') on the item assessing peer behaviour; and as *accepted* if they selected 4 ('agree') or 5 ('highly agree') on the item on feeling accepted by peers.

Table 2 demonstrates that the four measures were all positively and significantly correlated ($p < .001$), though not perfectly. *Not lonely* was consistently less correlated with the other indicators of social wellbeing. This provided a rationale for analysing each domain separately, as each captured a distinct aspect of social wellbeing that may have been differently influenced by classroom network structures.

Peer network measures

As part of the *Klassetrivsel* survey, pupils nominated up to three peers from their own class in response to the sociometric item: 'Who do you spend the most time with during recess (breaks between lessons)?' By treating each nomination as a directional connection – from the nominating pupil to the nominated peer – we were able to build social networks for each pupil and classroom; these networks did not include peers from other grade levels or classrooms. We constructed measures of both individual network structures (peers directly connected to the individual pupil) and classroom network structures (all other pupils in the classroom).

Formal definitions and descriptive statistics are presented in Table 3. The size of pupils' individual network (Panel A) was measured by the number of incoming connections from peers (*indegree*) and outgoing connections from the pupil to peers (*outdegree*), respectively. The strength of pupils' individual networks was measured through the indicators *any mutual connection* (equalling one if at least one of the pupils' connections was reciprocated, zero otherwise), and *any transitive connection* (equalling one if there was at least one connection between any two of the pupil's outgoing connections, zero otherwise).

Measures of classroom network (Panel B in Table 3): density; reciprocity; and clustering were constructed as class means among all classroom peers excluding the pupil (referred to as 'leave-one-out means') to disentangle the importance of the pupil's individual networks from the classroom networks[1]: This meant that we measured *density* as the share of realised connections relative to potential connections among all other pupils in the classroom excluding the individual; *reciprocity* as the share of reciprocated connections out of all connections among all other pupils in the classroom, excluding the pupil; and *clustering* as the average share of outgoing connections among all other pupils in the

Table 3. Measures of network structures in the classroom.

Network measures	Description	*M*	*SD*	Min	Max
Panel A: Individual Network					
Outdegree (size)	Number of sent nominations by pupil *i*, formally $\sum_j x_{ij}$	2.79	0.61	0	3
Indegree (size)	Number of received nominations for pupil *i*, formally $\sum_j x_{ji}$	2.75	1.62	0	11
Any mutual connection (strength)	Indicator for pupil *i* having at least one connection that is reciprocated by a peer *j*, formally $1\left(\sum_j x_{ij}x_{ji} \geq 1\right)$	0.86	0.34	0	1
Any transitive connections (strength)	Indicator for at having at least one connection between any two of pupil *i*'s outdegree connections *j* and *h*, formally $1\left(\sum_{j,h} x_{ij}x_{ih}x_{jh} \geq 1\right)$	0.87	0.34	0	1
Panel B: Classroom Network					
Density (leave-one-out mean)	The share of potential connections among all peers for pupil *i* that is realised, formally $\frac{\sum_{-ij} x_{ij}}{3\cdot(N_c-1)}$	0.91	0.06	0.56	1
Reciprocity (leave-one-out mean)	The share of connections among all peers for pupil *i* that is reciprocated, formally $\frac{\sum_{-ij} x_{ij}x_{ji}}{\sum_{-ij} x_{ij}}$	0.61	0.10	0.21	0.94
Clustering (leave-one-out mean)	The average share of potential connections that is realised among all outdegree connections of all peers for pupil *i*, formally $\frac{\sum_{-i} f(x_i)}{N_c-1}$ where $f(x_i) = \begin{cases} 0 for \sum_j x_{ij} \in 0,1 \\ \frac{\sum_{j,h} x_{ij}x_{ih}x_{jh}}{\left(\sum_j x_{ij}\right)\left((\sum_j x_{ij})-1\right)} for \sum_j x_{ij} > 1 \end{cases}$	0.48	0.12	0.17	0.88
Centralisation	The difference in indegree connections between the pupil with most and fewest indegree connections in classroom *c* normalised by the largest possible difference in the class, formally $\frac{\max_i\left(\sum_j x_{ji}\right) - \min_i\left(\sum_j x_{ji}\right)}{N_c-1}$	0.28	0.07	0.12	0.57

Notes. x_{ij} denotes a nomination from pupil *i* to pupil *j* in classroom *c* with class size N_c. Each pupil may nominate up to three peers. The sample is 16,961 pupils in 905 classrooms covering grades 4–9. *M* = Mean, *SD* = Standard deviation, *Min* = Minimum value, *Max* = Maximum value.

classroom (excluding the individual) that were themselves connected with each other, i.e. the average share of the pupils' connections that were connected to each other.

Finally, we measured *centralisation* to account for the three-nomination cap on peer connections (Almquist 2011). Specifically, centralisation was the largest difference in incoming connections among all pupils in class normalised by the largest possible span of incoming connections (class size minus one, since one cannot nominate oneself). Centralisation, therefore, would equal 1 if one pupil was nominated by all other pupils in class and at least one pupil received no nominations at all, whereas classrooms where all pupils received an equal number of nominations would record zero for centralisation.

Panel A in Table 3 (*Individual networks*) shows that pupils reported, on average, 2.8 nominations, indicating that many took up the maximum amount of nominations.[2] Also, pupils' individual networks were generally characterised as strong: 86% of pupils had at least one reciprocated connection and 87% had some degree of transitivity among their outdegree connections. Appendix Table A1 presents the pairwise correlations of the measures of individual network structures. Unsurprisingly, the measures of the size and strength were positively correlated. In particular, indegree connections and the probability of having at least one reciprocated connection were strongly, positively correlated

($r = 0.44$, $p < .001$): all else equal, the probability of having at least one reciprocated connection increased with the number of peers nominating the individual. This is likely to be particularly true when measuring responses to 'Who do you spend the most time with during recess', since time spent together is symmetric (although pupils' perceptions may differ). Likewise, the likelihood of having some degree of transitivity among one's outdegree connections was strongly related to outdegree connections ($r = 0.61$, $p < .001$). This was in part mechanical as a transitive outdegree connection required that the pupil nominated at least two peers. The remaining correlations were positive, but more modest in size.

Table 3, Panel B (*Classroom networks*) shows that the density of classroom networks confirmed the high take-up of the three-nominations cap – 91% of potential nominations among class peers were utilised. Out of all the connections among classroom peers, 61% were reciprocated. The average degree of clustering was 48%, and centralisation was 28% on average, indicating that the difference in nominations between the pupil in class receiving the most and the fewest nominations spanned 28% of the entire class. To allow for comparable interpretations of the estimated relations between these measures and social wellbeing, we standardised all classroom network measures to zero mean and a standard deviation of one.

As demonstrated in Appendix Table A1, all measures of classroom network structures with the exception of reciprocity and centralisation were positively correlated. The negative association between reciprocity and centralisation ($r = -0.34$, $p < .001$) was expected in a constrained setting: the possibility of reciprocating a nomination is necessarily smaller the more nominations go towards one or a few popular pupils, since they only have three nominations to send back. On the other hand, clustering was highly correlated with both density ($r = 0.37$, $p < .001$) and reciprocity ($r = 0.44$, $p < .001$). The clustering coefficient is necessarily zero for all pupils who refrain from nominating any peers, and in its extreme, where clustering equals one (all pupils' connections are themselves connected), reciprocity must necessarily also be one.

Finally, Appendix Table A1 demonstrates several significant correlations between measures of individual and classroom network structures, thus, highlighting the importance of studying classroom and individual networks as conjoined rather than separate factors for pupils' outcomes (Cappella et al. 2013; van Rijsewijk et al. 2018).

Control variables

To account for any systematic differences in social wellbeing and peer networks between pupils from different backgrounds, we controlled for pupil gender, ethnic minority status (as determined by own or parents' country of origin), age for grade, and socioeconomic background including mother's educational attainment and age at birth of the pupil, and family status (see Table 1). Importantly, because the nature of pupils' peer interactions, as well as their socio-emotional skills for managing these, likely develop with age (Bowker 2004; Hay, Payne, and Chadwick 2004), we included controls for the grade level of the classroom in all analyses.[3] This ensured that the variation in outcomes was compared only among pupils of similar grade levels.

Table 4. Estimated associations between classroom peer network measures and pupils' social wellbeing.

		(1)			(2)			(3)			(4)		
	Covariates	DV = Not lonely			DV = Belong			DV = Prosociality			DV = Accept		
Model 1		Beta	SE	*p*-value	Beta	SE	*p*-value	Beta	SE	*p*-value	Beta	SE	*p*-value
Classroom network	Density (leave-one-out, Z-score)	−0.001	0.004	.731	0.003	0.005	.570	0.018	0.005	<.001	0.003	0.004	.587
	Reciprocity (leave-one-out, Z-score)	−0.024	0.005	<.001	−0.016	0.005	.003	−0.011	0.005	.015	−0.022	0.005	<.001
	Clustering (leave-one-out, Z-score)	0.011	0.005	.012	0.0100	0.005	.063	−0.003	0.005	.556	0.005	0.005	.307
	Centralisation (Z-score)	−0.009	0.004	.041	−0.011	0.005	.046	−0.005	0.005	.288	−0.008	0.005	.080
Model 2													
Classroom network	Density (leave-one-out, Z-score)	−0.002	0.004	.608	0.003	0.005	.545	0.018	0.005	<.001	0.002	0.005	.732
	Reciprocity (leave-one-out, Z-score)	−0.015	0.005	.001	−0.010	0.005	.066	−0.006	0.005	.196	−0.015	0.005	.003
	Clustering (leave-one-out, Z-score)	0.006	0.004	.195	0.006	0.005	.302	−0.006	0.005	.163	0.001	0.005	.828
	Centralisation (Z-score)	−0.005	0.004	.210	−0.010	0.005	.073	−0.004	0.005	.389	−0.007	0.005	.154
Individual network	Indegree	0.029	0.002	<.001	0.023	0.002	<.001	0.020	0.002	<.001	0.028	0.002	<.001
	Outdegree	0.029	0.012	.012	0.042	0.012	<.001	0.035	0.011	.002	0.046	0.012	<.001
	Any mutual connections	0.044	0.011	<.001	0.009	0.012	.455	0.005	0.011	.635	0.001	0.012	.417
	Any transitive connections	0.046	0.013	<.001	0.044	0.013	<.001	0.025	0.012	.039	0.026	0.013	.051

Notes. Estimates from multivariate OLS specifications, *DV* = Dependent variable. All models further control for pupil gender, ethnic minority status, age for grade, siblings, family structure, mother's age at birth, mother's educational attainment, and grade level, school year, and school fixed effects (see Table 1). $N = 16{,}961$. Column 1: $R^2 = 0.04$ of Model 1, $\Delta R^2 = 0.03$ from Model 1 to Model 2, Column 2: $R^2 = 0.03$, $\Delta R^2 = 0.02$, Column 3: $R^2 = 0.03$, $\Delta R^2 = 0.02$. Column 4: $R^2 = 0.02$, $\Delta R^2 = 0.03$. *SE*: Cluster-robust standard errors within classrooms.

Data analysis

Relationships between the pupil wellbeing outcomes: *Not lonely; Belong; Prosociality; and Accepted*, and measures of the classroom network structures outlined in Hypotheses H1-H4 were analysed separately in a standard linear probability model (LPM) framework (labelled *Model 1* in Table 4) using ordinary least squares (OLS) and adjusting for systematic differences in network formation and social wellbeing according to the pupil characteristics outlined in Table 1. H1-H4 were, respectively:

H1. Denser classroom networks are *positively* related to pupils' social wellbeing.

H2. Reciprocity in the classroom network is associated with pupils' social wellbeing, but the direction of this association is theoretically ambiguous.

H3. Clustering in the classroom network is associated with pupils' social wellbeing, but the direction of this association is theoretically ambiguous.

H4. More centralised classroom networks are *negatively* related to pupils' social wellbeing.

The LPM was chosen for its accessibility and ease of interpretation: coefficients can be directly understood as changes in the probability of having high social wellbeing in the relevant domain associated with a one unit change in the explanatory network variable. Moreover, it allows for the inclusion of school-fixed effects and clustered standard errors. School fixed effects can weed out the effect of factors that were constant within schools – such as facilities, and the composition of the pupil and teacher populations. This approach is recommended in the context of educational research over alternative models (for example, random effects or hierarchical linear models), when limited information about the selection process of pupils into schools is available (Clarke et al. 2010).[4] To avoid overestimating the precision of our estimated relations, we adjusted standard errors to account for the fact that pupils in the same classroom were likely to be more similar to each other than pupils from different classrooms.

In addition to the classroom network, it was plausible that pupils' subjective social wellbeing was highly related to their own peer relations in the classroom. To explore this more fully, further analyses were conducted controlling for individual network structures (labelled *Model 2* in Table 4). In addition to estimating the relation between individual network structures and social wellbeing (Hypothesis H5: Individual networks with more connections, any reciprocated connections, and/or any transitive connections, are *positively* related to social wellbeing), *Model 2* allowed us to further disentangle the size and strength of the individual's class network from the relation between classroom network structures and high social wellbeing (for example, pupils in classroom networks with high densities may themselves have more connections).

Findings

Table 4 presents the estimated associations between the peer network structure measures (Hypotheses H1-H5) and the four indicators of high social wellbeing for pupils;

Model 1 estimates included classroom network measures only (H1-H4), while *Model 2* further controlled for the size and strength of individual networks (H5).

Providing some support for H1, classroom network density was found to be positively and statistically significantly associated with the outcome *Prosociality* (column (3), *Model 1*), although not meaningfully associated with the outcomes *Not lonely*, *Belong* and *Accepted*. The empirical relation was further robust to the inclusion of individual network controls (column (3), *Model 2*): increasing the density by 1 SD (equivalent to a total increase of 3.8 connections in an average classroom of 22 pupils) was associated with a 1.8 percentage point (pp) increase in the likelihood of perceived prosociality. However, the estimate was modest in size: 1.8 pp corresponds to roughly 2% of the mean reported perceived prosociality.

Regarding H2, classroom network reciprocity was consistently, negatively related to all four indicators for high social wellbeing in *Model 1*. This finding suggests that the stability of classroom networks – in terms of many reciprocated friendships among the individual's peers – was not related to increased levels of social wellbeing; rather the opposite was true. The estimated relations were weaker (but not significantly so) when further controlling for individual network structures (*Model 2*). This suggests that the size and strength of individual networks may only mitigate the negative relation between classroom reciprocity and social wellbeing to a small extent. Again, the estimated association was relatively modest in size; a 1 SD increase in reciprocity corresponded to increasing reciprocity of the mean classroom by almost 16% but was only associated with a 1.5 pp increase in the probability of not feeling lonely and feeling accepted by peers.

In terms of H3, a higher level of clustering was found to be positively associated with *Not lonely* and *Belonging* (Columns (1) and (2), *Model 1*); however, these relations were weaker and not significant once controlling for the size and strength of the individual networks (*Model 2*). There was thus only weak evidence for H3 when individual network structures were not accounted for.

There was some support for H4 in that the degree of centralisation in the classroom was negatively related to three out of four social wellbeing indicators in *Model 1* (except for *Prosociality* in column (3)). However, these relations were weak and remained only marginally significant for *Belong* when controlling for individual network structures (column (2), *Model 2*). Increasing centralisation with 1 SD (which corresponds to increasing the number of nominations to the most popular pupil in an average classroom of 22 pupils by 2.52 nominations) was associated with a decrease in belonging by 1 pp.

There was general support for H5 and only small quantitative differences across the social wellbeing indicators for the measures of individual network structures (*Model 2*). Having more connections in class both in terms of indegree and outdegree nominations was associated with increased probability of high social wellbeing across all four domains: *Not lonely*; *Belong*; *Prosociality*; *Accept*. There was also some evidence that having transitive connections (coherence in friendship groups) was positively related to social wellbeing (although only marginally significant for *Accept*, column (4)). Nominating peers who were themselves connected with each other (transitive connections) increased the probability of not feeling lonely by 4.6 pp and feeling like one belonged by 4.4 pp. Having at least one reciprocated connection in the classroom was only significantly related to *Not lonely*, where it was associated with a 4.4 pp increase in the probability of not feeling lonely (column 1).

The results of *Model 2* highlighted an interesting trade-off between the social wellbeing of the individual pupil and that of his/her peers in class when considering peer networks. Most predominantly, classroom reciprocity was consistently associated with lower social wellbeing, in contrast to having a reciprocated peer connection, which improved pupil wellbeing along the loneliness domain. Specifically, while having one, rather than no, reciprocated connections was related to an increase in the individual's likelihood of not feeling lonely (by 4.4 pp), the corresponding increase in classroom-level reciprocity in an average classroom translated to an increased likelihood of feeling lonely of 0.5 pp for each pupil. With 22 pupils in an average classroom, this amounts to a combined increase in loneliness of 10 pp, although one might argue that improving social wellbeing for a pupil without reciprocated relations in class, could be worth a smaller setback among better-connected pupils. A similar, though less pronounced, trade-off was observed for an already well-connected pupil between indegree connections (positively related to the individual's feeling of belonging in school) and classroom centralisation (negatively related to the belonging of all pupils in the classroom).

Discussion

In this paper, we have investigated the association between pupils' peer networks and their social wellbeing in school. Our results show that aspects of classroom and individual network structures are significantly associated with aspects of social wellbeing. As we have outlined in the conceptual framework, the relation between network structure and social wellbeing is under-theorised and our understanding of how to interpret network structures (especially for some structural features) is limited. In this context, some of our results support existing theories and are in line with previous empirical findings while others offer insights into previously undiscovered territory or provide new perspectives that nuance or challenge existing understandings.

Classroom networks

Our findings on classroom network density align with theoretical expectations and prior research, where density is often viewed as an indicator of social cohesion and linked to positive outcomes (Ahn and Rodkin 2014; Falci and McNeely 2009; Rimpelä et al. 2020). We find that this association is robust – it persists even when controlling for individual networks – but that it is also domain-specific, emerging only in relation to perceived *prosociality*. The absence of associations with *acceptance*, *belonging*, or *loneliness* suggests that density may reflect a narrower dimension of social cohesion than typically assumed. Future research should therefore examine which specific aspects of cohesion are captured by density, rather than treating it as a comprehensive measure.

A noteworthy finding is the consistent negative association between classroom reciprocity and all four domains of social wellbeing. This result is somewhat unexpected, given the lack of clear theoretical predictions and mixed evidence in prior studies. Although the strength of the association decreases when individual network structures are accounted for, it remains statistically significant. We therefore encourage researchers to further explore the role of classroom reciprocity in shaping pupil wellbeing. Specifically,

longitudinal network data could help clarify the extent to which reciprocity captures aspects of network stability (Rao and Bandyopadhyay 1987), and how such stability may influence pupils' social outcomes.

Some of our findings contradicted our expectations. Existing literature clearly associates centralisation with poorer mental health, behavioural and academic outcomes (Ahn and Rodkin 2014; Almquist 2011; Cappella et al. 2013; Gest and Rodkin 2011; Rimpelä et al. 2020; van Rijsewijk et al. 2018). Thus, we were surprised to find centralisation to be only weakly and narrowly related to social wellbeing when we accounted for the individual network. Further, contrary to our hypothesis, we found no substantial relation between classroom clustering and social wellbeing, at least not when we accounted for the individual network.

While the differences were not statistically significant, the general weakening of the estimated relations between classroom network structures and pupil social wellbeing when accounting for individual networks, underscores the value of analysing peer networks at both levels to understand how school social environments relate to pupil outcomes (Cappella et al. 2013; van Rijsewijk et al. 2018).

Individual networks

Our findings on individual networks align with previous studies showing that both network size and strength are positively associated with social wellbeing (Bearman and Moody 2004; Falci and McNeely 2009; Gifford-Smith and Brownell 2003). Between these, network size appears the more influential: pupils with more peer connections – whether incoming or outgoing – report higher *acceptance*, *belonging*, and *prosociality*, and *less loneliness*. While we also find positive associations for network strength, these are more domain specific. Notably, having at least one reciprocated connection is linked only to *reduced loneliness*, suggesting a more limited role than previously assumed (Baumeister and Leary 1995). In contrast, the connectedness of a pupil's peers is more broadly associated with wellbeing across three domains, highlighting the potential importance of group inclusion for the individual. This suggests that future research should give attention to the structure of pupils' immediate peer groups – beyond the presence of reciprocated ties – when studying social outcomes.

Evidence shows that teachers tend to prioritise teacher–pupil relationships despite pupils viewing peer relations as more central to their wellbeing (Graham, Powell, and Truscott 2016). Meanwhile the work of Alan, Carlana, and Leone (2024) suggests that teachers act on information on peer network structures when presented to them, improving classroom peer relations. Accordingly, we hope that our findings can increase and nuance teachers' understanding of peer networks in school.

Limitations

There are several limitations that should be considered when interpreting the study findings. First, the cross-sectional nature of the data limits our ability to assess the development of peer networks over time. As a result, we cannot, nor did this paper intend to, establish causal links between peer network structures and pupil wellbeing. Next, limiting pupils to three peer nominations likely captured only their closest

connections in class and may have biased the resulting network measures. As Milardo (1992) notes, individuals typically have about five close peers, and because most sampled pupils listed the maximum of three, the density measure may therefore mainly reflect the proportion of pupils with few or no nominations. It is possible that network density along other margins might result in more pronounced empirical relations with pupil wellbeing (e.g. Ahn and Rodkin 2014; Rimpelä et al. 2020). Our analysis also did not account for gender differences. The literature suggests that peer network structures can differ by gender (Bowker 2004); therefore, exploring differential patterns in the relation between peer networks and social wellbeing across gender and age groups may be interesting avenues for further research.

Due to the exploratory nature of our analyses, we focused on specific domains of social wellbeing rather than a broader composite measure. We note, however, that the precision of the estimated relations would likely improve notably with access to several validated items assessing each domain. Converting Likert responses to binary indicators improved clarity but reduced variation and statistical power. Similarly, our use of linear probability models, although more accessible and less sensitive to distributional assumptions, may have limited explanatory power, as reflected in low adjusted R^2 values.

Among the four selected wellbeing items, *loneliness* was the only item that did not explicitly refer to the school or classroom context. Therefore, pupils' responses to this item may have reflected general feelings rather than relating to connections in class specifically. However, since all items were drawn from the DSWS – administered in schools and designed to measure school-related wellbeing – we expect that responses reflected classroom dynamics, at least to some extent. Finally, pupils in our sample reported significantly higher levels of social wellbeing than the broader population of pupils in the same municipalities. This partly reflects that there were notable differences in pupil characteristics between the sample and the population, but it may also indicate that the schools using *Klassetrivsel* to collect classroom peer data were already particularly focused on promoting school wellbeing. As such, caution is warranted when generalising our findings to the wider school population.

Conclusion

This paper has demonstrated that both classroom and individual network structures are linked to pupils' social wellbeing. Classroom network density and clustering are positively associated with social wellbeing (perceived *prosociality* and *not feeling lonely*). Classroom network centralisation is negatively associated with social wellbeing (*belonging* and *not feeling lonely*), while classroom network reciprocity is negatively associated with all social wellbeing domains. These associations are reduced, but generally persist, when pupils' individual networks are included in the analysis. The size of individual networks is positively associated with social wellbeing (across all domains), whereas the strength of individual networks is also positively, but more domain-specifically, associated. Overall, our findings suggest that specific network features relate differently to different domains of social wellbeing. Future research should account for this complexity. Our findings can also be used by teachers to help them broaden and nuance their understanding of peer networks, and their links to social wellbeing, thereby better equipping them to influence and improve peer relations in class.

Notes

1. Classroom centralisation was defined using only class size and maximum and minimum indegree connections in the classroom and was therefore less prone to a confounding relationship with the individual's network.
2. The slight difference between in- and out-degree resulted from the exclusion of pupils with missing outcome responses.
3. Conceptually, we acknowledge the exploratory nature of this study and therefore prefer the increased power of a pooled sample over analyses on separate age groups.
4. Results did not differ qualitatively when using hierarchical linear modelling and the gains in statistical efficiency appeared limited in practice.

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Appendix

Table A1. Pairwise correlations of individual- and classroom-level peer network measures.

	1	2	3	4	5	6	7	8
Network measures								
Individual level								
1. Indegree centrality	–							
2. Outdegree centrality	0.20***	–						
3. Any mutual connection	0.47***	0.29***	–					
4. Any transitive connection	0.17***	0.61***	0.20***	–				
Classroom level								
5. Density (Z-score)	0.08***	0.04***	−0.02**	0.04***	–			
6. Reciprocity (Z-score)	−0.07***	−0.02**	−0.00	−0.00	0.11***	–		
7. Clustering (Z-score)	0.02*	0.03***	0.00	0.10***	0.37***	0.44***	–	
8. Centralisation (Z-score)	0.02*	0.02*	−0.09***	0.03***	0.10***	−0.34***	0.08***	–

Outcomes and network measures among 16,961 pupils in grades 4–9. Symbols denote level of significance, *** $p < .001$, ** $p < .01$, * $p < .05$.