# A social network perspective on formation of peer relationships in Czech lower-secondary classrooms

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Peer relationships in lower-secondary classrooms play a crucial part in students' academic and personal lives. This study uses social network analysis to investigate aspects influencing formation of both likeability and antipathy ties between students in Czech lower-secondary schools, with a special focus on the role on socioeconomic status. Data and research design employing exponential random graph models (ERGMs) allow researchers to explore roles of SES, gender, and several other structural network variables simultaneously. Using cross-sectional data from 435 students in 21 classrooms, this study suggests that high-SES students tend to receive more likeability ties and less antipathy ties compared to others. The overall results do not suggest a tendency of students to give preference to same-SES peers, however, SES homophily was found significant in 2 of the 21 sample classrooms. Additionally, this study confirms the effects of gender homophily, mutuality, transitivity, and preferential attachment on formation of peer relationships. The effects of SES seem to be related to the effect of mutuality, with networks with high mutuality effect not influenced by the effects of SES.

## Introduction

Peer relationships in lower-secondary classrooms play an important part in students' academic and personal lives. Good peer relationships in classrooms were found to positively influence students' emotional well-being (Wentzel, 2018), school engagement (Liem & Martin, 2011), and academic achievement (Wentzel, 2018; Liem & Martin, 2011). Low social acceptance was also found to be related to unexplained school absences (Schwartz et al., 2006). Moreover, peer rejection in school was related to long-term psychological adjustment in adolescence (Ollendick et al., 1992) and mental health problems in early adulthood (Roff, 1990). It is therefore important to pay attention to aspects influencing formation of peer relationships, as understanding these aspects may help to alleviate negative effects stemming from poor relationships with peers.

Formation of peer relationships, however, is not a trivial process which can be explained by a single variable. Quite the opposite, peer relationships in lower-secondary schools are a result of a combination of individuals' many characteristics and group processes. This study aims to investigate both dimensions by employing a quantitative *social network analysis* (SNA) design assuming that any relationship between two students is embedded in a wider network composed of peer relationships between other peers (Figure 1). Hence, a relationship between two students is not only influenced by unconnected decisions of the two students, but is also a result of an interplay of both individual and network-level processes. An example would include a process of transitivity – a tendency to form relationships with peers whom one has common acquaintance(s) with as illustrated in Figure 1. A transitive relationship is a result of both the decisions of the two actors involved, and wider relationship contexts in a social network.

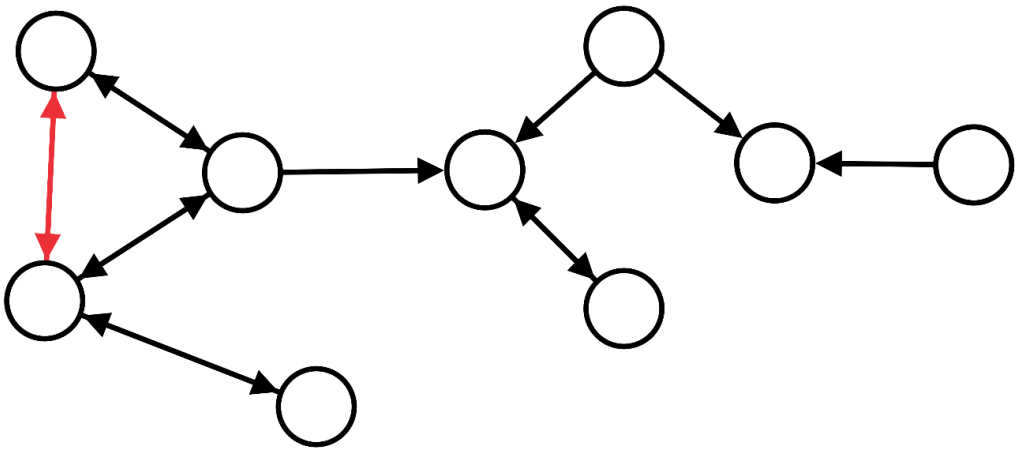

Figure 1: An illustrative social network consisting of students and their likeability ties. If a student rated another student as likeable, the arrow is outgoing. The red tie (left) is transitive.

Research on peer relationships therefore benefits from a relational approach, when both individual and network-level processes are considered as factors influencing formation of relationship between two individuals. Social network analysis is a methodological approach which grasps the two dimensions and sees each actor and each relationship as part of a wider network composed of all other actors and relationships (Scott, 2012). SNA emerged from structural approaches in sociology aiming to represent and analyse social structures occurring in the world with network and graph theory (Freeman, 2004). Instead of building on individual-level variables, SNA accentuates positions of actors within the real-world social structures (Borgatti et al., 2009) and allows an authentic mathematical representation of such structures (Wasserman & Faust, 1994).

To date, most studies focusing on peer relationships have not employed SNA. Furthermore, very few studies have included socioeconomic status (SES) as a factor influencing peer relations (e.g., Schmiedeberg & Schumann, 2019; Campigotto et al., 2021), and very few studies have considered both positive and negative relationships in classrooms (e.g. De La Haye et al., 2017; Huitsing et al. 2012; Dijkstra et al., 2007). This study aims to address the following question: *What and with what strength influences formation of peer relationships in Czech lower-secondary classrooms?* It aims to address the question by (1) employing SNA to realistically examine peer relationships in a wider context of social networks; (2) considering both positive (likeability) and negative (antipathy) relationships; (3) examining the role of SES in formation of peer relationships along with other well-documented effects; and (4) discussing possible interaction between the effects of SES with other considered effects and its implication for intervention strategies.

## Aspects influencing formation of peer relationships

### SES popularity

In theory, higher SES can lead to greater propinquity to receive likeability ties indirectly by granting socioeconomic capital (Leonard, 2005), which translates into popularity in classroom via numerous paths. Conversely, low SES can lead to greater propinquity to receive antipathy ties. First, lack of family economic resources can limit students' ability to participate in extracurricular activities which moderate peer relations and reinforce peer status. Consequently, the inability to spend free time with peers may lead to stigmatisation and self-exclusion which damages peer relations (Odenbring, 2019; Fernqvist, 2013). Second, economic resources can translate into higher popularity with consumption patterns. While students possessing ample economic resources can afford extensive spending, students with limited resources may deviate from expected consumption patterns, lacking branded apparel (Elliott & Leonard, 2006), material equipment such as computer or bike, and ability to spend money on extra consumables (Fernqvist, 2013). Inability to spend money beyond necessities may therefore add up to the processes leading to peer rejection and victimisation via deviation from group norms (Thornberg & Knutsen, 2011). Third, low family SES may translate into poorer social abilities as children from low-SES families are at higher risk of unsupportive parenting behaviour (Conger et al., 2010), and values and social interaction patterns of low-SES families may be inadequate in preparing children for peer interactions in school (Asher & Coie, 1990).

Indeed, several studies have shown that students from low-SES families have considerably worse social position in classroom. In a longitudinal study with over 10.000 students, both low family income and low parental education were found to contribute to student's higher probability of being rejected by their peers (Schmiedeberg & Schumann, 2019). Similarly, two studies with over 5.000 participants showed that low family income contributes to student's higher probability of having smaller number of friendships (Hjalmarsson & Mood, 2015; Olsson, 2007), with similar results provided by Vandell & Hembree (1994) on low parental education (over 300 participants).

Previous studies including comprehensive samples therefore strongly suggest that notwithstanding the specific conceptualisation of SES, low-SES students have fewer friends and are more likely to be rejected. What all these studies have in common, however, is an employment of non-relational regression models to infer relationships between SES and social position in classroom. Hence, while these studies may have captured interactions between student-level variables, they could not have captured interactions between student-level and network variables. By employing social network analysis, this study overcomes the limits of non-relational models, allows for interaction between both student and network-level variables, and, compared to previous research, this study should provide more accurate estimates on the relationship between SES and students' popularity.

### SES homophily

Another way in which SES can influence peer relationships is homophily – a tendency to create ties with people having same characteristics as oneself. Homophily is one of the most influential principles influencing formation of interpersonal relationships. Broadly speaking, people of all ages in all settings tend to group with others with similar characteristics and this principle influences all types of tie formations (McPherson et al., 2001). In theory, SES should influence propinquity to form homophilous ties as same-SES adolescents often share neighbourhood, values, and extracurricular activities (e.g. Odenbring, 2019).

In previous studies, SES homophily remains relatively unexplored. SES homophily is often implied when race homophily in concerned (e.g. Leszczensky & Pink, 2015), however, studies explicitly considering influence of SES on relationship formation in schools remain scarce. Exceptions include Campigotto et al.'s (2021) study, which suggests that while adolescents with university-educated parents give preference to other peers with university-educated parents, shared number of books and rooms at home have weaker and opposite effect. Doyle & Kao's (2007) study suggested that adolescents whose mother achieved at least high-school education tend to nominate best friends whose mother has similarly achieved at least high-school education. Furthermore, in King & Easthope's (1973) study, 60.8% of students in secondary schools picked their best friend from the same social class when pupils were divided into working class/middle class categories.

Previous studies dealing with SES homophily suggest that students give preference to relationships with same-SES peers (with an exemption when SES in conceptualised as rooms at home). Also, similarly to the relationship between SES and popularity, previous studies dealing with SES homophily employed only non-relational models. Such models therefore yield estimates not accounting for potential interaction between student and network-level variables.

### Gender homophily

While school populations tend to be gender heterogenous, adolescents at schools - both girls and boys - were found to give preference to having friendships with same-gender peers (van der Wilt et al., 2021; Duarte-Barahona et al., 2020; Mjaavatn et al., 2016; Leszczensky & Pink, 2015; Goodreau et al., 2009; Shrum et al., 1988). The propensity to create gender homophilous positive relationships among adolescents in schools was found to range from 61% (Duarte-Barahona et al., 2020) to 95% (De La Haye et al. 2017). Gender homophily among secondary-school students, however, becomes less notable with higher age (McPherson et al., 2001; Shrum et al., 1988). Concerning negative relationships, De La Haye et al. (2017) found a tendency of adolescents to direct antipathy ties towards opposite gender. Similarly, Dijkstra et al. (2007) found strong cross-gender rejection and cross-gender acceptance of bullying among preadolescents. This suggests that pupils are more likely to express negative sentiment towards opposite gender peers.

### Mutuality

Mutuality is one of the elementary aspects of human interpersonal relationships and a major feature of adolescent friendships (Rubin et al., 1998). Based on social exchange theory (Emerson, 1976; Blau, 1986), people tend to maintain relationships which yield rewards higher than the costs. In theory, unreciprocated relationships do not reward senders, such relationships therefore tend to be scarce as senders eventually terminate them. Practically all studies of adolescent social networks support this theory and suggest a strong tendency of students to form mutual positive ties (e.g. De La Haye et al., 2017; Jiao et al., 2017; Leszczensky & Pink, 2015; Huitsing et al. 2012; Lubbers, 2003) with propinquity ranging from 74% (Leszczensky & Pink, 2015) to almost 100% (Jiao et al., 2017). Students were also found to reciprocate antipathy ties, although with a lower propinquity of around 65% (De La Haye et al. 2017; Huitsing et al. 2012).

### Transitivity

Transitivity – a tendency to form ties with others, with whom one has common acquaintance(s) - is another aspect of relationship formation thought to be present universally across all human social networks (Bianconi et al., 2014). In social networks, this tendency shows as community structure (in peer social network context - cliques), in which community members have dense connections with other members of the community and sparse connections with others. Similarly to the effect of mutuality, the effect of transitivity was found in practically all adolescent social networks (Duarte-Barahona et al., 2020; De La Haye et al., 2017; Jiao et al., 2017; Leszczensky & Pink, 2015; Goodreau et al., 2009; Lubbers, 2003) with propinquity to create transitive ties ranging from 67% (De La Haye et al. 2017) to 88% (Jiao et al., 2017).

### Preferential attachment

Preferential attachment refers to a tendency of actors with a high number of receiving ties (popular actors) to attract a disproportionally higher number of ties compared to others above what would be expected in a random graph. In other words, it refers to a tendency of actors to form highly centralised networks with a small number of actors in the centre having many ties to others and a periphery consisting of actors having few ties. While this tendency is well documented in networks of collaboration (e.g. Jeong et al., 2003), in adolescent social networks, it remains relatively unexplored. An exception is van der Wilt et al.'s (2021) study, which showed a positive effect of preferential attachment across several classrooms. On the other hand, Jiao et al. (2017) found only little and Duarte-Barahona et al. (2020) only a negative effect of preferential attachment on adolescent network formation.

## Hypotheses

Based on the previous research and the underlying theories, I formulated the following hypotheses:

| | |
|---|---|
| Hypothesis 1a<br>SES popularity | High-SES students are more likely to receive likeability ties and less likely to receive antipathy ties with an opposite effect for low-SES students. |
| Hypothesis 1b<br>SES homophily | Students of the same SES are more likely to form likeability ties and less likely to form antipathy ties. |
| Hypothesis 2a<br>Gender homophily | Students of the same gender are more likely to form likeability ties and less likely to form antipathy ties. |
| Hypothesis 2b<br>Mutuality | Students tend to reciprocate both likeability and antipathy ties. |
| Hypothesis 2c<br>Transitivity | Students tend to form likeability ties based on common acquaintance(s). |
| Hypothesis 2d<br>Preferential attachment | Students tend to disproportionately concentrate both likeability and antipathy ties on popular and unpopular students, respectively. |

## Materials and methods

### Ethical considerations

An active consent was obtained from teachers as well as school principals participating in the study. Furthermore, children's guardians were given a letter explaining the research and its aims with an option to contact researchers in case they did not agree with their child´s participation in the research. Children were given the option to stop participating in the research at any moment of the research. The collected data were anonymised, so no identification of students or schools is possible.

### Sample and instruments

I used a non-probability sample containing data from 435 ninth grade (ISCED 2A) 14 to 15-year-old students in 21 classrooms in 14 lower-secondary schools in the Moravia Region of the Czech Republic, with data collected in November and December of 2017 as a part of a larger project - GA17-03643S. I used a standardised sociometric questionnaire designed for assessment of likeability between students in classrooms (Hrabal, 1988) to reconstruct cross-sectional directed peer social networks at the time of the measurement (see Appendix A for the sociometric questionnaire). It is a Likert-scale-type questionnaire listing all classmates in a random order and capturing likeability, neutral, and antipathy rating between any two students within a classroom.

I created two separate networks for each classroom – a likeability network and an antipathy network. I used personal questionnaires to assign individual students the variables of SES and gender. The personal questionnaires contained information about students' parents' occupations along with short descriptions of the occupations. I used the information on parents' occupations to calculate students' SES represented by their

parents' highest occupational status using a three-class version of the ESeC - European Socio-economic Classification (Harrison & Rose, 2006; Rose & Harrison, 2007): *salariat* - a group of professions encompassing large employers, professionals, managers, and supervisory occupations usually requiring university-level education; *intermediate* - a group of professions encompassing small employers, self-employed, higher-grade white collar, and higher-grade blue collar occupations; and *working-class* encompassing lower and routine service, sales, clerical, and manual occupations.

Table 1 presents descriptive statistics of the sample. On average, there are slightly more boys and one classroom consisted of boys only. Most students had working-class SES background, followed by students with intermediate and salariat backgrounds. One of the classrooms did not contain any salariat-background students and one of the classrooms did not contain any intermediate-background students.

Table 1: Descriptive statistics of the sample (N=345)

| | | The sample | Per classroom | | | |
|---|---|---|---|---|---|---|
| | | N | M | SD | min | max |
| Students | | 435 | 20.71 | 3.16 | 16 | 27 |
| Gender composition | Girls | 203 (46.7%) | 46.7% | 14.7% | 0.0% | 63.2% |
| | Boys | 232 (53.3%) | 53.3% | | 36.8% | 100.0% |
| SES composition | Salariat | 92 (21.1%) | 21.8% | 13.6% | 0.0% | 50.0% |
| | Intermediate | 137 (31.5%) | 31.0% | 13.9% | 0.0% | 50.0% |
| | Working class | 206 (47.4%) | 44.8% | 19.5% | 5.6% | 94.7% |

### Data substitution

Some individual questionnaires within the classrooms were missing and the data had to be substituted. This was due to a fact that some students either missed the school the day the data were collected, did not fill out the questionnaires, or did not assign ratings to some of their classmates. A total of 607 one-way relationships (ties) between the students (6.42%) and a total of 10 SES variables (2.30%) were missing. A maximum of 33% of relationships were missing in one of the networks, however, most of the networks were complete. The missing ties between the students were reconstructed from their incoming reciprocal equivalents - if a student's sociometric questionnaire was missing, the value of the relationship directed from the student with missing data to other student was reconstructed with the value, which was given to the student with missing data from the student with non-missing data. This procedure assumes tendency to reciprocate ties of likeability in social networks and was chosen as arguably the least structurally-impairing post-collection method of imputing low-amount missing network data (Huisman, 2009). In case there were missing edges from more than one student in a classroom, this caused unknown values on both *x* and *y* axes of the relationship matrix between the two students. In this case, the relationship was treated as neutral as there was no way of assuming value of that relationship. Missing students' SES was assigned at random from the probability of the sample.

## Data analysis

I employed exponential random graph models - ERGMs - (Lusher et al., 2013) in the *statnet* package in *R* (Handcock et al., 2021; Hunter et al., 2008) to test the research hypotheses. ERGMs aim to identify effects influencing network formation by assessing which micro-configurations (e.g. transitive ties) are found in a given network above what would be expected in a random graph. ERGMs can incorporate multiple effects for a single network which allows a study of interdependencies between the individual effects. Results of ERGMs are log odds of existence of a tie conditioned by the model effects. Log odds is a logarithm of odds metric often used in ERG modelling because it allows symmetry around the value of zero; i.e. if the value is above zero, it suggests an increased probability of occurrence (in our case an increased probability of a tie creation conditioned on some effect) and if the value is below zero, it suggests a decreased probability of occurrence.

I created two different model specifications each for both likeability and antipathy networks – *Likeability model A, Likeability model B, Antipathy model A,* and *Antipathy model B.* I estimated the models with Markov chain Monte Carlo maximum likelihood estimation (MCMCMLE) which is presently a preferred and arguably the most accurate and most well-understood estimation method for ERGMs, despite computational difficulties and problems with model convergence (non-convergence means that the estimation procedure was not successful and the results of the model are invalid [Lubbers & Snijders, 2007; Snijders et al., 2006]). I used parametric forms of shared partner and degree distributions with fixed decay parameters to reduce convergence problems (Snijders et al., 2006). I assessed each model's convergence using *mcmc.diagnostics* command and goodness of fit using AIC and visual goodness of fit display using *gof* command. Both convergence and goodness of fit plots from all the networks are available in the dedicated data repository (cited in Acknowledgements below).

The results from the individual classrooms were pooled in meta-analyses using maximum likelihood estimation which yielded estimates of the overall effects across the classrooms. Additional to the overall effects, the meta-analyses yielded $I^2$ indices measuring the relative degree of heterogeneity across the classrooms. The $I^2$ index aims to quantify the proportion of the variance in effect estimates which is due to heterogeneity rather than sampling error; the higher the $I^2$ index, the higher the relative degree of heterogeneity. The meta-analyses were performed using *mixmeta* package in *R* (Sera et al., 2019). Finally, the effect sizes in the individual classrooms were compared and SES effects were put into a perspective of potentially relevant interactions with other observed effects. Unfortunately, the number of classrooms (N = 21), combined with the lack of potentially relevant background data on the individual classrooms and a large number of included effects, rendered meta-regression procedures unsuitable. Therefore, the resulting comparison is purely descriptive and does not aim to model the dependencies between the effects.

*Likeability model A*
This the most complete specification which could be fit to all 21 likeability networks. It includes terms for SES and gender popularity (in-degree), SES and gender homophily

(nodematch), mutuality (mutual), transitivity (gwesp), SES and gender expansiveness (out-degree) – a tendency to send ties, and overall connectedness (edges) – an equivalent of intercept in regression models. Therefore, Likeability model A tests for hypotheses 1a, 1b, 2a, 2b, and 2c. The expansiveness and popularity terms based on gender and SES beyond this research's hypotheses are included for convergence reasons and to control for the effect sizes of homophily and transitivity, as they are interacting terms.

*Likeability model B*
This specification tests all our research hypotheses, however, it could be fit to 14 likeability networks only, as 7 of the networks did not converge. It includes all the terms from Likeability model A plus the effects of preferential attachment (gwidegree), out-degree distribution (gwodegree), dyad-wise shared partners (gwdsp), and connectedness across two edges (twopath) – a general structural term. Out-degree distribution tests propinquity of network to have a small number of students sending a disproportionally high number of ties to others and it was included as an interacting term with preferential attachment. Dyad-wise shared partners term is included because it is an interacting lower-degree term with gwesp term. Therefore, a model with both gwesp and gwdsp terms gives a more accurate estimate of the transitivity effect size. Twopath is included for convergence reasons – with inclusion of additional terms for preferential attachment, most models did not converge without twopath term included as well. Positive model B therefore tests for all the research hypotheses, it is more complete, and has a slightly better goodness of fit compared to positive model A; however, it is based on a smaller number of classrooms.

*Antipathy model A*
This is the most complete specification which could be to the highest number of antipathy networks - 18. It includes the same terms as Likeability model A and therefore tests for hypotheses 1a, 1b, 2a, and 3b. The term for transitivity is included as well for convergence and goodness of fit reasons. Unfortunately, no specification which would include the relevant terms could be fit to all antipathy networks, as not all the models converged.

*Antipathy model B*
This specification tests all our research hypotheses related to antipathy networks, however, it could be fit to 9 networks only, as 12 of the networks did not converge. Compared to Antipathy model A, it does not include the transitivity term, however, it includes preferential attachment and out-degree distribution terms. Antipathy model B is more complete and has slightly better goodness of fit compared to Antipathy model A; however, it is based on a smaller number of classrooms.

## Results

In the following section, I present the results of the four ERG models. For each model and effect term, I include the pooled effect size in the form of log odds, standard error (SE), and relative heterogeneity score in the form of $I^2$ index resulting from the meta-analysis. Furthermore, to give a more solid picture of how the effects played a role in the

formation of the individual networks, I report the number of classrooms, in which a given effect was found with a significance level of $p<0.05$ and divide these classrooms by positive/negative effect size. Finally, I provide a brief case-to-case comparison of the individual classrooms in terms of effect sizes and the potential interactions between the effects. Figure 2 shows illustrative likeability and antipathy networks from two randomly selected sample classrooms. Visualisations from all networks are available in the dedicated data repository.

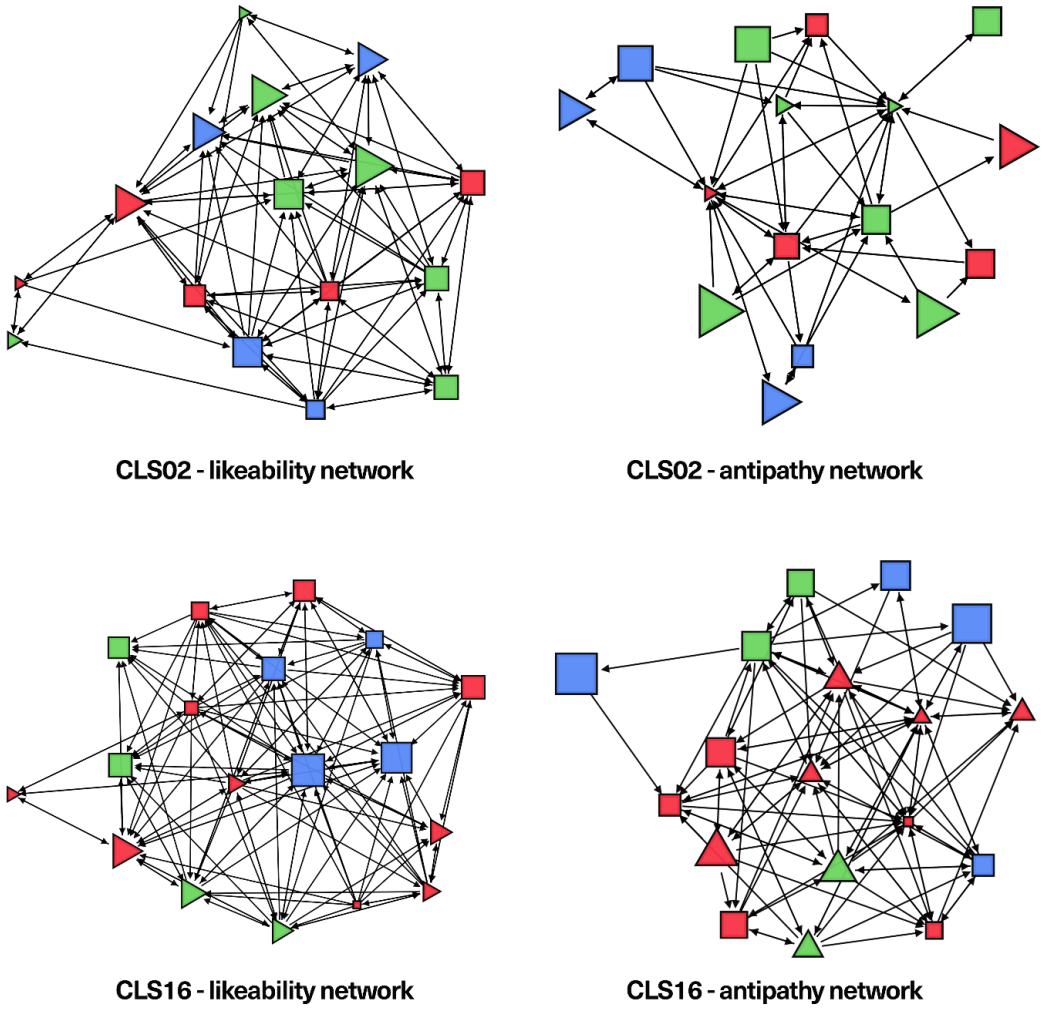


Figure 2: Visualisation of likeability and antipathy networks from two randomly selected sample classrooms. Note: the bigger the node, the more incoming likeability ties they have; node shape represents gender (triangle = girl, square = boy), node colour represents SES (blue = salariat, green = intermediate, red = working class); edges represent directed likeability/antipathy ties. The visualisation was performed in Gephi (Bastian et al., 2009). (Use 'zoom in' function with web reader or PDF reader to improve legibility)

### Likeability model A

The pooled Likeability model A (Table 2) confirms the formative effect of SES popularity, with salariat students receiving more and working-class students receiving fewer likeability ties compared to others. However, the effect is not present with a $p<0.05$ in most of the individual networks. The effect of SES homophily is not significant in the pooled model and is present with a $p<0.05$ in 2 of the 21 classrooms. The pooled model further confirms positive effects of gender homophily, mutuality, and transitivity on network formation and these effects are also present in most of the individual classrooms. Additional to our hypotheses, positive significant working-class expansiveness effect is present with a $p<0.05$ in 5 classrooms – in these classrooms, working-class students send a disproportionally higher number of likeability ties to others compared to salariat and intermediate peers. However, this effect is not significant in the pooled model. Boys neither receive nor send more likeability ties compared to girls in the pooled model, however, in 4 classrooms boys receive significantly more likeability ties compared to girls, with an opposite effect in 2 other classrooms. Furthermore, in 4 classrooms, boys send significantly more likeability ties compared to girls, with an opposite effect in 5 other classrooms.

Table 2: Results of Likeability model A

| Likeability model A (21 classrooms) | | Pooled effects | | | No. indep. classooms with $p<0.05$ | |
|---|---|---|---|---|---|---|
| | | log odds | SE | $I^2$ index | positive effect value | negative effect value |
| H1a - SES popularity | salariat receiving ties (in-degree) | 0.24† | 0.13 | 0.0% | 4 | 1 |
| | working-class receiving ties (in-degree) | -0.40** | 0.12 | 14.3% | 0 | 7 |
| H1b - SES homophily (nodematch) | | 0.13 | 0.10 | 0.0% | 2 | 0 |
| H2a - gender homophily (nodematch) | | 0.50** | 0.10 | 0.0% | 14 | 0 |
| H2b - mutuality (mutual) | | 1.39** | 0.17 | 47.0% | 19 | 0 |
| H2c - transitivity (gwesp) | | 0.74** | 0.10 | 16.0% | 16 | 0 |
| Other structural effects | salariat expansiveness (out-degree) | 0.17 | 0.13 | 0.0% | 1 | 1 |
| | working-class expansiveness (out-degree) | 0.15 | 0.12 | 0.0% | 5 | 0 |
| | boys receiving ties (in-degree) | 0.01 | 0.11 | 10.6% | 4 | 2 |
| | boys expansiveness (out-degree) | -0.02 | 0.13 | 34.2% | 4 | 5 |
| | overall connectedness (edges) | -3.59** | 0.28 | 53.5% | 0 | 17 |

Significance codes: **p < 0.01, *p < 0.05, †p < 0.10

Likeability model A therefore suggests that while we cannot generalise differences between girls and boys in either sending or receiving likeability ties, in many

individual classrooms, gender seems to influence both popularity and expansiveness. Overall, there is a low heterogeneity in effect sizes between the classrooms except for mutuality and boys expansiveness with $I^2$ index at 47.0% and 34.2%, respectively.

### Likeability model B

A fuller, Likeability model B (Table 3), yields slightly different results compared to Likeability model A.

Table 3: Results of Likeability model B

| Likeability model B (14 classrooms) | | Pooled effects | | | No. indep. classooms with p<0.05 | |
|---|---|---|---|---|---|---|
| | | log odds | SE | $I^2$ index | positive effect value | negative effect value |
| H1a - SES popularity | salariat receiving (in-degree) | 0.18 | 0.14 | 0.0% | 1 | 0 |
| | working-class receiv-ing ties (in-degree) | -0.15 | 0.13 | 0.0% | 0 | 1 |
| H1b - SES homophily (nodematch) | | 0.14 | 0.13 | 0.0% | 2 | 0 |
| H2a - gender homophily (nodematch) | | 0.34** | 0.11 | 0.0% | 7 | 1 |
| H2b - mutuality (mutual) | | 1.67** | 0.22 | 46.3% | 14 | 0 |
| H2c - transitivity (gwesp) | | 0.38** | 0.09 | 0.0% | 12 | 0 |
| H2d - preferential attachment (gwideg) | | -0.92* | 0.45 | 57.7% | 0 | 1 |
| Other structural effects | salariat expansiveness (out-degree) | 0.15 | 0.14 | 0.0% | 1 | 0 |
| | working-class expan-siveness (out-degree) | -0.01 | 0.13 | 0.0% | 0 | 0 |
| | boys receiving ties (in-degree) | -0.02 | 0.12 | 0.0% | 1 | 1 |
| | boys expansiveness (out-degree) | -0.07 | 0.12 | 0.0% | 1 | 2 |
| | out-degree distribution (gwodeg) | -1.09† | 0.56 | 71.0% | 0 | 1 |
| | dyad-wise shared partners (gwdsp) | 0.13 | 0.10 | 0.0% | 4 | 1 |
| | overall connectedness (edges) | -1.37** | 0.52 | 68.0% | 0 | 4 |
| | connect. across two edges (twopath) | -0.17** | 0.07 | 0.0% | 0 | 11 |

Significance codes: **p < 0.01, *p < 0.05, †p < 0.10

Like Likeability model A, Likeability model B confirms positive effects of mutuality, transitivity, and gender homophily on formation of peer social networks. However, their effect sizes differ, and, compared to Likeability model A, the effect of SES popularity in the pooled model becomes insignificant. The effect of SES homophily remains insignificant as well, with a p<0.05 in 2 of the 15 individual classrooms. On the other

hand, Likeability model B suggests that students tend to create disproportionally more likeability ties with peers with high number of receiving ties (a tendency to form highly centralised networks around a small number of students) – this is suggested by the negative value of the preferential attachment term. Furthermore, the model suggests that students who send many ties to others tend to do so disproportionately often - this is suggested by the negative value of the out-degree distribution term. Interestingly, while the preferential attachment and the out-degree distribution terms are significant in the pooled model, they are present with $p<0.05$ in one individual classroom each only. Compared to Likeability model A, Likeability model B renders gender popularity and gender expansiveness significant in fewer individual classrooms. Overall, there is a low heterogeneity in effect sizes between the classrooms except for mutuality, preferential attachment, and out-degree distribution.

The differences between Likeability model A and B are caused by added terms in Likeability model B which interact with other effects originally included in Likeability model A. The dyad-wise shared partners term interacts with the transitivity term. On the other hand, the preferential attachment and the out-degree distribution terms interact especially with the homophily and the popularity terms. This is because a tie between two students with the same attributes or a tie to a student with high SES may exist as a result of a tendency to direct ties to popular students or a result of a tendency of a small number of students to send many ties. The differences in effect size between the two likeability models therefore suggest that salariat students are also popular, however, the model is unable to tell if students tend to send disproportionately more ties to salariat students because of their SES.

### Antipathy model A

Similar to Likeability model A, Antipathy model A (Table 4) confirms the effect of SES popularity, with salariat students less likely and working-class students more likely to receive antipathy ties. The model also confirms negative effect of gender homophily and positive effect of mutuality on formation of antipathy ties. Negative effect of gender homophily means that students of the same gender are less likely to direct antipathy ties between each other and more likely to direct them towards opposite gender. The effect of SES homophily is insignificant in both the pooled model and the individual classrooms. Interestingly, the model suggests that transitivity plays role in antipathy networks as well. Similar to Likeability model A, Antipathy model A suggests that in some classrooms, gender may lead to receiving or sending more antipathy ties, however, as these effects differ across classrooms, overall results in this matter are inconclusive. There is low relative heterogeneity in effect sizes between the classrooms except for mutuality with $I^2$ index at 47.4%.

### Antipathy model B

Antipathy model B (Table 5) gives a weak support for SES popularity hypothesis, with borderline significant working-class and non-significant salariat in-degree terms. Like Antipathy model A, Antipathy model B confirms negative effect of gender homophily and

Table 4: Results of Antipathy model A

| Antipathy model A (18 classrooms) | | Pooled effects | | | No. indep. classooms with p<0.05 | |
|---|---|---|---|---|---|---|
| | | log odds | SE | $I^2$ index | positive effect value | negative effect value |
| H1a - SES popularity | salariat receiving ties (in-degree) | -0.33* | 0.16 | 0.0% | 0 | 3 |
| | working-class receiving ties (in-degree) | 0.38** | 0.15 | 30.0% | 4 | 1 |
| H1b - SES homophily (nodematch) | | -0.18 | 0.13 | 0.0% | 0 | 1 |
| H2a - gender homophily (nodematch) | | -0.53** | 0.12 | 20.3% | 0 | 9 |
| H2b - mutuality (mutual) | | 1.18** | 0.20 | 47.4% | 14 | 0 |
| H2c - transitivity (gwesp) | | 0.27** | 0.09 | 0.0% | 11 | 0 |
| Other structural effects | salariat expansiveness (out-degree) | -0.12 | 0.15 | 0.0% | 1 | 1 |
| | working-class expans-iveness (out-degree) | -0.04 | 0.15 | 31.9% | 2 | 4 |
| | boys receiving ties (in-degree) | -0.05 | 0.12 | 0.0% | 2 | 2 |
| | boys expansiveness (out-degree) | -0.04 | 0.12 | 2.5% | 2 | 4 |
| | overall connectedness (edges) | -2.03** | 0.16 | 2.9% | 0 | 18 |

Significance codes: **p < 0.01, *p < 0.05, †p < 0.10

positive effects of mutuality on formation of antipathy ties. Similarly, the effect of SES homophily is insignificant in both the pooled model and the individual classrooms. Moreover, Antipathy model B confirms a tendency of students to direct antipathy ties to a small number of students, but with high intensity (preferential attachment), and a tendency of students who send many antipathy ties to do so with high intensity as well (out-degree distribution). Compared to other models, Antipathy model B yields the most heterogeneous effect sizes across classrooms.

Table 5: Results of Antipathy model B

| Antipathy model B (9 classrooms) | | pooled effects | | | No. of indep. classooms with p<0.05 | |
|---|---|---|---|---|---|---|
| | | log odds | SE | $I^2$ index | positive effect value | negative effect value |
| H1a - SES popularity | salariat receiving (in-degree) | -0.18 | 0.19 | 0.0% | 0 | 1 |
| | working-class receiving ties (in-degree) | 0.37† | 0.20 | 36.9% | 3 | 1 |
| H1b - SES homophily (nodematch) | | -0.17 | 0.17 | 0.0% | 0 | 0 |
| H2a - gender homophily (nodematch) | | -0.38* | 0.15 | 0.0% | 0 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| H2b - mutuality (mutual) | | 1.52** | 0.24 | 43.1% | 8 | 0 |
| H2d – preferential attachment (gwideg) | | -2.00** | 0.47 | 59.5% | 0 | 6 |
| Other structural effects | salariat expansiveness (out-degree) | -0.22 | 0.19 | 0.0% | 0 | 1 |
| | working-class expansiveness (out-degree) | 0.16 | 0.19 | 6.1% | 2 | 0 |
| | boys receiving ties (in-degree) | 0.08 | 0.16 | 0.0% | 0 | 1 |
| | boys expansiveness (out-degree) | -0.09 | 0.18 | 29.0% | 2 | 1 |
| | out-degree distribution (gwodeg) | -1.91** | 0.29 | 4.1% | 0 | 6 |
| | overall connectedness (edges) | -1.11** | 0.34 | 66.4% | 1 | 7 |

Significance codes: **p < 0.01, *p < 0.05, †p < 0.10

## Summary of findings from meta-analyses

Table 6 provides a summary of findings from the meta-analyses focusing on the tested hypotheses. In addition to the tested hypotheses, the results suggest that in many individual classrooms, gender plays a significant role in both receiving and sending both likeability and antipathy ties. However, these effects differ between classrooms, with some classrooms having popular boys, some having popular girls, and some having neither. In the pooled models, the role of gender in receiving and sending likeability and antipathy ties therefore remains inconclusive. Yet, this does not mean that the effect should be overlooked. Quite the opposite, it apparently influences formation of peer relationships in many classrooms, its role just differs across the classrooms.

Table 6: Overview of results of meta-analyses

| Hypothesis | Results |
|---|---|
| 1a - SES popularity | Supported by two models. Weak/no support in models including preferential attachment and out-degree distribution terms. Not uniformly present in all classrooms.<br>• This suggests interaction between the terms - salariat students are also popular, however, the degree to which they are popular because of their SES or because of the general tendency of students to direct ties towards popular peers is unclear. |
| 1b - SES homophily | Not supported by any of the pooled models. Present in 2 classrooms.<br>• This suggests that overall, students do not tend to create same-SES ties. Yet, this tendency can be observed among students in a small number of classrooms. |
| 2a - gender homophily | Uniformly supported by all models. Not uniformly present in all classrooms. |
| 2b - mutuality | Uniformly supported by all models. Present in most classrooms. |
| 2c - transitivity | Uniformly supported by all models. Present in most classrooms. |
| 3c - preferential attachment | Supported by models where the term is included. Not uniformly present in all classrooms. |

### Comparison of effect sizes in classrooms and their potential interactions

Comparison of the individual classrooms in terms of effect sizes found in the respective models point to two probable interactions. First, where SES homophily was found significant (with $p<0.05$ in 2 classrooms), there was always SES popularity present as well. This may indicate that if there are classrooms in which SES plays role, SES plays dual role and may at the same time influence both propinquity to direct likeability ties to high-SES students and propinquity to direct likeability ties to same-SES students. Second, with an exemption of one classroom, in classrooms where SES popularity (and homophily) effects were found significant, the effect of mutuality was lower compared to classrooms where neither of the SES effects was significant and positive. It is therefore possible that the effect of SES (both SES popularity and SES homophily) is suppressed by the effect of mutuality. Unfortunately, the limited sample size, the lack of potentially relevant background data on the individual classrooms, and a large number of included effects prevented valid meta-regression procedures, which could identify such relationships using modelling and significance testing.

## Discussion and conclusion

The aim of the present study was to investigate aspects influencing formation of both likeability and antipathy ties between lower-secondary school students with a special focus on the role of SES. Two models provided support for SES popularity influencing formation of peer relationships, one model provided weak support, and one model none. It cannot be confirmed as an aspect influencing formation of peer relationship across all classrooms as it was found significant in around one third of the classrooms. The data did not support a hypothesis of SES homophily; nevertheless, SES homophily was found significant in 2 of the 21 sample classrooms. It is therefore possible that SES homophily may play a part in some peer networks; however, this study is unable to confirm it as a universal aspect influencing peer network formation. On the other hand, the results uniformly confirm that students are more likely to form likeability ties with same-gender peers with an opposite effect for antipathy ties; students are more likely to have both likeability and antipathy ties reciprocated; students are more likely to form transitive ties; and students tend to send a disproportionately high number of both likeability and antipathy ties towards a small number of peers.

Findings of this study concerning the role of SES popularity differ slightly from previous studies (e.g., Schmiedeberg & Schumann, 2019). Pooled models yield weaker support for its role in formation of peer relationships. Also, in contrast with previous studies on SES homophily (Campigotto et al., 2021; Doyle & Kao, 2007; King & Easthope, 1973), this study does not confirm its universal formative existence across the classrooms. It is important to note that neither of the aforementioned studies included SNA research design. It is therefore likely that SES homophily co-occurs with other effects and while models incorporating SES homophily without other structural network effects yield statistically significant results, more complex network models do not. The difference in the results of this study compared to the previous ones may also be a result of different operationalisation of SES. While two previous studies (Campigotto et al., 2021; Doyle &

Kao, 2007) used parents' education and number of books at home as a measure of SES, this study operationalises SES based on parents' highest occupational status.

Findings of this study concerning the role of gender homophily, mutuality, transitivity, and preferential attachment in formation of peer relationships coincide with previous studies (e.g. Goodreau et al., 2009) and support theories of homophily (McPherson et al., 2001) and social exchange (Emerson, 1976; Blau, 1986). Compared to previous studies, however, the resulting effect sizes in this study are smaller. I assume that the differences in effect sizes between this study and the previous studies are caused by the fuller model specifications used for this study. However, it is important to note that the model specifications used in this study yielded very high goodness of fit and can therefore be considered reliable in reproducing the observed data.

Although this study aimed to incorporate several relevant aspects influencing formation of peer relationships in lower-secondary classrooms and therefore provide a realistic insight into peer social networks, it has its limitations. First, models in this study certainly do not incorporate all aspects influencing formation of peer relationships and are therefore unable to rule out the possibility that some effect sizes from this study would differ if other aspects were included. Second, this study is limited to classrooms and therefore does not consider inter-classroom relationships, which, however, do occur (e.g. Goodreau et al., 2009). Third, this study has a solely quantitative character, limited sample, and therefore has limited grasp of interplay between varying effect sizes, e.g. it is unable to prove causation between high-SES and a high number of likeability ties as it is unable to prove the role of mutuality in alleviating the effect of SES. Hence, apart from considering a network approach and including relevant model effects, future studies should aim to include qualitative methods investigating peer relationships from students' understanding of social reality. Moreover, it would certainly be useful to consider the role of SES and gender in formation of peer relationships and explore it in more detail.

The findings of this study have several practical implications. The likely role of SES in formation of peer relationships even when gender and structural network effects are accounted for indicates that low-SES students are more likely to suffer from peer rejection. Consequently, poor peer relationships negatively influence mental well-being (Wentzel, 2018), school engagement (Liem & Martin, 2011), and academic achievement (Wentzel, 2018; Liem & Martin, 2011). Peer social networks may therefore be one of the fields through which SES influences other aspects of students' academic and personal lives. Hence, efforts to alleviate negative effects of SES on students' lives should include efforts to alleviate negative effects of SES on formation of relationships in school. Concerning possible intervention strategies, the results point in the direction that promoting reciprocal relationships between students could alleviate the effects of SES popularity and therefore lead into greater equity in classrooms. Finally, this study proves that social networks are innately influenced by several overlapping effects which are not always homogenous across classrooms. Research aiming to explore aspects influencing the formation of peer relationships would therefore benefit from including advanced network models (such as ERGMs or SAOMs) able to grasp the interplay of co-occurring effects.

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*Data availability statement*
The data presented in this study are openly available in Mendeley Data repository at https://doi.org/10.17632/5vzy6rykm7.1

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## Appendix A: Sociometric questionnaire

This is a template of the sociometric questionnaire used in this study based on Hrabal (1988). Each student was asked to rate all other classmates on a scale from very likeable to very antipathetic. The values of "very likeable" and "likeable" were used to denote the likeability ties. The values of "very antipathetic" and " antipathetic" were used to denote the antipathy ties. The "number" column was used for anonymisation and encryption purposes as the original names of the students were later removed, but the ratings between the students had to be identified.

The questionnaire was translated and adapted from the Czech original by Tomáš Lintner.

**LIKEABILITY**: A likeable person is a person whom we like and who we like spending time with. Rate your classmates based on how you feel about them.

| **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|
| very likeable | likeable | neutral | antipathetic | very antipathetic |

**Do not omit anyone – apart from yourself!**

Example of completion:

| NAME | NUMBER | LIKEABILITY | | | | |
|---|---|---|---|---|---|---|
| **Ján Novák** | 35 | **1** | **2** | **(3)** | **4** | **5** |

| NAME | NUMBER | LIKEABILITY | | | | |
|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |
| | | **1** | **2** | **3** | **4** | **5** |

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