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# Seeing the teacher through my peers' eyes? A social network study on adolescents' teaching quality perceptions

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ABSTRACT

*Background:* Prior research has documented the pervasive influence that peers can exert on adolescents' lives. However, knowledge on whether adolescents' perceptions of the quality of the teacher's instruction are also prone to peer influences is lacking.
*Method:* This study ($N$ = 248 German adolescents) used longitudinal social network analysis to investigate whether (a) friends become more similar in their teaching quality perceptions (influence effects) and/or whether (b) students with initially more similar perceptions of teaching quality were more likely to become friends (selection effects). We also explored whether (c) students with more positive teaching quality perceptions were better integrated socially.
*Results:* We did not find support for influence or selection effects. However, students who rated their teacher's instruction more positively were better integrated socially.
*Conclusions:* Our work adds to research on the role of peers in adolescence and enhances our understanding of peer influences on students' perceptions of instruction.

Teachers and the quality of their instruction (teaching quality) play a role in promoting students' positive development and learning outcomes (e.g., [1–4]). At the same time, classrooms are inherently social places and particularly during adolescence the salience of peer relations increases substantially (e.g., [5]). Peers do not only affect students' engagement in risk behavior (e.g., drinking, substance abuse, e.g., [6]), but also their academic outcomes. For example, peer influence effects have been observed for educational achievement and expectations (e.g., [7,8]). It seems reasonable to assume that students' perceptions of teaching quality could also be susceptible to peer influences. For most adolescents, being accepted by one's own peer group is of tremendous importance, and in order to "fit in", adhere to peer norms, and establish a sense of belonging, individual students could adapt their perceptions accordingly ([9–11]; for a general discussion on the fundamental human need to share the same perceptions with others, see [12]). Moreover, social comparison processes (e.g., [13]) can come into play as students evaluate their own attitudes and perceptions—including those of the teacher and the quality of the teacher's instruction—in reference to their friends and their attitudes and perceptions. Close friends may then become role models, resulting in assimilation processes and thus respective increases or decreases in a students' attitudes and (teaching quality) perceptions. It has also been suggested that teachers may change their behavior towards a specific student if the teacher perceives that this student befriended someone the teacher thinks highly of (see research on teacher attunement and perceptual bias, e.g., [14,15]).

On the other hand, research also stresses that friendship ties are more likely to develop between individuals who resemble each other (i.e., selection effects, e.g., Friemel, 2015; [16]); hence, similarity in teaching quality perceptions could drive adolescents' friendship formation. Importantly, influence effects (friends become more similar in their characteristics or perceptions) and selection effects (individuals with more similar characteristics or perceptions are more likely to be friends) are not mutually exclusive. To illustrate, even though Lorenz and colleagues [7] were able to demonstrate the effect of peer influences on educational expectations, they also found that students tended to select friends with similar educational expectations.

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A relevant additional question concerns the link between teaching quality perceptions and social integration, that is, whether a student with more positive teaching quality perceptions is more likely to be considered as a friend by others and is more likely to consider others as their friends. A positive link between higher achievement and higher levels of social integration has previously been established (e.g., [17]; for a meta-analysis, see [18]), and a similar pattern may emerge for teaching quality perceptions. On the other hand, as adolescence is a period in which students tend to become less engaged in school and often devalue their academic experiences (e.g., [19,20]), it may also be that those who perceive the teacher more positively are not well integrated.

The aim of the present study was to shed light on the extent to which students' teaching quality perceptions are entangled with social processes in terms of friendships among classmates. Teaching takes place in a group (classroom) setting, therefore, understanding students' perceptions of teaching quality necessitates accounting for social processes among students (see also [21]). Further, student surveys to capture students' perceptions of teaching quality are frequently used both in research and educational practice and policy (e.g., as part of teacher evaluation systems, [4,22]). Hence, finding peer effects on students' teaching quality perceptions would have important implications for the design, interpretation, statistical modelling, and validity of student survey data. For instance, it is standard practice in educational psychology to apply multi-level models in which individual student perceptions are aggregated to the class level to measure the "shared perceptions" of teaching quality (i.e., the mean ratings of the students within each class). However, finding that specific sub-groups (friends) within a class show substantial overlap in their teaching quality perceptions could raise the question of whether the classroom is always the most appropriate (and whether it should be the only) level of aggregation.

## 1. The present study

This study addressed three research questions (see Fig. 1). First, do friends become more similar in their teaching quality perceptions over time (influence effects, *Research Question 1*)? Based on theory and prior research on other educationally relevant variables (e.g., achievement), we hypothesized to find evidence for influence effects. Second, do students with initially more similar perceptions of teaching quality are more likely to become friends over time (selection effects, *Research Question 2*)? We hypothesized that selection effects should occur. Third, we were interested in the interplay between teaching quality perceptions and social integration and thus asked whether students with more positive teaching quality perceptions are more (less) likely to be nominated as friends by their classmates and/or are more (less) likely to nominate other classmates as friends (*Research Question 3*).

Our work is based on a longitudinal study with four measurement points (yearly assessments from fifth to eight grade) conducted in German secondary school mathematics classes of the combined track ("Mittelschule"). We used students' perceptions of teachers' academic and social support as core aspects of teaching quality (e.g., [2,3]), in mathematics. Hence, students rated the patience and the support for learning provided by their mathematics teacher as well as their teacher's appreciation of and personal interest in the students (see also [23,24]).

We focused on mathematics as one of the most important school subjects given that poor mathematics skills at school can have negative long-term consequences (e.g., with respect to access to better-paying and more rewarding jobs) [25–29]. Mathematics is also a subject that students tend to find most difficult, are anxious about, and oftentimes dislike, especially in adolescence (e.g., [30–34]). We adopted longitudinal social network analysis (Stochastic Actor-Oriented models, SAOMs; [35]) to analyze the data. Using social network analysis, we can jointly model the evolution of teaching quality perceptions and friendships over time. The simulation approach employed by SAOMs enables us to disentangle the effect of friendships on teaching quality perceptions (influence processes) from that of teaching quality perceptions on friendships (selection processes, also called homophily), taking into account that both change over time. A regression approach would need to treat friendships as fixed at an earlier time point to be able to explain teaching perceptions at a later time point. SAOMs are able to consider changes that happen in friendships during the modelled time period, including changes that happen based on teaching quality perceptions themselves. In addition to teaching quality perceptions, the main interest of our work, the models also included variables that are important to account for in research on adolescents' social networks in classrooms. Specifically, we included academic achievement in mathematics, gender, socio-economic status, and students' migration background. This is to take into account that students with different individual backgrounds may perceive teaching quality differently, and also to control for secondary selection effects. In addition to primary selection effects (friendships develop among students with similar perceptions of teaching quality), so-called secondary selection effects may occur as students' homophily is not one-dimensional and also operates based on other attributes (see also e.g., [7,36]). The SAOMs further considered basic network structure dependencies, such as reciprocity (the tendency to reciprocate friendships) and transitivity effects (the tendency to become friends with friends of friends).

## 2. Method

### 2.1. Sample

This study analyzed data from a large-scale longitudinal German study (TRAIN) with four measurement points, which is hosted by the Hector Research Institute of Education Sciences and Psychology at the University of Tübingen in Germany. The TRAIN study was conducted with students from two federal states, Baden-Württemberg and Saxony. However, as social network data was only collected in Saxony, we restricted our analyses to students from Saxony. We only included classes with homeroom teachers who taught mathematics (see also "Measures" below) and classes which stayed with the same teacher for at least two consecutive measurement waves.[1] Further, not all students from the TRAIN-study in Saxony had parental consent for the social network part of the study and we could only consider those with consent. We also excluded classrooms with too much missing data (more than 25 % in either wave). The sample analyzed in our study contained data of 248 secondary school students from 19 classes. Across all measurement points, 48.7 % of the students identified as females and they were, on average, 14.19 years old ($SD = 0.57$) at the fourth measurement point. All students attended a combined secondary school track ("Mittelschule"). The assessments took place in grades 5 to 8, when students were, on average, 11 to 14 years of age. The study was approved by the state authorities of Saxony, who, at this time, were responsible for approving empirical studies like this one. Parental consent was required for study participation and for the participation in the social network part of the study.

### 2.2. Measures

Students' perceptions of *teacher academic and social support* were measured using eight items adopted from Baumert et al. [[37], sample

[1] Note that if a class had a teacher change after two waves (e.g., after wave 1 and 2), we did not include data from the next wave with a different teacher. However, if both next two waves were taught by the same (new) teacher, we included this second period (i.e., wave 3 and 4) as well. As described in detail in the Statistical Analyses section, our units of analysis were classrooms/periods; a period was defined as two consecutive measurement points (i.e., wave 1 and wave 2; wave 2 and wave 3; wave 3 and wave 4).

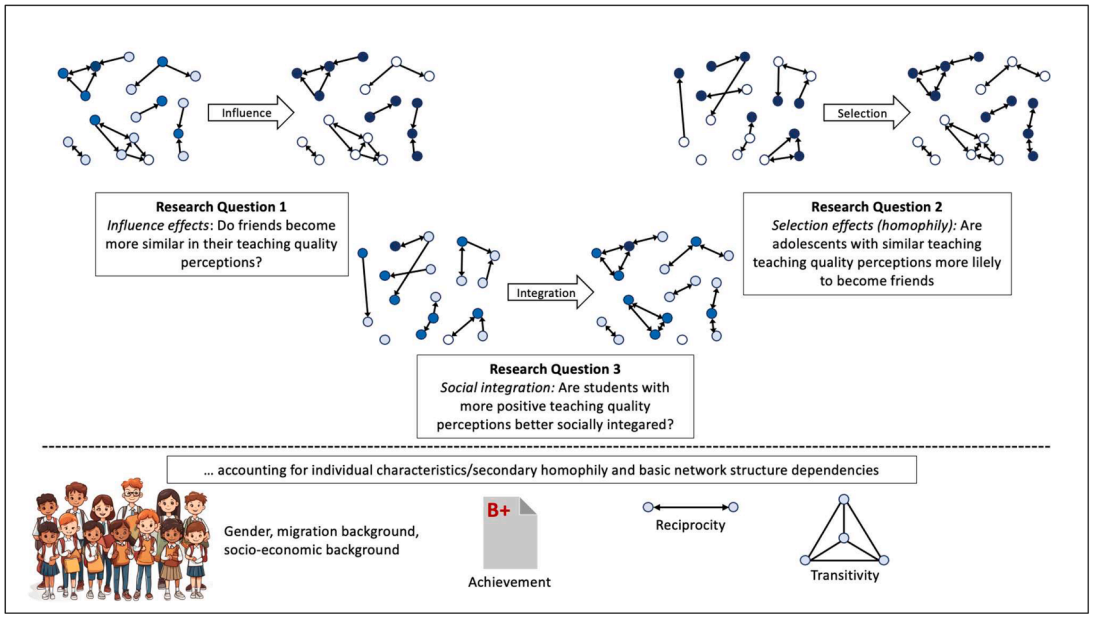


**Fig. 1.** Overview of the research questions addressed in this study.

items: "Our homeroom teacher provides additional support when we need help"; "Our homeroom teacher tries to understand us."]. The items were rated on a 4-point scale (1 = *completely disagree* to 4 = *completely agree*) and all items referred to students' "homeroom teacher". In the German school systems, students typically spend the entire day with the same group of students, and each class is assigned a homeroom teacher. The home room teacher teaches at least one subject, but also has social responsibilities for the class (e.g., the homeroom teacher goes on school trips with the class, provides counseling to students and parents, [23]). In our study, only classes in which the homeroom teacher taught mathematics were included; hence the teacher academic and social support items referred to support provided by the mathematics teacher. Please note that we analyzed academic and social support items together as one scale given that these two types of support are highly entangled in classrooms, and following prior research that could not empirically distinguish between academic and social support when using the same items as we did, with both types of support loading on one factor (see [23]). Reliability coefficients (Cronbach's Alpha) for the four waves were .92, .91, .93, and .94, respectively. Note that for our social network analyses, categorical dependent variables were needed, and we thus split the range into six categories that were used in the subsequent analyses. We decided to use six categories to retain as much information as possible. All eight items are displayed in the Online Supplement S1.

*Mathematics achievement* was assessed using standardized achievement test scores. The tests covered standard content from the federal states' mathematics curricula, such as arithmetic rules and linear equations. Different response formats (open ended, closed ended, and multiple-choice) were used. Item and person parameters for students' mathematics and German achievement have previously been estimated with longitudinal, multidimensional, two-parameter item response theory models [38], and we used weighted likelihood estimators (WLEs, [39]) of students' mathematics achievement. Students' *migration background* was measured relying on student reports and coded as 0 = no migration background, and 1 = with migration background. Family socio-economic status was gauged using parent reports of the highest socio-economic index of occupational status of the parents (HISEI, [40]). The HISEI integrates information on income and education, ranging range from 16 [cleaner] to 90 [judge]). The information on students' gender (0 = female, 1 = male) was assessed using both student and teacher ratings, which were combined in one variable. Hence, in the presence of missing data on gender from students, information from teacher reports could be used.

As a measure of friendships, we used *peer nominations*. For each classmate, a student had to indicate whether the student liked this classmate ("I like this student a lot") on a scale ranging from 1 = *strongly disagree* to 7 = *strongly agree.* For our analyses, a dichotomous friendship variable was needed. Hence, ratings ranging from 5 to 7 were coded as "friends", whereas all ratings below 5 were coded as "not friends". As a robustness check, we also estimated models with a different cut-off, only considering nominations of 7 as friendship and 1 to 6 as non-friendship. Using this way of coding, our results were replicated.

### 2.3. Statistical analyses

We applied Stochastic Actor-Oriented models (SAOMs; [35]). These can be used to model the co-evolution of social networks and individual attributes based on panel data. We opted for SAOMs because we were interested in the effect of friends' perception of teaching quality on students' own perception of teaching quality but we needed to take into account that not only friendships can influence perceptions, but also perceptions can influence friendships (e.g., those who have similar perceptions of teaching quality may be more likely to become and stay friends). By applying SAOMs, we could estimate parameters for changes in both networks (friendships) and in individual attributes (perceptions of teaching quality), allowing the joint investigation of friendship selection and friend influence processes.

In the SAOM framework, changes in friendships and perceptions between two observed data waves are modeled as a result of actors' choices about their outgoing friendship ties and about the level of their perceptions. The former observed data wave serves as a starting point of this process, and the latter wave serves as a target. Changes are represented as parallel sequences of stepwise changes, in which one actor at a time gets a chance to change either a friendship tie or their perception value. In a "network step", an actor is randomly selected and is allowed to create or terminate one of their outgoing friendship ties, and in an "attribute step", an actor may increase or decrease their teaching perception value.

Friendship choices and perceptions are explained by a set of independent variables each. For friendships, these may be based on various characteristics of Ego (the decision-making actor), Alter (the actor

towards whom Ego considers creating, maintaining, or terminating a tie), and similarities between Ego and Alter, as well as network structure dependencies that are independent of individual attributes (such as reciprocity, the tendency to form mutual ties). Perception changes are modeled based on independent variables including characteristics of Ego, and characteristics of Ego's friends.

We were primarily interested in the effect of friends' perceptions on Ego's perceptions, so we started with describing the model specification for the social influence part of the model. According to standard practices of SAOM modelling, we included two forms of intercept (linear and quadratic shape) to explain linear and quadratic baseline tendencies in the evolution of teaching quality perceptions. In terms of friend characteristics, we included our main variable of interest, the average teaching perceptions of friends. In terms of own characteristics, we included own achievement, gender, ethnicity, and socio-economic background (HISEI).

For social selection, we included the teaching perceptions and academic achievement of both Ego and Alter (to account for the fact that those with more positive perceptions/higher achievement may be more likely to nominate or be nominated by others as friends). In terms of similarities between Ego and Alter, we included similarity in teaching perceptions and academic achievement, as well as same gender, same ethnicity, and similarity in parental occupational status (to account for the fact that students who are more similar along these dimensions are more likely to name each other as friends more frequently). To capture network structure dependencies, we included a set of variables in line with Ripley et al. [41]. Reciprocity captures individuals' tendency to form and maintain mutual ties. Transitive triplets models captures their tendency to choose friends of friends as friends. Transitive reciprocated triplets is the interaction of these two variables. Indegree and outdegree of Alter express, respectively, the tendency of those who name more friends or named more as friends to receive additional friendship nominations. Outdegree of Ego expresses the tendency of those who already name more friends to name additional people.

To be able to analyze all classrooms together in a joint model, we applied the Bayesian random-coefficient multilevel version of SAOMs [42]. We set intercepts and structural processes (which are typically different between classroom-level networks) to randomly varying following a normal distribution and the rest to fixed across groups. For choosing prior distributions and assessing convergence, we relied on Ripley et al. [41]. Handling of missing data by SAOMs is also described in Ripley et al. [41]. All analyses were performed using RSienaTest R package, the sienaBayes function. Our units of analysis were classrooms/periods; a period was defined as two consecutive measurement points (i.e., wave 1 and wave 2; wave 2 and wave 3; wave 3 and wave 4). To illustrate, one unit was one classroom during the first period (wave 1 to 2), one unit the same classroom during the second period (waves 2 to 3), another unit was another classroom during the first period (wave 1 to 2) etc. The same applied to students within these classes. This approach was chosen to increase the sample size and power.[2]

## 3. Results

Table 1 displays descriptive statistics and bivariate correlations. Table 2 shows the results of the longitudinal social network analysis. Part 1 focuses on social influence processes, and part 2 on social selection processes. Both part 1 and part 2 come from the same model. Estimates should be interpreted as similar to conditional log odds ratios in logistic regression models.

In the influence part (part 1), friends' average level of teaching quality perceptions did not significantly influence students' own perceptions of teaching quality (Est. = 1.579, $p = .262$). Therefore, our first hypothesis assuming *influence effects* had to be rejected. We did not find other variables having a significant effect on teaching quality perceptions, either.

In the selection part (part 2), similarity in teaching quality perceptions did not seem to be a significant driver of friendships (Est. = −0.110, $p = .348$), meaning that our second hypothesis on the existence of selection effects based on teaching quality perceptions was not confirmed. With regard to *social integration*, the results showed that teaching quality perceptions did seem to influence friendship formation. Those who perceived teaching quality as better were more likely to nominate ("teaching quality perceptions of Ego", Est. = 0.280, $p = .001$) and be nominated by ("teaching quality perceptions of Alter", Est. = 0.192, $p = .006$) others. In terms of other attributes (gender, SES, migration background, achievement in mathematics), those who shared the same gender were more likely to form and maintain friendships (Est. = 0.569, $p < .001$). There were no effects for SES, migration background, and achievement. In terms of structural characteristics, we obtained positive and significant effects for both reciprocity and transitivity (see Table 2), indicating that students preferred mutual friendships and were often friends with the friends of their friends.

## 4. Discussion

The study of peer relations, and specifically, peer influence and selection effects, can notably enhance current understandings of the social nature of teaching quality perceptions and the role of peers as factors shaping students' perceptions of the teacher. Here, we report, to the best of our knowledge, the first social network study on students' perceptions of teaching quality. We focused on students' perceptions of teacher academic and social support in mathematics and the unfolding of their friendships over four years in secondary school. To summarize, we did not find empirical support for influence effects on teaching quality perceptions, meaning that friends in a class did not become more similar in their perceptions of the teacher over time. The findings also did not reveal evidence for selection effects; hence students did not form friendships with classmates who had similar teaching quality perceptions. Nonetheless, we showed that students who rated their teacher's instruction more positively had a better social standing in their class: Students with higher teaching quality ratings of teachers' social and academic support were more often nominated as friend by others and more often nominated others as friends. In accordance with prior research on social networks, our results further demonstrated positive and significant effects for both reciprocity (students tended to reciprocate friendships) and transitivity (students befriended the friends of their friends). Students of the same gender were more likely to form and maintain friendships, which confirms another common finding about adolescent friendships [43].

We draw three major conclusions from our findings. First, the fact that no selection or influence effects for teaching quality perceptions emerged in our study contributes to the existing body of knowledge, and arguably contrasts with prior research on other educationally relevant constructs, such as achievement and educational expectations (e.g., Lorenz et al., [7]). One important difference between teaching quality perceptions and previously investigated constructs in relation to friendships is that achievement or expectations reside within the student, whereas teaching quality perceptions focus on another person (i.e., the teacher). Nonetheless, there is scarce social network research documenting peer influence effects on students' perceptions of others (see [44]). Our findings could also imply that other factors are more critical in shaping students' teaching quality perceptions than their friends in class. For example, a student's perceptions are likely shaped by specific interactions between this student students and their teacher, and by the extent to which the teacher tailors their academic or emotional support to this individual student's' needs (i.e., adaptivity) (e.g., [45,46]). For research on teaching quality and the validity of student ratings of teaching quality, the lack of significant peer effects is positive, as it

[2] Preliminary robustness checks where we included time-period-dummies in the analysis revealed the same pattern of results.

**Table 1**
Descriptive statistics and bivariate correlations between the variables investigated in the study.

| Variable | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Teaching quality T1 | | | | | | | | | | | |
| 2. Teaching quality T2 | **.532** | | | | | | | | | | |
| 3. Teaching quality T3 | **.395** | **.496** | | | | | | | | | |
| 4. Teaching quality T4 | **.303** | **.351** | **.439** | | | | | | | | |
| 5. Achievement T1 | −.061 | .075 | .075 | −.001 | | | | | | | |
| 6. Achievement T2 | .007 | .023 | .109 | −.048 | **.681** | | | | | | |
| 7. Achievement T3 | .037 | .042 | .108 | **.161** | **.622** | **.639** | | | | | |
| 8. Achievement T4 | .166 | .100 | .066 | .035 | **.457** | **.574** | **.677** | | | | |
| 9. SES | .014 | .005 | −.073 | .082 | .094 | .093 | .068 | .098 | | | |
| 10. Gender | **−.154** | .033 | .005 | **−.174** | **.237** | **.243** | **.212** | **.247** | −.054 | | |
| 11. Migration background | −.097 | −.124 | **−.263** | −.149 | −.090 | −.059 | −.078 | −.028 | −.041 | .011 | |
| *M* or% | 3.29 | 3.07 | 2.99 | 2.92 | 0.86 | 1.30 | 1.69 | 2.28 | 45.62 | 51.3 % | 9.4 % |
| *SD* | 0.62 | 0.65 | 0.73 | 0.75 | 1.02 | 1.15 | 1.12 | 1.32 | 11.89 | – | – |

*Note:* SES = Socio-economic Status; Gender was coded as a dichotomous variable with 0 = female and 1 = male; Migration background was coded as a dichotomous variable with 0 = no migration background and 1 = migration background; SES was measured using the highest socio-economic index of occupational status of the parents, HISEI; [40]), a continuous measure which integrates information on income and education; Achievement = Standardized mathematics achievement test scores (WLEs). Statistically significant correlation coefficient at α = .05 are boldface.

**Table 2**
SAOM results.

| | Estimate | | Standard deviation | Credible interval | | *P* | Varying |
|---|---|---|---|---|---|---|---|
| | | | | from | to | | |
| **Part 1: Social influence** | | | | | | | |
| **Dependent variable: teaching quality perceptions** | | | | | | | |
| Linear shape | 0.205 | | 0.347 | −0.502 | 0.875 | .264 | + |
| Quadratic shape | −0.537 | | 0.526 | −1.721 | 0.424 | .133 | + |
| **Friend characteristics** | | | | | | | |
| Average teaching quality perceptions of friends | 1.579 | | 3.474 | −6.519 | 8.792 | .262 | – |
| **Own characteristics** | | | | | | | |
| Own achievement | 0.056 | | 0.148 | −0.233 | 0.355 | .349 | – |
| Own gender (1= boy) | 0.445 | | 0.337 | −0.185 | 1.142 | .085 | – |
| Own ethnic minority status (1= ethnic minority) | 0.230 | | 1.321 | −2.157 | 3.121 | .451 | – |
| Own SES | −0.010 | | 0.014 | −0.039 | 0.017 | .239 | – |
| **Part 2: Social selection** | | | | | | | |
| **Dependent variable: friendship** | | | | | | | |
| Outdegree (intercept) | −2.389 | *** | 0.351 | −3.089 | −1.704 | <.001 | + |
| **Individual characteristics** | | | | | | | |
| Teaching quality perceptions of Alter | 0.192 | ** | 0.077 | 0.040 | 0.345 | .006 | – |
| Teaching quality perception of Ego | 0.280 | *** | 0.098 | 0.103 | 0.491 | .001 | – |
| Similarity in teaching perception | −0.110 | | 0.364 | −0.781 | 0.702 | .348 | – |
| Achievement of Alter | −0.046 | | 0.037 | −0.120 | 0.024 | .105 | – |
| Achievement of Ego | −0.033 | | 0.037 | −0.106 | 0.039 | .190 | – |
| Similarity in achievement | 0.057 | | 0.321 | −0.580 | 0.688 | .429 | – |
| Same gender | 0.569 | *** | 0.081 | 0.413 | 0.731 | <.001 | – |
| Same ethnic group | 0.093 | | 0.079 | −0.062 | 0.247 | .119 | – |
| Similarity in SES | 0.163 | | 0.215 | −0.261 | 0.583 | .219 | – |
| **Structural characteristics** | | | | | | | |
| Reciprocity | 1.658 | *** | 0.326 | 1.025 | 2.307 | <.001 | + |
| Transitive triplets | 0.566 | * | 0.247 | 0.079 | 1.054 | .012 | + |
| Transitive reciprocated triplets | −0.373 | | 0.281 | −0.926 | 0.178 | .089 | + |
| Indegree of Alter | −0.048 | | 0.214 | −0.479 | 0.368 | .411 | + |
| Outdegree of Alter | −0.234 | | 0.222 | −0.678 | 0.196 | .141 | + |
| Outdegree of Ego | −0.072 | | 0.199 | −0.473 | 0.316 | .357 | + |

*Note.* Estimate (posterior mean); Standard Deviation (posterior standard deviation) 95 % Bayesian credible intervals; *p* (posterior probability); varying = whether the parameter was set to randomly varying or fixed.

suggests that factors relating to the teacher and the teacher's behavior are more influential in shaping students' perceptions of teaching quality (in addition to individual student characteristics and their interactions with teacher behavior, and student-teacher relationship quality, see e.g., [47,48]). On a related note, as typical network features (e.g., reciprocity) and well-documented gender effects were present in our data, we are reasonably confident that the lack of significant selection and influence effects was not due to problems with the social networks. Nevertheless, the present study's findings need to be replicated before definite conclusions on the absence of peer effects on teaching quality perceptions can be reached.

Second, we found that having more positive ratings of teaching quality was linked to better social integration in class. It has previously been presumed that in adolescence, it may not be perceived as 'cool' to show interest in school matters and like a teacher, and that consequently, those who appreciate the teacher and view the teacher's instruction positively may be derogatorily labelled as 'nerds', and could even become excluded and victimized (e.g., [31,49]). Our results contradict this assumption and are in line with prior research revealing positive relationships between higher achievement and different indicators of social integration (among those, friendships, [17,18]). From a developmental perspective, our findings highlight a "double social

advantage" as students with positive teaching quality perceptions did not only seem to like the teacher and the teacher's instruction, but they also liked their classmates and were liked by them. Cumulatively, our study's results regarding social integration, along with the results of related work (e.g., [17]) underline the importance of re-thinking and empirically testing common assumptions (e.g., the stereotype of the not-well-integrated 'nerd').

Third, our study highlights the potential of social network analysis in research on teaching and learning processes. As studying influence and selection effects is not possible when applying standard (multi-level) regression models, social network techniques have to be adopted to address such questions (e.g., Snijders et al., 2017). Moreover, selection and influence effects may lead to the same cross-sectional outcome (the similarity of friends in certain attributes); therefore, a longitudinal social network approach is needed to separate the two effects. Our study contained data from four years, spanning adolescents' lower secondary school career and employed advanced and well-suited longitudinal social network methods (Bayesian random-coefficient multilevel version of SAOMs, [42]), which represent considerable strengths.

Finally, limitations and directions for future research should be mentioned. While the current sample was selected to be representative, the students all came from one German federal state and all of them attended one secondary school type, which may limit the generalizability of the findings. Also, we focused on mathematics and teaching quality in terms of academic and social support in classrooms; hence, future studies should expand the scope of our study to include more subjects, different teaching quality dimensions (e.g., [2,50]), and both offline- and online-learning settings (e.g., social interactions on discussion boards, and teacher support in intelligent tutoring systems, e.g., [51,52]). Moreover, very few students in that state had a migration background when the data was collected, and future network studies might benefit from more diverse samples. Overall, we hope that our study encourages replications and provides a basis for researchers to conduct social network studies to continue unravelling the "social side" of students' teaching quality perceptions.

**Financial disclosure:** There are no financial conflicts of interest to disclose.

**Ethical statement:** All proedures were performed in compliance with relevant laws and institutional guidelines and have been approved by the appropriate institutional committee(s). The study was approved by the state authorities of Saxony, who, at this time, were responsible for approving empirical studies like this one. Parental consent was required for study participation and for the participation in the social network part of the study.

## CRediT authorship contribution statement

**Lisa Bardach:** Writing – review & editing, Writing – original draft, Conceptualization. **Zsofia Boda:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Claudia Neuendorf:** Writing – review & editing, Conceptualization. **Wolfgang Wagner:** Writing – review & editing, Conceptualization. **Kyle Davison:** Writing – review & editing, Conceptualization. **Ulrich Trautwein:** Writing – review & editing, Funding acquisition, Conceptualization.

## Declaration of competing interest

None

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tine.2024.100224.

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