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The individual & the structure – the peers & their relations in schools

Doctoral thesis

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Abstract

Schools are the primary social context for students, where they develop social relationships. This thesis, comprising four distinct studies, explores the peer relations of early adolescents in the Czech Republic. It investigates how students' relationships are formed and how these peer relations influence students using social network analysis. In line with the principles of analytical sociology, this work focuses on the mechanisms through which students' agency contributes to the formation of social structures and, reciprocally, how these structures influence students' agency. Study A examines the effects of endogenous mechanisms, gender, and socioeconomic status on the formation of peer relationships, revealing that socioeconomic status significantly influences the formation of both positive and negative relationships. Study B investigates the effect of ethnicity on the formation of peer relationships in the context of the Ukrainian refugee crisis, demonstrating that classroom ethnic composition impacts the social integration of Ukrainian students. Study C explores the effect of peer relations on students' perceptions of bullying roles, showing that dyadic relationships, peer groups, and classroom bullying norms all influence students' perceptions of these roles. Study D analyzes the emergence of interactions among students during classroom group work, indicating that interactions largely emerge from endogenous structural mechanisms and friendships. Together, the four studies provide evidence that characteristics often understood as individual-level traits – such as social attractiveness and activity – are inherently non-individual and dependent on a broader relational context.

Declaration

I hereby declare that the thesis titled **The individual & the structure – the peers & their relations in school** that I have submitted for assessment is entirely my original work, and that no part of it has been taken from the work of others unless explicitly cited and acknowledged within the text of my thesis.

Brno June 2, 2024

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Tomáš Lintner, MA

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1 Introduction

When children enter school, they acquire the roles of peers, with peer relations constituting a key aspect of their lives in school and beyond the school. Peer relationships in school are highly formative; schools are students' primary social context, where they develop and maintain social relations (Coleman, 1961; Ryan & Ladd, 2012; Steinberg, 2020). It is then not surprising that studying *how peer relations are formed* and *how peer relations influence students* has been one of the key research agendas in educational research.

The problem is that the two frequently researched questions have been frequently addressed with suboptimal methods. This is not "only" the methodological problem *per se*, the problem is inherently linked to misalignment of methods and theory. Quantitative analyses are meaningful only when they are rooted in credible models outlining the processes responsible for the phenomena under examination (Coleman 1964; 1981; 1986). When the methods and the theory are not aligned, the analyses do not yield meaningful results and interpretations.

Several seminal works have made conclusions about *how peer relations are formed* and *how peer relations influence students* based on research with mismatched theory and methods. Just to name three examples: Graham & Cohen (1997) showed that students gave preference to same gender and same race peers working with an individual-level metrics based on averaging students' sociometric preferences; Schwartz et al. (2006) showed that for aggressive adolescents, increases in popularity were associated with worse academic performance, again, working with an individual-level metrics based on averaging students' sociometric ratings on popularity and aggression; and Webb (1980) showed that high-ability students are more likely to give explanations to peers during group work, by counting the number of occurrences of explanatory events among the students.

Now, what is the problem with those conclusions? The matter with Graham & Cohen's (1997) conclusion is that by averaging individual preferences for same-gender peers, it is impossible to distinguish actual students' preference for same-gender peers from structural mechanisms such as transitivity. It may be possible that, to some degree, the underlying causal mechanism behind the observed same-gender preferences is not based on gender, but on wider relationship structures. The matter with Schwartz et al.'s (2006) conclusion is that by measuring students' aggressiveness by averaging student perceptions, it does not account for the fact that individual students' perceptions may be influenced by their relationships with the respective peers they are asked to assess. In other words, each peer perception is a unique tie, and its emergent properties are not accounted for if they are pooled together. Finally, the matter with the Webb's (1980) conclusion is that by counting the number of occurrences of events and inferring the influence of student ability on the tendency to

initiate an event, it is not accounted for the fact that spoken events are, indeed, interactions, they have relational character, and they are, to a large degree, influenced by endogenous mechanisms not related to student attributes, such as conversational turn-taking. In other words, if some student interacts many times, it may be purely the result of another student's tendency to repeatedly invite the given student to respond, instead of their ability.

The illustrative studies are based on models assuming that sociometric preference, popularity, aggression, and interaction in group work are characteristics nested within individual students. However, all those "characteristics" are not really characteristics in a sense that they would allow to characterize an individual. They do not exist independently of social context and more than anything else, they characterize emergent properties of social relations and interactions dependent on multiple individuals' perceptions and behaviors. Hence, the studies miss an important part in the puzzle and their conclusions about *how peer relations are formed* and *how peer relations influence students* have limited value, because they never attempted to model the *mechanisms* beyond formation peer relations or peer relations' influence on students.

In this thesis, I aim to justify a simple assertion: *any student attribute that explains certain social characteristics should not be considered as merely individual, nor modeled or interpreted as such*. I will argue that this assertion has far-reaching implications, necessitating that theory aligns closely with methods to accurately represent the real-world phenomena. I will provide evidence for my assertion with four empirical investigations into the *mechanisms* of emergence of relationship and interactions among students, showing that the individual and the structure are, in essence, indivisible. The students and their social relations and interactions constitute a nexus, where attributes deemed social are not merely personal but are the outcomes of the individual's position within, and an interaction with, a social structure.

1.1 Structure, agency, and networks

The problem of how to address questions on *how peer relations are formed* and *how peer relations influence students* are inherently linked to the problem of how to study structure and agency. In its broadest sense, the study of structure and agency entails the study of how structure – referring to the patterns of social life that are not reducible to individuals – and agency – referring to formation, transformation, and maintenance of structure by individuals by the means of their individual choices – co-create social reality (Hays, 1994). Asking *how peer relations are formed* is essentially asking how students' agency forms social structure, and asking *how peer relations influence students* is essentially asking how that social structure in turn influences individuals.

In social sciences, there have historically been two distinct lines of thoughts when it comes to understanding structure and agency – *structuralism* and *individual-*

ism. On its extremes, the two lines of thought are two distinct worlds which do not have much common ground in the essential understanding of social reality.

Structuralism posits that the only relevant subject of study in social sciences are the structures. Structuralism *a priori* does not recognize human agency, arguing that all aspects of human behavior – including the individuals' choices – can be explained on the individual level by biology, whereas what is left is the study of structures, which both enable and constrain the individuals (Mayhew, 1980). Structuralism argues for viewing social reality not merely as a collection of individuals, but as a system defined by the structures of interrelations within which these individuals operate. The approach of prioritizing the examination of overarching structures over individual members has deep historical roots (e.g., Durkheim, 1984; Marx, 1973), and it gained refinement in modern structuralism, which asserts that the primary task is not merely to document the empirical manifestations of social structures but to understand and explain why these structures exist (Blau, 1977). Structuralism emphasizes the role of social structures and organizational patterns in shaping individual behaviors and societal outcomes, positioning these structures as the central subjects of sociological study (Mayhew, 1980). Hence, for structuralism, structures extend beyond direct relations to include the broader structure of a given social system. For example, a student's popularity in the classroom does not stem only from their direct relations, but also indirectly from the perceptions of other peers in the classroom, who may be influenced in their perceptions by the perceptions of those they have relations with. Thus, structuralists would say it is necessary to ground the scientific inquiry of *how peer relations are formed* and *how peer relations influence students* in a structural perspective.

On the other extreme, there is individualism positing that the only relevant subject of study in social sciences are the actors. Individualism does not disregard the existence of social structures, however, it sees all structures as dependent and stemming from individuals (Spencer, 1851). Individualists argue that structures themselves cannot act, only the actors can act, everything in social reality can therefore be explained by actors' choices, which they perform, because they want to (Agassi, 1975). Individualism stems from an idea that individuals have – at least to some degree – *free will* – and this free will is the formative agent behind social reality (Ritzer et al., 1979). Structures have therefore no causal power, but they have a crucial explanatory role (Bulle, 2019). Assuming that students have the ability to make choices for themselves using free will, individualists would say it is necessary to ground the scientific inquiry of *how peer relations are formed* and *how peer relations influence students* in an individualistic perspective.

Naturally, structuralists and individualists often see each other's perspective as futile and irreconcilable with their own. For structuralists, the individualist proposition that actors act, because they want to, because they have free will is a circular argument fallacy, and the proposition that explanations of all social phenomena can be

eventually reduced to free will is an *ipse dixit* fallacy based on a common belief, not science (Mayhew, 1980). On the other hand, for individualists, the structuralist attempt to explain social reality by structures does not make sense, as in their view, these structures are created and maintained purely by the actors (Bulle, 2019).

Using their respective logic, the structuralist and individualist viewpoints at the extremes are, indeed, hardly reconcilable. However, neither structure, nor agency needs to be seen as the sole formative force behind social reality. To address the questions of *how peer relations are formed* and *how peer relations influence students*, it would be reckless to disregard either the formative effect of structure on students' lives or the formative effect of students' agency on formation of relations. For disregarding the structure, it would be reckless to assume that the interdependencies of relations and the wider relational contexts do not enable and constrain students' lives. For disregarding the agency, it would be reckless to assume that it is only the relations between the students, which have the causal power to form their lives. Hence, it is more beneficial to understand the formative interaction of structure and agency.

Giddens' (1984) theory of structuration aids in understanding how structure and agency manifest and influence each other, without giving an absolute primacy to any of them. It articulates that social life is recursive, characterized by structure acting both as the medium and the outcome of the reproduction of practices. This dual role of structure illustrates that although it may guide and constrain behavior, it is also continuously shaped and modified by the actions of individuals. Hence, assuming that structure and agency are not conflicting forces where one has the absolute primacy, but rather complementary elements that coexist within a dynamic social system, it is more beneficial to shift our attention away from the effort to conclude if free will should be accounted for in social reality into how structure and agency form each other. In other words, rather than pursuing the futile task of determining whether the egg or the chicken came first, it is more productive to explore the specific *mechanisms* through which structure and agency interact.

The aim to explore the mechanisms through which structure and agency interact reflects Hedström's (2005) analytical sociology approach. The approach aims to unravel the complex social processes by breaking them down into their fundamental elements and closely examining these components. Analytical sociology is dedicated to uncovering explanations rather than just descriptions. It shifts the focus from the superficial 'what' questions to the more profound 'why' questions (Hedström, 2005). It posits that while agency has theoretical primacy – implying that without actors there would be no structure – the existence and influence of structure cannot be disregarded. This interdependence suggests that without structure, the very notion of agency would lack context and meaning. By concentrating on the *mechanisms*, analytical sociology not only enhances the understanding of how individual actions are shaped by broader social structures but also elucidates the dynamic interdependen-

cies that influence students' peer relationships within educational settings (Hedström, 2005).

Now, the study of the mechanisms behind *how peer relations are formed* and *how peer relations influence students* requires a *social network analysis* approach. Crossley (2022) argues that structure is fundamentally a network comprising social actors and the relations connecting them. From this perspective, structure has measurable properties that generate opportunities and constraints for actors, influencing processes like diffusion that affect and implicate them. In this model, both structure and agency are integral: actors are the nodes of the network, and their relations are continuously built, maintained, modified, and broken through their interactions. Thus, both agency and structure are seen as emergent properties of social relations that reciprocally act upon and shape those relations. This relational approach not only resolves the theoretical dilemmas but also enhances the empirical analysis of structure, further enriching the understanding of the complex dynamics within social networks.

Social network analysis offers a toolset for examining the detailed structures within which individual actions and relationships unfold. Building upon the structuralist thought, network analysis assumes that a comprehensive understanding of any social system necessitates knowledge of all its parts and their functions (Borgatti & Ofem, 2010). Borrowing from the individualistic thought, it allows to account for the actors' agency (Crossley, 2022). In the realm of social networks, this translates to an analysis of both the actors and the ties (relationships or interactions) that connect them. Importantly, these ties are not treated in isolation; rather, the influence between actors is often indirect, highlighting the interdependencies that shape social structures.

Analytical sociology with network analysis provide a robust framework for understanding real-world social mechanisms. Network analysis reframes the view of social phenomena, shifting the focus from individuals to the broader structures that shape their interactions. Analytical sociology complements this by delving into the 'why' behind these phenomena, emphasizing the need for explanations that reach beyond superficial descriptions to uncover the mechanisms at play. Together, they set the groundwork necessary for dissecting and analyzing the networked nature of social interactions, aligning theory with methods.

Network analysis distinguishes between two analytically distinct domains: *the theory of networks*, explaining the mechanisms of network formation focusing on the antecedents of networks, and the *network theory*, explaining the effects of networks on individuals focusing on the consequences of networks (Borgatti & Ofem, 2010). The two domains frame our two questions, with the former encapsulating *how peer relations are formed* and the latter *how peer relations influence students*. Both domains are integral to a comprehensive understanding of social dynamics within educational settings, as they allow researchers to trace the pathways through which so-

cial structures emerge and to assess the impact of these structures on individual behavior and development. By integrating both domains, we can illuminate the reciprocal influence between individual agency and structural conditions.

In network analysis, two principal approaches – *tie-oriented* and *actor-oriented* – offer distinct frameworks for conceptualizing the interplay of structure and agency, influencing both methods and interpretations of social interactions within networks. Both approaches allow for the study of interplay of structure and agency, however, they differ in their perspectives. The tie-oriented tradition emphasizes structure as the primary determinant of social relations, considering ties as outcomes of random processes influenced by local configurations and global network structures. It therefore affirms the theoretical primacy of structure in determining network dynamics, focusing on global network statistics that apply uniformly across the network (Block et al., 2016). Conversely, the actor-oriented approach is grounded in the notion that network dynamics result from the purposeful actions of individuals who strategize their social relations based on personal preferences and the existing network context. This approach also focuses on exploring local configurations and their effects on the network, but it adopts the perspective of focal actors, rather than assuming a uniform distribution of local configurations across the network (Snijders, 1996). Both approaches allow for the study of similar mechanisms behind the tie formation; however, they differ in how they view these mechanisms – either from the structure's perspective or from the actor's perspective.

The discussion about structure and agency has been going on for a long time. On the one hand, the structuralist view holds that individuals' agency should not be included in the study of social phenomena. On the other hand, the individualist view holds that structures have no causal formative power beyond the power of the individuals. Analytical sociology with social network analysis provide a solution to this debate by shifting the subject of study from finding the single causative antecedent of social reality to identifying the formative mechanisms behind the structure and agency interaction.

1.2 The many varieties of peer relations

Ties in networks can be differentiated on different conceptual levels that represent real-world qualities of students' social relations and interactions. Among other things, the relations differ in their substance, strength, and temporal granularity. Friendships are the most studied peer relations in schools (e.g., Goodreau et al., 2009), but there are other relations, arguably having at least as significant impact on student lives as the friendships, such as bullying or exclusion (Jadambaa et al., 2020). It would therefore be irresponsible to assume that friendships alone capture the full complexity of social interactions within educational settings. The relations can also

have different strengths and they may form and dissolve at various times, such as during transitions between schools, which can dramatically shift social dynamics and peer group alignments.

It is not in the scope of this work to cover all kinds and intensities of relations, but it is useful to account for the key interdependencies between positive and negative relations. It was shown that most peer relations in adolescent networks fall within three distinct clusters: positive, negative, and social role attributions (Vörös & Snijders, 2017). The different relations do not occur in isolation, rather, it is reasonable to expect than one type of relation may propagate or mitigate another. For example, students may show a decreased tendency to exclude those peers they consider friends.

These interdependent relations form *multiplex networks* (Vörös & Snijders, 2017). In the structural paradigm, multiplex networks exemplify how different types of relations interact within the same social framework. This perspective views each layer of social relations as interconnected, influencing and shaping the network's structure as a whole. Properly modeling the interplay among different networks is crucial for aligning theoretical approaches with methodological applications. This alignment is essential not only for accurately describing social phenomena but also for uncovering the underlying mechanisms that drive social dynamics. By investigating how one type of relation influences another, we can provide detailed explanations of causal pathways and mechanisms.

Peer relations can be classified into two fundamental types based on their temporal nature: *states* and *events*. State-type ties, such as friendships, exhibit continuity over time, possessing an open-ended persistence that reflects ongoing social roles and emotional connections. These ties might not be permanent but are characterized by their enduring nature. On the other hand, event-type ties are marked by their discrete and transitory nature, encapsulating interactions that are specific to particular moments or events, such as verbal interaction (Borgatti & Halgin, 2011).

It is essential that these two types of ties – states and events – are distinctly recognized and appropriately modeled to ensure that theoretical approaches align with methodological applications. States require an analytical focus on higher-order structures to understand their enduring influence on social dynamics. In contrast, events require focus on the temporal order of interactions. A mismatch, such as analyzing a network of interactions by aggregating ties over time, obscures the dynamic nature of events and inaccurately portrays them as stable, ongoing relations. This misalignment can significantly distort the understanding of how transient interactions are formed.

1.3 Positioning this work

This work revolves around four distinct studies. Each study focuses on a unique set of mechanisms of formation of peer relations and interactions or the influence of relations on students. Each study is based on a different research project and a different dataset. Neither of the datasets overlap. Two studies stem from cross-sectional, one from longitudinal, and one from timestamped dynamic interactional data. All studies cover early adolescents in the Czech Republic. Table 1 shows basic characteristics of the studies. Together, the studies comprise 1478 students in 72 lower-secondary classrooms.

Table 1. Basic characteristics of the studies.

Study	Sample	Data	Main question	Modeling framework
Study A: A social network perspective on formation of peer relationships in Czech lower-secondary classrooms	435 Grade 9 students in 21 classrooms	Cross-sectional likeability and antipathy ties	What and with what strength influences formation of peer relationships?	Tie-oriented
Study B: Ukrainian refugees struggling to integrate into Czech school social networks	266 Grades 5-9 students in 12 classrooms	Cross-sectional friendship and exclusion ties	How do refugee status and classroom composition influence integration of refugees within peer social networks?	Tie-oriented
Study C: Relational dynamics in bullying, victimization, and defending perceptions	632 Grade 7 students in 27 classrooms	Longitudinal liking, disliking, and bullying roles perception ties	How do relations shape students' perceptions of bullying roles?	Actor-oriented
Study D: Interaction dynamics in classroom group work	145 Grade 6 students in 62 groups in 12 classrooms	Timestamped on-task and off-task interaction in group work, friendship ties	What influences interaction dynamics in classroom group work?	Actor-oriented

Early adolescence is a critical period for studying peer relationships due to the important changes and developments that occur in social dynamics during this stage. As students transition from childhood into adolescence, peer groups gain increasing importance in their lives, often influencing their social and emotional development more than family members (Brown & Larson, 2009; Li et al., 2011; Williams & Anthony, 2015). This shift is especially pronounced during the transition to a new educational level, such as Grade 6 in the Czech Republic, where students often encounter a new social environment and a fresh peer group. As students navigate these new settings, they actively form, dissolve, and renegotiate relationships, providing a rich con-

text to explore the mechanisms of peer relation formation and the influence of these dynamics on adolescent behavior and adjustment.

In line with the principles of analytical sociology (Hedström, 2005), each study within this thesis delves into the mechanisms that underpin the formation of peer relations and their influence on students. Rather than merely describing the observable patterns of peer interactions, this work aims to unravel the causal processes by which individual students' decisions – students' agency – contributes to the formation of social structures, and reciprocally, how these structures influence individual's decisions on relationships formation. By systematically examining the interactions between agency and structure, these studies provide robust explanations of how social dynamics are constructed and maintained in educational settings. This approach not only aligns with the theoretical goals of uncovering mechanisms but also ensures that the research provides substantive insights into the reciprocal nature of structure and agency within the social fabric of early adolescence.

The four studies cover both the *theory of networks* and the *network theory*. The first two studies can roughly be seen as diving into the *theory of networks*, by explaining the mechanisms behind peer relationships formation. On the other hand, the other two studies can be seen as diving into both the *theory of networks* and the *network theory*, by explaining the co-evolution of relationships formation and the effects of those relationships and interactions on students' behavior.

Study A deals with the mechanisms behind the formation of likeability and antipathy relations. It builds on the tie-oriented modeling framework looking at the structure's perspective in explaining the mechanisms behind formation of relations. It shows that students' relations are mostly influenced by the structural effects of reciprocity, transitivity, and preferential attachment. It also shows that both gender and socioeconomic status (SES) have formative effects on relations formation. However, it shows that ignoring the structure could lead to incorrect assumptions about the strength of the gender and SES effects by showing that attribute-based popularity is inherently linked to preferential attachment. **Study A yields a practical implication**: reciprocity seems to be related to the effect of SES in a way that in classrooms where the effect of SES was significant, reciprocity was low. This suggests that promoting reciprocal relations may be a pathway through which the effects of SES can be minimized.

Study B deals with the mechanisms behind the formation of friendship and exclusion ties. Like Study A, it builds on the tie-oriented modeling framework looking at the structure's perspective in explaining the mechanisms behind formation of relations. However, compared to Study A, Study B employs a multiplex network approach and explicitly accounts for the interdependencies between friendship and exclusion ties. Also, compared to Study A, it focuses on the role of ethnicity in formation of relations, using the unique situation, which arose in 2022 in the Czech Republic, following the influx of Ukrainian refugees in the Czech system of education. The study con-

firms the strong formative effects of structure on relations from Study A, however, it also shows that in the situation in 2022, ethnicity was even stronger formative agent of relations than the structural mechanisms. **Study B yields a practical implication**: classroom composition is related to social integration of Ukrainian refugees in terms of their tendencies to form inter-ethnic friendships and friendships in general, with lower proportion of Ukrainian students in classroom related to higher tendency of Ukrainian students to form inter-ethnic friendships and friendships in general. This suggests that it is beneficial to form classrooms in a way that they do not comprise large proportion of Ukrainian students, as it may hinder their social integration.

Study C deals with the mechanisms behind formation of bullying roles perceptions conditioned on liking and disliking relations between the students. It builds on longitudinal data and the actor-oriented modeling framework looking at the actors' primacy in explaining the mechanisms behind formation of relations. The study shows that bullying roles perceptions are highly subjective, individual, and biased by immediate relations, perceptions of classmates whom one likes, as well as by the classroom-level bullying norms. **Study C yields a practical implication**: assessing bullying roles based on reputational peer ratings should not be done summatively on a student level, but relationally accounting for the interdependencies between the perceptions and student relations.

Study D deals with the mechanisms behind emergence of interactions in classroom group work. It builds on dynamic timestamped data, and, like Study C, it builds on the actor-oriented modeling framework looking at the actors' primacy in explaining the mechanisms behind emergence of interactions. The study shows that interactions emerge from previous interactions, student relations, as well as students' characteristics. Hence, it is important to consider the dynamic, relational, and actor-oriented nature of interaction, which cannot be reduced to individual-level attributes. **Study D yields a practical implication**: friendship ties have strong influence on interaction in group work, hence, when teachers form groups, they should not mix friends with non-friends together in the same group as those who are not friends with others in the group are at the risk of being excluded from the interaction.

Together, the four studies provide a picture of *how peer relations are formed* and *how peer relations influence students*, focusing on the underlying *mechanisms*, while acknowledging the role of both *structure* and *agency* as formative aspects of students' lives. The studies provide evidence that characteristics often understood as individual-level characteristics – such as social attractiveness and activity – are inherently non-individual and dependent on wider relational context.

2 Study A: A social network perspective on formation of peer relationships in Czech lower-secondary classrooms

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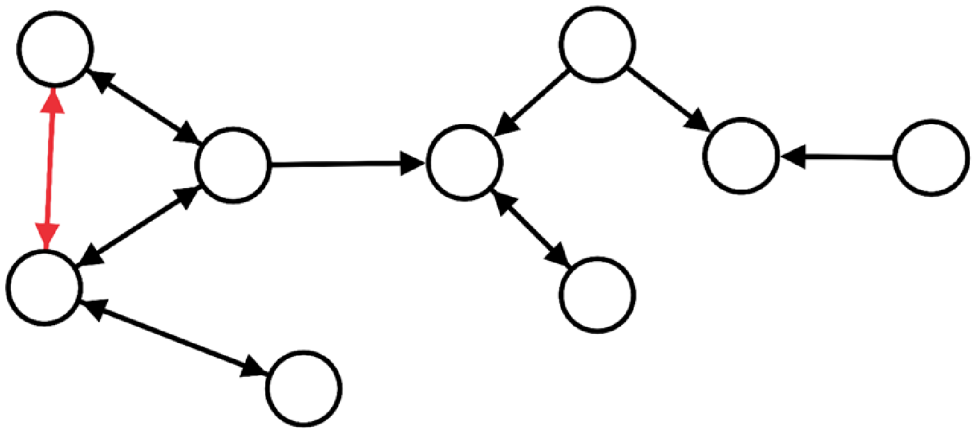
Abstract: Peer relationships in lower-secondary classrooms play a crucial part in students' academic and personal lives. This study uses social network analysis to investigate aspects influencing formation of both likeability and antipathy ties between students in Czech lower-secondary schools, with 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.

2.1 Introduction

Peer relationships in lower-secondary classrooms play an important part in students' both academic and personal lives. Good peer relationships in classroom 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 peer relationships.

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 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) as illustrated in Figure 1. A transitive relationship is a result of both decision of the two actors involved, as well as a result of a wider relationship context 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 is transitive.



Research on peer relationships therefore benefits from a relational approach, when both individual and network-level processes are considered 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 position of actors within the real-world social structures (Borgatti et al., 2009) and allows an authentic mathematical representation of such structures (Wasserman & Faust, 2019).

To date, most studies focusing on peer relationships have not employed SNA. Furthermore, a very few studies have included socioeconomic status (SES) as a factor influencing peer relations (e.g., Schmiedeberg & Schumann, 2019; Campigotto et al., 2022) and a very few studies have considered both positive and negative relationships in classroom (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.

2.2 Literature review of aspects influencing formation of peer relationships

2.2.1 SES popularity

In theory, higher SES can lead to greater propensity 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 propensity 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 stigmatization 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 victimization 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 conceptualization of SES, low-SES students have less 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 relationship between SES and students' popularity.

2.2.2 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 propensity 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 (2022) 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 suggests 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 conceptualized as rooms at home). Also, similarly to the relationship between SES and popularity, previous studies dealing with SES homophily employ only non-relational models. Such models therefore yield estimates not accounting for potential interaction between student and network-level variables.

2.2.3 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 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.

2.2.4 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 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 propensity 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 propensity of around 65% (De La Haye et al. 2017; Huitsing et al. 2012).

2.2.5 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 propensity to create transitive ties ranging from 67% (De La Haye et al. 2017) to 88% (Jiao et al., 2017).

2.2.6 Preferential attachment

Preferential attachment refers to a tendency of actors with high number of receiving ties (popular actors) to attract 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 centralized 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 exemption is van der Wilt et al.'s (2021) study, which showed 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 negative effect of preferential attachment on adolescent network formation.

2.2.7 Hypotheses

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

- **Hypothesis 1a – 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 – SES homophily**: Students of the same SES are more likely to form likeability ties and less likely to form antipathy ties.
- **Hypothesis 2a – gender homophily**: Students of the same gender are more likely to form likeability ties and less likely to form antipathy ties.
- **Hypothesis 2b – mutuality**: Students tend to reciprocate both likeability and antipathy ties.
- **Hypothesis 2c – transitivity**: Students tend to form likeability ties based on common acquaintance(s).
- **Hypothesis 2d – preferential attachment**: Students tend to disproportionately concentrate both likeability and antipathy ties on popular and unpopular students, respectively.

2.3 Materials and methods

2.3.1 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 option to stop participating in the research at any moment of the research. The collected data were anonymized, so no identification of students or schools is possible.

2.3.2 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 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 standardized 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 2 presents descriptive statistics of the sample. On average, there are slightly more boys and one classroom consists of boys only. Most students have working-class SES background, followed by students with intermediate and salariat backgrounds. One of the classrooms does not contain any salariat-background students and one of the classrooms does not contain any intermediate-background students.

Table 2. Descriptive statistics of the sample.

	the sample	***per classroom***			
	N	**M**	**SD**	**min**	**max**
students	435	20.71	3.16	16	27
gender composition					
girls	203 (46.67%)	46.72%	14.71%	0.00%	63.16%
boys	232 (53.33%)	53.28%		36.84%	100.00%
SES composition					
salariat	92 (21.15%)	21.76%	13.61%	0.00%	50.00%
intermediate	137 (31.49%)	31.03%	13.85%	0.00%	50.00%
working-class	206 (47.36%)	44.84%	19.54%	5.56%	94.74%

2.3.3 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.

2.3.4 Data analysis

I employed exponential random graph models – ERGMs – (Lusher et al., 2013) in *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 to study interdependencies between the individual effects. Results of ERGMs are log odds ratios of existence of a tie conditioned by the model effects. Log odds ratios 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.

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 is 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 is a specification which 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 propensity of network to have small number of students sending 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 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.

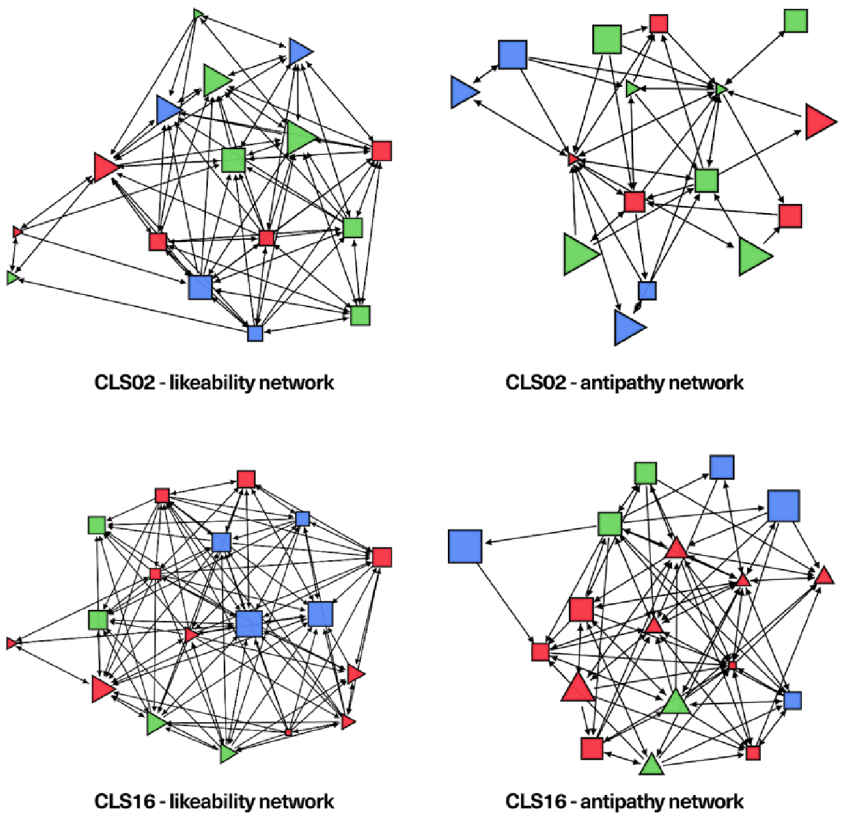
Antipathy model B is a specification which tests all our research hypotheses related to antipathy networks, however, it could be fit to 9 networks only, as 12 of the networks did not converge. Compared to Antipathy model A, it does not include the transitivity term, however, it includes preferential 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.

2.4 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 ratios, 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 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. Visualizations from all networks are available in the dedicated data repository.

Figure 2. Visualization 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 color represents SES (blue = salariat, green = intermediate, red = working class); edges represent directed likeability/antipathy ties. The visualization was performed in Gephi (Bastian et al., 2009).



2.4.1 Likeability model A

The pooled Likeability model A (Table 3) 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 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. Likeability model A therefore suggests that while we cannot generalize 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.

Table 3. Results of Likeability model A.

Likeability model A (21 classrooms)	**pooled effects**			**no. of ind. classrooms with p<0.05**	
	log OR	**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

*Signif. codes: **p < 0.01, *p < 0.05, †p < 0.10*

2.4.2 Likeability model B

A fuller, Likeability model B (Table 4), yields slightly different results compared to Likeability model A. 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 centralized 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 1 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.

Table 4. Results of Likeability model B.

Likeability model B (14 classrooms)	**pooled effects**			**no. of ind. classrooms with p<0.05**	
	log OR	**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 receiving 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 expansiveness (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

*Signif. codes: **p < 0.01, *p < 0.05, †p < 0.10*

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 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 sized 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.

2.4.3 Antipathy model A

Similar to Likeability model A, Antipathy model A (Table 5) 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%.

Table 5. Results of Antipathy model A.

Antipathy model A (18 classrooms)	**pooled effects**			**no. of ind. classrooms with p<0.05**	
	log OR	**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 expansiveness (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

*Signif. codes: **p < 0.01, *p < 0.05, †p < 0.10*

2.4.4 Antipathy model B

Antipathy model B (Table 6) 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 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 6. Results of Antipathy model B.

Antipathy model B (9 classrooms)	**pooled effects**			**no. of ind. classooms with p<0.05**	
	log OR	**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

*Signif. codes: **p < 0.01, *p < 0.05, †p < 0.10*

2.4.5 Summary of findings from meta-analyses

Table 7 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 7. 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. • 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. • 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.

2.4.6 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 propensity to direct likeability ties to high-SES students and propensity 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 relationship using modelling and significance testing.

2.5 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 relationships across all classrooms as it was found significant in around one third of the classrooms. The data did not support hypothesis of SES homophily, nevertheless, SES ho-

mophily was found significant in 2 of the 21 sample classrooms. It is therefore possible that SES homophily may play 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 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., 2022; 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 operationalization of SES. While two previous studies (Campigotto et al., 2022; Doyle & Kao, 2007) used parents' education and number of books at home as a measure of SES, this study operationalizes 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 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 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 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 high

number of likeability ties as it is unable to prove role of mutuality in alleviating the effect of SES. Hence, apart from considering network approach and including relevant model effects, future studies should aim to include qualitative parts 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 to the direction that promoting reciprocal relationships between students could alleviate the effects of SES popularity and therefore lead into greater equity in classroom. Finally, this study proves that social networks are innately influenced by several overlapping effects. Furthermore, the effects are not always homogenous across classrooms. Research aiming to explore aspects influencing formation of peer relationships would therefore benefit from including advanced network models (such as ERGMs or SAOMs) able to grasp interplay of co-occurring effects.

3 Study B: Ukrainian refugees struggling to integrate into Czech school social networks

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All co-authors gave consent to the aforementioned author statement.

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Data availability statement: The dataset generated and analyzed during the current study as well as the supplementary materials are available in the Humanities & Social Sciences Communications Dataverse repository at https://doi.org/10.7910/DVN/1CKYUV

Abstract: We provide a brief insight into the integration of Ukrainian refugees in school social networks in the Czech Republic following the mass migration caused by the Russian invasion of Ukraine. Our sample contains twelve classrooms with a total of 266 students in grades 5 to 9; 21.05% of the students were of Ukrainian origin. We employed multiplex exponential random graph modelling to assess the level to which Ukrainian refugees were integrated within peer networks, capturing both friendship and exclusion ties. We then employed a meta-analytical procedure to aggregate the results from the individual classrooms and a meta-regression to study the relationship between classroom ethnic composition and the level of integration of Ukrainian refugees. We found social networks to be formed heavily along ethnic lines with strong ethnic homophily in friendship ties and a propensity of the Ukrainian students to both send and receive fewer friendship ties than their Czech classmates. We found

no evidence that the Ukrainian students sent or received more exclusion ties than their Czech classmates, suggesting that the Ukrainian students did not face explicit rejection from classmates; rather, we saw a tendency of the Ukrainian students to be neglected. Our findings stand in contrast to reports from school headmasters who asserted that the social integration of Ukrainian students was seamless. We further found a higher proportion of Ukrainian students in classrooms to be related to stronger homophilic behavior and a lower tendency of Ukrainian students to make friends. Our results therefore imply that increased classroom diversity may negatively influence the integration of refugees in social networks.

3.1 Introduction

On 24 February 2022, Russia launched an invasion of Ukraine, causing the biggest refugee crisis in Europe since World War II. As of September 2022, 7.5 million Ukrainians had fled to other European countries – 0.4 million to the Czech Republic alone, making the Czech Republic the country hosting the highest per capita number of Ukrainian refugees among all countries, at 37 Ukrainian refugees per 1,000 inhabitants (UNHCR, 2022).

The influx of refugees has put many Czech public services under an unprecedented strain, with the educational system among the most affected: 32% of the Ukrainian refugees fleeing to the Czech Republic were children under the age of 18 who required access to education (UNHCR, 2022). The Czech Republic pledged to provide free and accessible education to all refugee children in regular Czech state schools in inclusive classrooms along with Czech students (Bill no. 67/2022; Bill no. 199/2022). At the beginning of the 2022/2023 school year (September 2022), there were 52,107 Ukrainian children enrolled at Czech lower secondary schools, constituting 5% of the whole student population (Ministry of Education, 2022d). Hence, in a very short amount of time, Czech schools became home to large numbers of Ukrainian refugees who had no prior knowledge of Czech language, and Ukrainian refugees quickly became the largest ethnic minority in Czech schools.

To our knowledge, no study has yet researched peer relationships of Ukrainian refugees in the host country following the 2022 invasion. However, based on evidence from studies dealing with peer relationships of refugee students coming from other countries, we assume the Ukrainian refugees in the Czech Republic were at risk of social exclusion in schools[1]. Ukrainian refugee students in the Czech Republic faced a three-fold disadvantage in establishing peer relationships in schools – becoming an

[1] In contrast to the context of the Ukrainian refugee crisis, however, previous studies are from contexts in which refugees were entering the educational systems continuously and in smaller numbers.

ethnic minority in an educational system operating in an ethnically homogeneous society, lacking proficiency in the Czech language, and managing psychosocial adjustment problems stemming from their relocation and war experience in their home country. First, previous studies from primary and secondary school classrooms have provided comprehensive evidence that ethnic minority students are more likely to be excluded (Boda & Néray, 2015; Fisher et al., 2000; Wilson & Rodkin, 2011) and more likely to form friendships with classmates of the same ethnicity (Bellmore et al., 2007; Currarini et al., 2010; Goodreau et al., 2009; Hajdu et al., 2021; Kruse et al., 2016; Leszczensky & Pink, 2015; Rodkin et al., 2007; Shrum et al., 1988; Smith et al., 2014; Vermeij et al., 2009; Wilson & Rodkin, 2011; Wittek et al., 2020). Being an ethnic minority is in itself linked to having worse relationships in schools; it has been further argued that the previously ethnically homogenous Czech educational system does not provide any tangible support for ethnic minority students and implicitly promotes lower acceptance of non-Czech students (Jarkovská et al., 2015; Obrovská et al., 2021). Second, most Ukrainian refugees lack proficiency in the Czech language. A lack of proficiency in the national language is one of the greatest barriers for refugees to establishing friendships in schools and largely limits them to establishing friendships with other refugees (Cavicchiolo et al., 2023; Evans & Liu, 2018; Li & Grineva, 2016; Trickett & Birdman, 2005). Third, many Ukrainian refugees faced psychosocial distress stemming from their relocation and war experience, which further exacerbates refugee students' inability to form school friendships (Guarnaccia & Lopez, 1998; Lustig et al., 2004). It has been shown that traumatized children tend to isolate themselves from their peers (Cherewick et al., 2015; Macksoud et al., 1993). Numerous studies focusing specifically on the relationships of first-generation children in schools have confirmed that first-generation children are more likely to face exclusion (Alivernini et al., 2019; Bianchi et al., 2021; Boda et al., 2023; Cheung & Llu, 2012; Guo et al., 2019; Motti-Stefanidi et al., 2008; Oxman-Martinez & Choi, 2014; Plenty & Jonsson, 2017; Strohmeier et al., 2011; Zhang et al., 2020) and are more likely form friendships with other first-generation children (Campigotto et al., 2022; Schachner et al., 2016; Titzmann & Silbereisen, 2009; Windzio, 2015).

Having good peer relationships in school is, however, an essential part of a refugee's successful psychosocial adjustment to a new country, mental health, and academic performance. Adolescents often view school as their primary social context, where they develop and maintain social relations (Coleman, 1961; Steinberg, 2020). Student academic and social lives are therefore intrinsically connected (Juvonen & Wentzel, 1996). Good peer relationships help refugees with psychosocial adjustment by providing social support and a sense of safety (Almqvist & Broberg, 1999; Juang et al., 2018; Kovacev & Shute, 2004). Having good peer relationships in school also leads to better mental health among refugees (Emerson et al., 2022; Samara et al., 2020) and support from friends has a positive impact on refugees struggling with PTSD (Verelst et al., 2022). Furthermore, when refugees have good peer relationships in

schools, it positively influences their academic performance (Wong & Schweitzer, 2017). Conversely, when refugees are excluded by their peers in school and face discrimination from their classmates, they become academically less engaged and more likely to drop out of school (Umaña-Taylor, 2016). Good relationships between refugees and non-refugees in schools further benefit not only the refugee students themselves, but also the non-refugee students – they positively affect student mental health (van der Does & Adem, 2021), lead to lower perceived vulnerability (Graham et al., 2014), and reduce prejudice among students (Pettigrew & Tropp, 2008).

Several studies tried to determine how school or classroom ethnic composition can influence the social integration of refugees and the formation of cross-ethnic relationships among students. The studies have provided inconclusive results and, except for Boda et al. (2023), the studies were not aimed specifically at exploring the effect of classroom composition on the peer relationships of refugee students. On the one hand, Boda et al. (2023) found that ethnically diverse classrooms in Germany enhanced opportunities for refugee students to interact with peers from other ethnic minorities and increase acceptance by peers from the ethnic majority. Similarly, Quillian & Campbell (2003) reported an increase in inter-ethnic friendships as school ethnic diversity increased. Moreover, Kawabata & Crick (2011) and Hajdu et al. (2021) reported an increase in inter-ethnic friendships as classroom ethnic diversity increased. On the other hand, Joyner & Kao (2000) found the adolescent likelihood of having an inter-ethnic friendship decreased as the proportion of same-ethnicity students in their school increased. Smith et al. (2016) reported that the immigrant tendency to form intra-ethnic friendships disproportionately increased as immigrants saw more same-ethnic peers. Similar findings were provided by Bellmore et al. (2007) among middle school students in the United States. Munniksma et al. (2022) found classroom ethnic diversity to be related to worse social adjustment. Altogether, the link between school and classroom composition and the formation of cross-ethnic relationships among students has not been sufficiently researched and requires more investigation. It is useful to consider that the proportion of refugees coming into the individual schools and classrooms can usually be adjusted by the city-level policymakers and school management.

3.1.1 Integration in social networks as an essential component of social integration

The theoretical framing of social integration has evolved over the last hundred years. It has been established that social integration denotes the level of an individual's functioning within a wider social group. The ability of an individual to function within a social group is necessarily dependent on the interpersonal relationships they maintain with other members of the social group, as humans are innately social beings with a constant desire for interpersonal attachments and a need for be-

longing (Baumeister & Leary, 1995). Naturally, social integration of an individual encompasses more than just having relationships with other members of the group – a pivotal role is played by the quality of the relationships with others and by the level to which goals, values, and language are shared among the individuals (Callahan, 2009; Evans & Liu, 2018; Herrero & Gracia, 2004; Thorlindsson & Bjarnason, 1998). However, the ability to form and maintain interpersonal relationships with other members of a group, providing a sense of attachment and belonging, is arguably the essential component of successful social integration in any group. Without meaningful relationships with other members of a social group, an individual's functioning in the group is severely limited. The understanding of the importance of interpersonal attachments has led to a shift in the understanding of social integration, from role-based measures (e.g., Moen et al., 1992; Thoits, 1986) to measures based on interpersonal relationships (e.g., Cohen, 1991), and, more recently, to measures based on social networks (e.g., Hoffman et al., 2015; Rodkin et al., 2007; Wölfer et al., 2012).

Social network theory is highly complementary to the current understanding of social integration. Network theory asserts that to understand a social system, it is important to study how the individuals within that social system interact, what the whole structure of the interactions looks like, and what positions those individuals hold within the structure. As interpersonal relationships are inherently dyadic and dependent on the decisions of at least two individuals involved, social network analysis further asserts it is also important to assess the directionality of the relationships – both how each individual perceives others and how others perceive the individual. Network theory provides a framework for representing the real-world social structures as graphs and makes it possible to study the generative processes driving the network structures (Borgatti et al., 2009). Integrating Blau's (1960) theory of social integration and network theory (Borgatti & Lopez-Kidwell, 2014; Brissette et al., 2000), social integration represents an interactional and relational process in which members of a group form a cohesive social structure with each member both attracted to and attractive for others in the group in such a way that their relationships provide functional social support and equality. Social network analysis allows us to assess an individual's level of integration within a group by looking at how interconnected the individual is with others.

Integrating the paradigm seeing social integration as an interactional process and the paradigm of social networks, we understand the integration of a student within peer social networks as an essential component of the student's social integration within the school's social system, necessary for the student's social and academic functioning (Hoffman et al., 2015; Jiang & Altinyelken, 2022; Stinson & Antia, 1999). We understand student integration in school social networks (Stadtfeld et al., 2019; Windzio, 2015) as the degree to which students are interconnected with each other

through friendship ties and the degree to which students are excluded by their classmates.

3.1.2 Context of the present study

The Czech educational system has placed a high priority on integrating Ukrainian students into mixed classrooms – i.e., classrooms including both Czech and Ukrainian students and the Czech government was explicit about not wanting segregated Ukrainian-only classrooms. Recognizing the importance of successful social integration for the refugee students to ensure a good quality and equitable education, the Czech government has emphasized the need for successful social integration since the beginning of the invasion. In addition to the immediate benefits of social integration related to their academic outcomes, the Czech government expected that a significant number of the Ukrainian refugee students would remain in the Czech Republic indefinitely – eventually becoming a workforce for the Czech economy and members of the Czech society (Ministry of Education, 2022a; 2022c; Ministry of Interior, 2022). The Ministry of Education (2022b) launched a specialized web portal for schools with resources on how to deal with the influx of Ukrainian refugees; however, there were no specific guidelines on how to deal with the social integration of refugees.

Aiming to map the quickly developing situation in Czech schools and evaluate the process of social integration of Ukrainian refugee students, in April and May 2022, the Czech School Inspectorate (CSI) conducted a survey of 626 elementary schools that had ten or more enrolled refugees. The CSI survey was conducted mostly on the basis of inspector visits in the schools and interviews with school management. The CSI concluded that Czech schools were taking appropriate steps to promote the social integration of the Ukrainian students in mixed classrooms and that the social integration of Ukrainian students was adequate (Novosák et al., 2022). According to the CSI, almost all schools took some steps to promote the smooth start of school attendance for the Ukrainian refugees and approximately one fifth of the schools provided adaptation programmes comprised of intensive Czech language lessons and socialisation activities for groups of Ukrainian students. Additionally, the CSI noted that the relationships between Ukrainian and Czech students within the schools were generally positive, with most schools displaying mixed Ukrainian-Czech peer groups, and Czech students consistently demonstrating a willingness to assist their Ukrainian counterparts (Novosák et al., 2022).

3.1.3 Present study

We found the reports from the CSI to be intriguing, since the results of numerous previous studies dealing with the integration of refugee students in peer social net-

works have presented a different picture (e.g., Alivernini et al., 2019; Bianchi et al., 2021; Cheung & Llu, 2012; Campigotto et al., 2022; Schachner et al., 2016; Titzmann & Silbereisen, 2009). We assumed that the positive findings reported by the CSI could be related to the wave of solidarity with Ukrainian refugees and the strong support for the inclusion of Ukrainian pupils in Czech schools expressed by the Czech government and the Ministry of Education. We therefore decided to investigate the situation in the beginning of the 2022/2023 school year.

We provide a brief insight into the integration of Ukrainian refugees into social networks in Czech lower secondary school classrooms with the use of social network analysis. Our research is relevant to researchers, educators, and policymakers dealing with an influx of refugee students into the educational system. We address two research gaps –we provide early evidence on the peer relationships of refugees in the context of the Ukrainian refugee crisis, and we provide evidence on the influence of classroom composition on the formation of peer relationships with a focus specifically on classrooms with refugee students. Hence, we have two aims:

- to map the level to which Ukrainian refugee students are integrated within peer social networks by capturing two inverse dimensions – friendship and exclusion ties;
- to link the classroom ethnic composition to the level of integration of Ukrainian refugee students in peer social networks.

3.2 Methods

3.2.1 Ethical approval

All procedures in this study involving human participants were performed in accordance with the ethical standards of the institutional research committee. Prior to the data collection, the study was approved by the Research Ethics Committee of Masaryk University under the number EKV-2022-091.

3.2.2 Informed consent

Informed consent was given by all participants and their guardians. The teachers clearly explained the purpose of the study to the students and their guardians. Student guardians were given the option to contact the research team before, during, and after the data collection and the option to withdraw their consent and stop participating in the research at any time.

3.2.3 Participants and procedure

Our sample comprised 266 students in grades 5 to 9 (ages 11 to 15) in twelve classrooms in six lower secondary schools in Brno in the Czech Republic. Since we were interested in studying the integration of Ukrainian refugees in mixed classrooms, we aimed at including schools with high numbers of Ukrainian refugees. We employed data from the CSI and identified lower secondary schools with 30-60 Ukrainian refugees enrolled in the 2022/23 school year – there were a total of eight schools. We then contacted the school headmasters and invited them to participate in our research. Six of the eight schools agreed to participate. In each school, we randomly chose two mixed classrooms. We collected data in the first half of the 2022/2023 school year (October to December 2022) – in the period when most of the Ukrainian students were starting their education at Czech schools but had already spent some time with their Czech counterparts and had an opportunity to form relationships. Table 8 displays the key characteristics of the sample, which included a slight majority of boys and a diverse mix of genders and ethnicities across the classrooms. We had no missing data in the sample.

Table 8. Gender and ethnic composition of the sample.

	whole sample abs (%)	**per classroom abs (%)**			
	n	**M**	**SD**	**min**	**max**
students	266	22.17	3.95	17	29
gender composition					
girls	120 (45.11)	10.00 (44.72)	3.38 (11.06)	5 (27.59)	16 (59.26)
boys	146 (54.89)	12.17 (55.28)	3.16 (11.06)	8 (40.74)	21 (72.41)
ethnic composition					
Czech	210 (78.95)	17.50 (78.07)	4.54 (8.60)	11 (61.11)	25 (92.6)
Ukrainian	56 (21.05)	4.67 (21.93)	1.44 (8.60)	2 (7.41)	7 (38.89)

Our research team interviewed the six headmasters and their deputies in the schools in our sample before pursuing the data collection among the students. The school management unanimously called the social integration of Ukrainian refugees their priority and asserted that social integration at their respective school was a success. It was evident that social integration was perceived by the headmasters and their deputies as more important than academic goals. One of the deputies noted: 'Our initial response wasn't about their mastering the curriculum. It was about making them learn the Czech language and socializing in the classrooms.' There was a consensus that Ukrainian pupils were satisfactorily integrated and had established good relationships with their classmates. One of the headmasters commented: 'It looks to me like there's no problem with integration. The kids [Ukrainians] are just seamless in that classroom, they're having fun with the other kids during breaks, and they're running around outside with our [Czech] kids.' The noticeable optimism of the

school management led us to employ a sociometric approach to capture the perspective of all students in the sample classes.

3.2.4 Measuring relationships

We employed a pen-and-paper sociometric questionnaire with two nomination questions (Del Vecchio, 2011; Poulin & Dishion, 2008) – one question about friendship ties and one question about exclusion ties. The aim of the questionnaire was to capture both friendship and exclusion ties among all the students within the classroom. The first question was worded as 'Write the names of the classmates you are friends with. You can write as many names as you want. The order of the names does not make any difference.' The second question was worded as 'Write the names of the classmates with whom you would not like to share a desk. You can write as many names as you want. The order of the names does not make any difference.' The questionnaire was in a bilingual Czech and Ukrainian form. A trained researcher administered the questionnaire in group settings in the classrooms during school lessons and provided the participants with the necessary assistance. We collected data on student gender and ethnicity from the school administrative records provided by the class teachers.

3.2.5 Constructing social networks

After collecting the sociometric questionnaires, we transcribed data from the questionnaires into adjacency matrices. Based on the adjacency matrices, we constructed multiplex social networks for each classroom. A multiplex network contains various layers of ties between the same set of nodes – in our case, the nodes represented the individual students and the ties represented friendship and exclusion nominations. The two layers of ties – friendship and exclusion – are not necessarily mutually exclusive – i.e., it is possible for student A to nominate student B for both friendship and exclusion ties – however, the multiplex projection allows us to account for the fact that student A excluding student B lowers the chance of student A also nominating student B as a friend. The networks were directed – meaning that the ties between the students are directional – we capture the fact that while student A may have nominated student B, student B might not have reciprocated the nomination. The full anonymized adjacency matrices are available in Supplementary Table S1.

3.2.6 Data analysis

ERGM. To study the level to which Ukrainian refugees are integrated within peer social networks, we employed multiplex exponential random graph modelling (ERGM) (Lusher et al., 2013; Wang et al., 2009) on friendship and exclusion ties in *XPNet*

software (Wang et al., 2009). ERGM identifies what influences network formation by assessing which micro-configurations (e.g., reciprocal ties) occur in a network above what would be expected by chance in a random graph given other effects included in the model. ERGM can incorporate multiple effects for a single network. ERGM results in log odds ratios estimates of the existence of a tie conditioned by the model terms. The resulting log odds ratios estimates implicitly account for the interdependency between the individual terms. With the increasing number of included terms, the model therefore yields more conservative estimates and multiple comparisons do not pose a problem. The model terms represent the specific micro-configurations that embody the relational mechanisms we are interested in modelling.

We fitted a single model specification to all classrooms[2]. The model specification modelled the propensity of students to send and receive more ties dependent on their ethnicity, the tendency to form intra-ethnic friendship ties, and the tendency to form inter-ethnic exclusion ties while controlling for other nodal attribute, structural, and cross-layer dependency terms. The full list of included ERGM terms along with their descriptions is available as Supplementary Table S2.

We checked for the convergence and goodness of fit of all models. All the models converged. Goodness of fit was assessed by simulating a distribution of 1,000 networks from the final converged model for each classroom and subsequently comparing this distribution to the observed data on several structural indices. Overall, the models were good fits on the observed data on friendship layers and modest fits on exclusion layers as we did not include the full array of structural effects on the exclusion layers. The full goodness of fit results with the individual structural indices for the individual classrooms are available in Supplementary Table S3.

Meta-analysis and meta-regression. To provide overall effect estimates across the classrooms, we aggregated the results from the individual classrooms using a meta-analytical method. We employed a random-effect model, assuming differences in true effect sizes among the classrooms due to varying school locations, student composi-

[2] Network 12 had almost 100% collinearity between the structural terms (reciprocity, path closure, cyclic closure, multiple 2-paths, and alt.-in-alt.-out-star) and could not be fitted in the same specification as the rest of the networks. Hence, we fitted the next best model, which included reciprocity but excluded other structural terms. In networks 1, 2, 4, 10, and 12, there was no exclusion tie between any of the Ukrainian students, suggesting absolute heterophily. Since we could not get a model estimate, we had to exclude the homophilic effect for ethnicity on exclusion ties in these networks. Therefore, the aggregate effect estimate for the homophilic effect for ethnicity on exclusion ties should be taken only as tentative evidence.

tions, and teacher backgrounds[3]. In a random-effect model, we allow the true effect to vary from study to study and estimate the mean of a distribution of true effects. Each study is weighted by the inverse of both its within-study and its between-study variance. To link the classroom ethnic composition with the level of integration of its Ukrainian refugees, we conducted a mixed-effects meta-regression using the percentage of Ukrainian students in the classroom as a moderating variable for three friendship tie effects: the sender and receiver effect for Ukrainians and the ethnic homophily effect. The meta-analysis and the meta-regression were conducted in the *R* (R Core Team, 2020) package *metafor* (Viechtbauer, 2010).

3.3 Results

3.3.1 Descriptive statistics

We first provide an overview of the basic network descriptors showing several common characteristics present across the networks. Table 9 shows the network descriptors. Both friendship and exclusion layers exhibited several typical features of school networks – high density, centralisation, reciprocity, and transitivity, although the exclusion layers were generally lower on all observed network indices. This suggests that the exclusion layer is less cohesive than the friendship layer. We found positive gender and ethnic homophily on the friendship layer and negative gender and ethnic homophily on the exclusion layer, suggesting that both the exclusion and friendship ties were formed along the lines of gender and ethnicity. The negative correlation between friendship and exclusion ties indicates that the two relationships did not co-occur. The influence of gender and ethnicity on the formation of the ties is visible in Figure 3, with sociograms on the friendship layer exhibiting clusters of students by ethnicity and sociograms on the exclusion layer exhibiting mainly mixed ties.

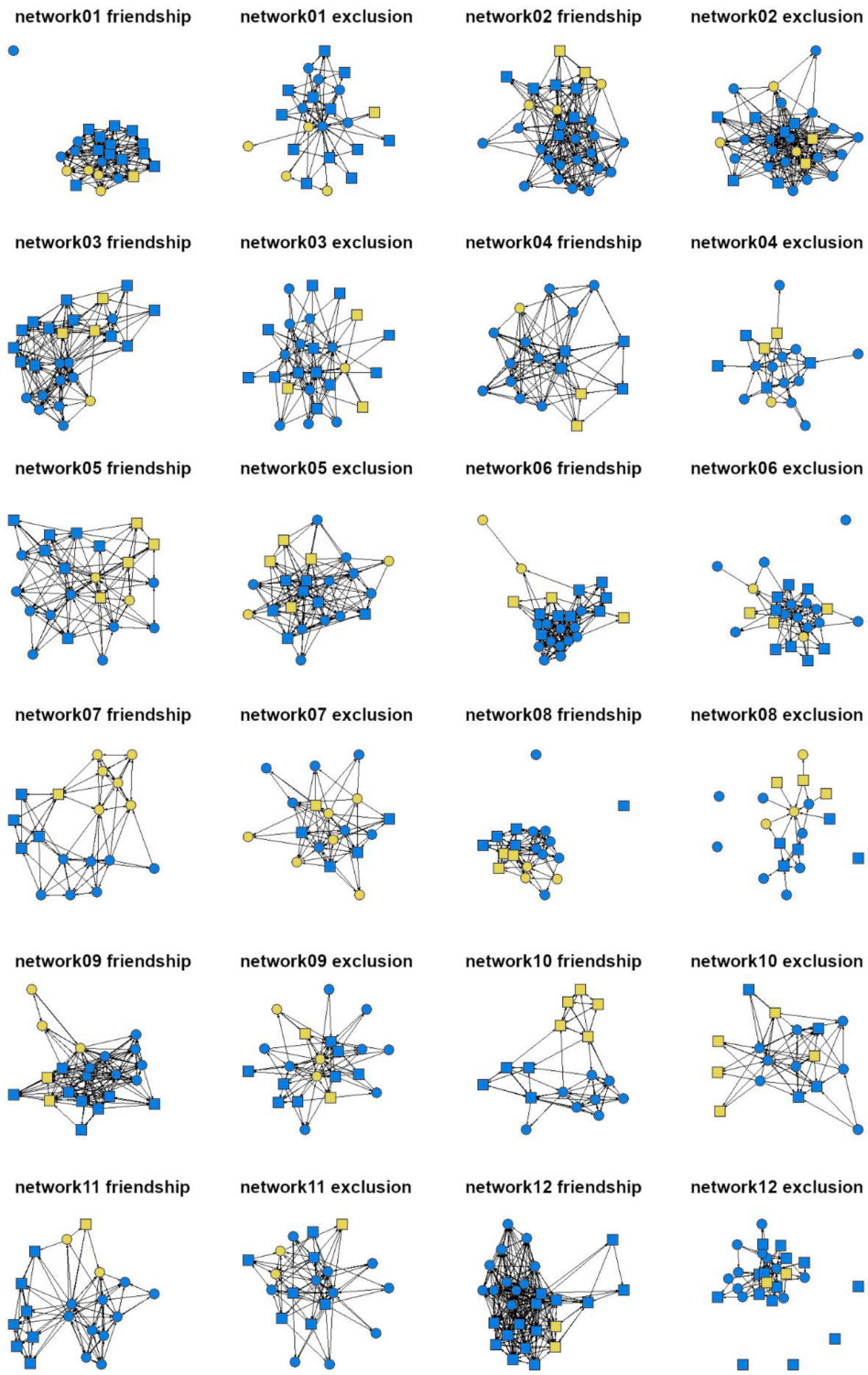
[3] We are aware that a multilevel meta-analytical procedure would have been methodologically more appropriate; however, we could not employ it due to the small sample size. Hence, we employed the second-best option, which was a random-effect model.

Table 9. Network summary statistics of the individual friendship and exclusion networks.

		n	dens.	centr.	recip.	trans.	avg. dist.	avg. deg.	hom. gndr.	hom. et.	cor.: fr. v. excl.
network01	fr.	23	0.42	0.35	0.68	0.68	1.57	9.22	0.24	0.19	-0.33
	excl.		0.17	0.73	0.49	0.34	1.96	3.70	-0.14	-0.10	
network02	fr.	29	0.33	0.30	0.59	0.59	1.80	9.28	0.25	0.26	-0.33
	excl.		0.27	0.48	0.33	0.49	1.85	7.55	-0.24	-0.12	
network03	fr.	26	0.30	0.31	0.52	0.60	2.17	7.46	0.40	0.14	-0.25
	excl.		0.16	0.28	0.24	0.31	2.45	3.88	-0.43	0.07	
network04	fr.	18	0.41	0.35	0.66	0.66	1.65	6.94	0.28	-0.05	-0.35
	excl.		0.17	0.20	0.35	0.28	2.28	2.83	-0.25	-0.15	
network05	fr.	23	0.28	0.42	0.59	0.51	1.92	6.22	0.18	0.27	-0.29
	excl.		0.29	0.29	0.36	0.51	1.91	6.35	-0.05	-0.13	
network06	fr.	25	0.36	0.34	0.71	0.71	1.64	8.64	0.23	0.24	-0.19
	excl.		0.15	0.30	0.30	0.34	2.19	3.68	-0.17	-0.04	
network07	fr.	18	0.31	0.17	0.78	0.58	2.01	5.28	0.58	0.64	-0.35
	excl.		0.25	0.17	0.37	0.36	2.28	4.22	-0.46	-0.32	
network08	fr.	19	0.30	0.27	0.65	0.62	1.74	5.37	0.41	0.27	-0.13
	excl.		0.07	0.22	0.16	0.24	1.38	1.32	-0.32	0.35	
network09	fr.	21	0.46	0.33	0.69	0.73	1.62	9.14	0.30	0.10	-0.41
	excl.		0.20	0.42	0.44	0.35	2.03	4.10	-0.35	-0.14	
network10	fr.	17	0.29	0.19	0.78	0.62	2.08	4.71	0.65	0.78	-0.30
	excl.		0.25	0.29	0.38	0.35	1.89	4.06	-0.50	-0.25	
network11	fr.	20	0.31	0.37	0.64	0.64	1.76	5.90	0.63	0.14	-0.30
	excl.		0.24	0.24	0.41	0.40	2.29	4.60	-0.52	0.04	
network12	fr.	27	0.52	0.40	0.77	0.77	1.55	13.41	0.23	0.02	-0.34
	excl.		0.12	0.24	0.22	0.26	2.18	3.00	-0.21	-0.12	

fr. = friendship; excl. = exclusion; dens. = density; centr. = centralisation; trans. = transitivity; avg. dist. = average distance; avg. deg. = average degree; hom. gndr. = gender homophily; hom. et. = ethnic homophily; cor.: fr. v. excl. = correlation on friendship versus exclusion ties.

Figure 3. Network visualizations of friendship and exclusion layers in the classrooms. Blue nodes denote Czech ethnicity, yellow nodes denote Ukrainian; squares denote girls and circles denote boys. Lines between the nodes denote the existence of a respective type of a tie between two students.



3.3.2 What shapes classroom networks?

We followed the network descriptors with ERGM accounting for the interdependency of the individual effects. The findings from the ERGM meta-analysis indicate that relationships among students in the classrooms were, indeed, largely based on ethnicity and gender. Table 10 shows aggregate ERGM estimates. We found positive and significant ethnic homophily on friendship ties, indicating that students had a strong tendency to form friendship ties with those of the same ethnicity; this tendency influences the networks among the included effects the most. The sender and receiver effects for Ukrainians on friendship ties were found to be significant and negative, indicating a lower tendency of Ukrainian students to form and receive friendship ties than their Czech counterparts. Next, we found a positive and significant homophily effect for gender on friendship ties, suggesting that students had a strong tendency to form friendship ties with classmates of the same gender. Sender and receiver effects for boys on friendship ties were found to be significant and negative, suggesting that boys tended to send and receive fewer friendship ties than girls. Regarding the structural terms on friendship ties, we found reciprocity, path closure, and alternating-in-alternating-out-star effects to be positive and significant, suggesting that students tended to reciprocate ties and to form transitive ties; there was a correlation between the number of sent and received ties. We further found ethnic homophily on exclusion ties to be positive and significant, suggesting that exclusion in the classrooms also followed ethnic lines. This means that students tended to exclude classmates from the same ethnic group. We did not find evidence that Ukrainian students had a higher tendency to exclude others or to be excluded by others compared to their Czech classmates, as both sender and receiver effects for Ukrainians on exclusion ties were not significant. We further found boys to receive significantly more exclusion ties than girls. We found reciprocity effects on exclusion ties to be positive and significant, suggesting that students also tended to reciprocate exclusion ties. Finally, we found the cross-layer tie formation term to be negative and significant, meaning that students had a negative tendency to form both friendship and exclusion ties with the same classmate.

Table 10. Aggregate ERGM results.

effect	log OR	SE	p-value	95% CI
structural effects on friendship ties				
intercept$_{friendship}$	-3.19	0.45	<.01	[-4.08, -2.30]
reciprocity$_{friendship}$	1.63	0.18	<.01	[1.27, 1.99]
path closure$_{friendship}$	1.39	0.17	<.01	[1.05, 1.73]
cyclic closure$_{friendship}$	-0.21	0.12	0.08	[-0.45, 0.02]
multiple 2-paths$_{friendship}$	-0.06	0.08	0.48	[-0.21, 0.10]
alternating-in-alternating-out-star$_{friendship}$	0.77	0.24	<.01	[0.31, 1.24]
covariate effects on friendship ties				
ethnic homophily$_{friendship}$	1.83	0.24	<.01	[1.37, 2.29]
sender effect for Ukrainians$_{friendship}$	-0.61	0.16	<.01	[-0.92, -0.30]
receiver effect for Ukrainians$_{friendship}$	-0.43	0.16	0.01	[-0.73, -0.12]
gender homophily$_{friendship}$	1.32	0.19	<.01	[0.95, 1.68]
sender effect for boys$_{friendship}$	-0.61	0.19	<.01	[-1.00, -0.23]
receiver effect for boys$_{friendship}$	-0.54	0.16	<.01	[-0.86, -0.22]
structural effects on exclusion ties				
intercept$_{exclusion}$	-1.41	0.26	<.01	[-1.92, -0.89]
reciprocity$_{exclusion}$	0.68	0.19	<.01	[0.31, 1.04]
covariate effects on exclusion ties				
ethnic homophily$_{exclusion}$	0.97	0.35	0.01	[0.28, 1.66]
sender effect for Ukrainians$_{exclusion}$	-0.42	0.32	0.19	[-1.04, 0.21]
receiver effect for Ukrainians$_{exclusion}$	-0.26	0.19	0.17	[-0.64, 0.11]
gender homophily$_{exclusion}$	-0.39	0.27	0.14	[-0.92, 0.13]
sender effect for boys$_{exclusion}$	0.34	0.29	0.25	[-0.23, 0.91]
receiver effect for boys$_{exclusion}$	0.48	0.22	0.02	[0.06, 0.90]
cross-layer dependence term				
cross-layer tie formation$_{friendship\ x\ exclusion}$	-2.43	0.20	<.01	[-2.82, -2.03]

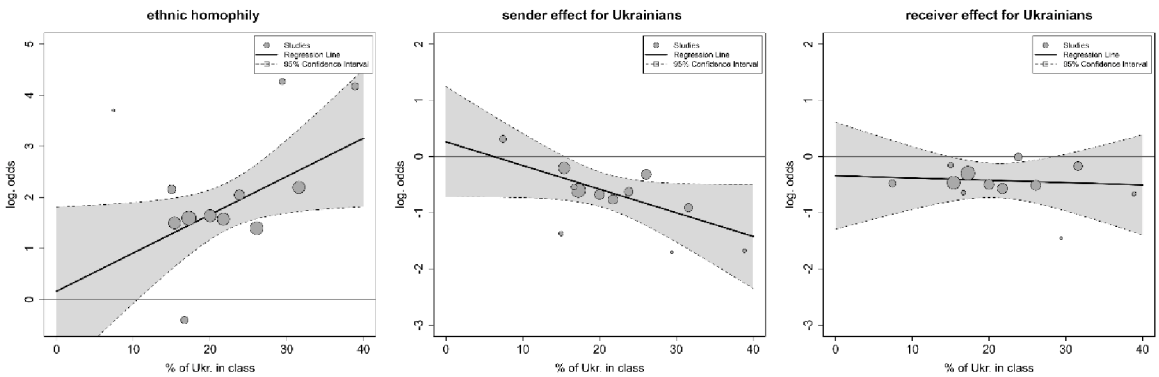
3.3.3 How does classroom composition moderate the integration of Ukrainian refugees in social networks?

Meta-regression revealed that the increasing percentage of Ukrainian students in classroom is related to their worse integration in social networks. Table 11 shows the results of the meta-regression; Figure 4 shows the corresponding bubble plots. The ethnic homophily effect on friendship ties was moderated by classroom composition with a 1% increase of Ukrainian students in a classroom leading to a 0.07 increase in the log odds ratios of homophily behavior significant at a p-value of 0.04. We further found a sender effect for Ukrainians on friendship ties to be moderated by classroom composition, with a 1% increase of Ukrainian students in the classroom leading to a decrease in the tendency of Ukrainian students to send ties by -0.04 log odds ratios at a p-value of 0.07. We find no evidence that the percentage of Ukrainian students in a classroom moderated the tendency of the Ukrainian students to receive ties.

Table 11. Meta-regression analysis results.

	log OR	SE	p-value	95% CI
ethnic homophily$_{friendship}$				
intercept	0.16	0.84	0.85	[-1.92, -0.89]
classroom composition	0.07	0.04	0.04	[0.00, 0.15]
sender effect for Ukrainians$_{friendship}$				
intercept	0.26	0.50	0.61	[-0.72, 1.24]
classroom composition	-0.04	0.02	0.07	[-0.09, 0.00]
receiver effect for Ukrainians$_{friendship}$				
intercept	-0.34	0.49	0.48	[-1.30, 0.61]
classroom composition	-0.00	0.02	0.86	[-0.05, 0.04]

Figure 4. Meta-regression bubble plots of ethnicity effects moderated by classroom composition. The point size is proportional to the weight that the ERGM estimates from the individual classrooms received in the analysis.



3.4 Discussion

We found solid evidence that social networks in Czech mixed classrooms with Ukrainian refugee students are heavily formed along ethnic lines even when interdependencies with gender and structural terms are accounted for, and that a higher percentage of refugee students in a classroom is related to refugees' worse integration in social networks. Ethnic homophily was found to have the strongest effect on the formation of friendship ties among all studied effects and this effect was higher with higher percentages of Ukrainian students in the classroom. Ukrainian students tended to both send and receive fewer friendship ties and the former effect is – like the homophily effect – higher with the higher percentage of Ukrainian students in classroom.

Our findings add to the array of previous studies proving that refugee students face a lack of integration in peer social networks. Our findings of strong ethnic homophily among refugee students support the findings of Campigotto et al. (2022),

Schachner et al. (2016), Titzmann & Silbereisen (2009), and Windzio (2015). Our findings of a lower tendency of Ukrainian students to receive friendship ties indirectly support previous findings of a higher risk of exclusion among refugee students (Alivernini et al., 2019; Bianchi et al., 2021; Guo et al., 2019). However, we did not find a significant tendency of Ukrainian students to receive more exclusion ties. Hence, we cannot speak of explicit rejection by their classmates; rather, we saw a tendency of the Ukrainian students to be neglected.

We provide evidence to the developing line of literature that classroom ethnic composition may indeed influence the level of refugees' integration in peer social networks. Our results support the results of Smith et al. (2016) and Munniksma et al. (2022), suggesting that a higher ratio of refugee students in a classroom may lead to worse inter-ethnic relationships. This finding contradicts Boda et al. (2023) and challenges the widespread belief among many educators that schools should be aiming for ethnically diverse classrooms. While Boda et al. (2023) also employed a network analysis framework, they did not explicitly model network structure, leaving aside terms like reciprocity and transitivity. Furthermore, they assessed the relationship between classroom ethnic diversity and refugee integration by categorizing classrooms into three groups. In contrast, our models explicitly modelled tie formation mechanisms, incorporated the structural terms, and measured the relationship between classroom ethnic diversity and refugee integration on a continuous scale, yielding finer results. We also believe our findings should be assessed in the light of our specific research context. We assume the relationship between the ratio of refugee students in the classroom and worse inter-ethnic relationships to be the result of increased opportunities for the refugee students to form ties and cliques with other refugee students, and more importantly with classmates speaking the same native language and with classmates sharing entry into classrooms in which peer social groups had already been formed and established before their arrival.

Our findings stand in contrast to reports from the CSI (Novosák et al., 2022) and the school management – while the CSI and the school management found social integration of Ukrainian refugees to be seamless, we found the opposite. We are convinced that this is a case of a perception bias in which the actors who are not part of the social system perceive situations in the social system differently than the actors who are part of the system. In our case, the perception of the school management – which was also the main source for the conclusions provided by the CSI – might perceive the situation among students differently than the students themselves do. The management might be unable to perceive the social integration among students accurately because it has little to no understanding of the relational nature of social integration (e.g., the management might perceive social integration as Ukrainian and Czech students simply sharing a common classroom) and because the management has only limited contact with the students and their perception is therefore skewed. It is also possible that the management pays attention to different aspects of peer

relationships than we measured, such as breaktime interactions, sports, or extracurricular activities. Again, in such cases, the perception of the situation from an external management's perspective may differ from that of students within the social system.

3.4.1 Limitations

Our study has several limitations. We had a limited sample size of twelve classrooms and these classrooms were not a random sample from the Czech Republic. The estimates with the p-values in the meta-regression accounted for the limited sample size, but we cannot exclude the possibility that our findings were affected by sampling error. The limited sample size further prevented us from employing a multilevel meta-analytical approach with classrooms nested in the individual schools. Moreover, we considered only friendship and exclusion ties, not accounting for other possible types of ties that might exist between the students such as bully-victim or romantic ties. These limitations reduce the generalisability of our findings. Furthermore, in one classroom, there was almost perfect collinearity between the structural terms, preventing the convergence of the full model specification. This might have caused bias effect estimates from the one exhibited perfect heterophily due to non-existent exclusion ties among the Ukrainian students, and this perfect heterophily could not be incorporated in the aggregate model. Finally, we relied on cross-sectional data although school social networks evolve over time and cross-sectional data do not make it possible to study changes occurring in the networks.

3.4.2 Implications

This study has several practical implications. The higher proportion of Ukrainian students in classrooms leading to the higher tendency to form homophilic friendship ties and the lower tendency of Ukrainian students to send friendship ties implies that to achieve a better integration of refugees in peer social networks, it would be useful to place refugee students in classrooms in such a way that they do not constitute more than 20% of the students. We do not suggest schools should form segregated classrooms – quite the opposite – we advise a more even distribution of refugees into the classrooms. Furthermore, the fact that Ukrainian refugee students face a lack of integration within peer social networks calls for the development, application, and evaluation of intervention strategies aimed at improving the cohesion of relationships in classrooms and overcoming the barriers limiting Ukraine students' ability to form relationships with the Czech students. The research has consistently shown that having good peer relationships in school is an essential part of refugees' successful psychosocial adjustment (Juang et al., 2018), mental health (Emerson et al., 2022), and academic performance (Wong & Schweitzer, 2017), and that good relationships between refugee and non-refugee students benefit the non-refugee students as well

(Pettigrew & Tropp, 2008). However, the Czech Ministry of Education has not yet published guidelines for schools with evidence-based recommendations on intervention strategies aimed at improving the social functioning of Ukrainian students in Czech schools. We assert that future guidelines should follow the line of research dealing with interventions aimed at forming relationships between refugee and non-refugee students. Examples of interventions found to improve cross-ethnic relationships include inter-ethnic tutoring (Datta & Singh, 1994), cooperative learning (Weigel et al., 1975; Slavin & Oickle, 1981), shared sport activities (Makarova & Herzog, 2014), and school-based extracurricular activities (Suh & Kim, 2011). The refugees often lack proficiency in the Czech language; eliminating the language barrier should therefore be a priority as the lack of national language proficiency is a critical barrier in forming peer relationships (Cavicchiolo et al., 2023).

This study provides guidance for future research. Based on the comparison between the results of our network study and the reports of the CSI along with the school management, we are convinced that any research aiming to explore social integration or relationships between students should be a network study among the students themselves and such research should not rely solely on reports from other actors. Relying solely on reports from headmasters or teachers may provide results that do not reflect reality. We are further convinced that it is important to study how exogenous factors influence the formation of ties among students in classrooms. In our study, we have concluded that classroom composition influences homophilic behavior. However, other actors involved in education, such as teachers with practices aimed at improving inter-ethnic relationships, might be able to influence student tendencies to form inter-ethnic relationships as well. Hence, our research team is already planning a more extensive data collection with a longitudinal design focused on peer networks in Czech mixed classrooms with the hope of shedding more light on practices improving the social functioning of Ukrainian refugee students.

4 Study C: Relational dynamics in bullying, victimization, and defending perceptions

Reference: Lintner, T., Klocek, A., Ropovik, I., Kollerová, L. (2023). Relational dynamics in bullying, victimization, and defending perceptions. *PsyArXiv preprint*. https://osf.io/7edcp/

Journal meta-data: preprint at PsyArXiv, under review in Aggressive Behavior.

CRediT author statement: Tomáš Lintner (50%): conceptualization, research design, data analysis, writing and revising the paper. Adam Klocek (20%): data analysis, writing and revising the paper. Ivan Ropovik (15%): data preparation, data analysis, writing and revising the paper. Lenka Kollerová (15%): data collection, writing and revising the paper.

All co-authors gave consent to the aforementioned author statement.

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Data availability statement: The data, the analytical code, and the supplementary materials are available at OSF at https://osf.io/7edcp/.

Abstract: Bullying, victimization, and defending are frequently measured using reputational peer nominations. However, students' bullying role perceptions may be biased by their affective relationships. This study applied multiplex stochastic actor-oriented modelling on 27 classrooms with 632 early adolescents to assess whether dyad- and group-level relationships shape students' bullying roles perceptions and to examine the moderation effect of classroom bullying norms. We used longitudinal design with two timepoints allowing us to assess the directionality of the interactions between relationships and bullying role perceptions. We show that liking a classmate increased the likelihood to perceive them as a defender. The bullying role perceptions of liked classmates further influenced one's own perceptions, with classroom moral disengagement reducing the influence of defender perceptions towards these classmates. Future research should account for students' affective relationships to mitigate bias in bullying role perceptions.

4.1 Introduction

Bullying is a universally occurring phenomenon in schools (Craig et al., 2009) with long-lasting negative effects extending beyond the directly involved individuals (Copeland, 2013; Klomek et al., 2007; Midgett & Doumas, 2019; Moore et al., 2017; Yuchang et al., 2019). Considering the universal presence of bullying in schools and the detrimental effects bullying has on students, it is crucial to provide targeted interventions aimed at lowering the incidence of bullying at schools. However, to design tailored interventions, it is crucial that we have accurate methods for identifying bullying in schools and that we understand the processes driving bullying in schools.
Typically, bullying is identified by two methods – a direct relational approach or a reputational peer nominations approach. In the former approach, students are asked to identify bullying (and sometimes defending) ties between them and the classmates, or between the classmates (e.g., Huitsing & Monks, 2018; Veenstra & Huitsing, 2021). In the latter approach, students are asked to rate each other on specific items aiming to capture bullying, victimization, or defending using a scale (e.g., Hunter et al., 2021; Veenstra & Huitsing, 2021), or to directly nominate classmates based on specified bullying roles (e.g., Huitsing & Veenstra, 2012; Malamut et al., 2020; Obermann, 2010; Raine et al., 2006; Salmivalli et al., 1996). Typically, researchers calculate the average scores for each student and use various cut-off classification schemes to assign peer roles such as bully, victim, or defender (Solberg et al., 2007).

There is an understudied problem with the reputational peer nominations approach – students' perceptions of bullying may be biased by their affective relationships with classmates. In the context of peer social networks, social support theory posits that friends provide support to each other, which leads to a sense of moral commitment and obligation (Colvin et al., 2002; Cullen, 1994). It was argued that the sense of moral commitment and obligation is frequently shown as loyalty towards one's friend (Brezina & Azimi, 2018). It is then reasonable to expect that perceiving a classmate as a bully or a willingness to admit to perceiving a classmate as a bully will, to some degree, be negatively influenced by one's friendship with the bully. Conversely, it is reasonable to expect that if a student dislikes another student, they are more likely to perceive the student as a bully.

Similarly, social support may play a part in students' bullying roles' perceptions on a group-level. It has been established that students form peer groups with members within a peer group having good and dense relationships with each other and worse or less dense relationships with classmates outside the peer group (Espelage et al., 2007; Hallinan & Smith, 1989; Kindermann & Gest, 2009). It is therefore possible that if two or more peer groups are in some form of conflict, students within the peer groups are more likely to perceive each other positively – for example as defenders – and those in the opposing peer group more likely to perceive as bullies.

Finally, because classroom-level bullying norms present the most proximal context to students' attitudes and behaviors related to bullying (Pozzoli et al., 2012; Salmivalli, 2010) they might moderate the willingness to admit to perceiving a friend as a bully. Norms against bullying might reduce the willingness to admit to perceiving a friend as a bully while the opposite might apply in case of pro-bullying norms.

4.1.1 Evidence for the role of dyadic relationships

Previous evidence for interaction between students' relationships and perceptions of their classmates' bullying roles is scarce, focuses on student self-reports, and does not consider the bidirectional nature of the interaction. Dyadic investigation of cross-sectional relational nominations showed that self-reported bullies nominated classmates to be their victims more often when they disliked the classmates, and a similar association was found for the perspective of self-reported victims (Veenstra et al., 2007). Self-reported victims were also more likely to nominate classmates as their defenders when they liked them (Oldenburg et al., 2018; Rambaran et al., 2022). Corresponding effects for reputational nominations have not been examined. Since reputational nominations measure related but distinct constructs to relational nominations, it is reasonable to ask whether the fact that a student likes or dislikes a classmate affects what participant role in bullying the student will ascribe to that classmate.

4.1.2 Evidence for the role of group relationships

Previous evidence for the group-level processes influencing students' perceptions of their classmates' bullying roles is missing and we can draw only limited inference from the existing studies focusing on bullying group-level processes in general. In network studies, group-level processes have been operationalized as mixed triadic effects – i.e., the tendency of students to form some type of tie towards another classmate conditioned on the existence of other types of ties between the given student and a third student. It was found that when student A dislikes classmate B and classmate B dislikes classmate C, there is a higher probability that student A will like classmate C (Huitsing et al., 2012). The authors pointed out that at the structural level, classroom structure of liking ties partially explained structures of disliking and bullying ties (Huitsing et al., 2012). It was further found that there is a complex interdependency between disliking and defending, such as that defending was more likely to occur between students who disliked the same classmates (Oldenburg et al., 2018; Rambaran et al., 2022). In other words, previous research suggests the existence of influence of peer group members' bullying and defending preferences on other group members' preferences. However, research on ingroup and outgroup dynamics between liking or disliking and perceptions of bullying, victimization, and defending is limited.

4.1.3 Evidence for the role of classroom norms

Bullying research documented that classroom norms adopted by peers contribute to peer group processes related to bullying, because they set what behaviors in classrooms are common or valued and what behaviors are rare or socially sanctioned (Salmivalli, 2010). Theoretically relevant classroom norms could include both norms approving bullying (Sentse et al., 2007), including classroom moral disengagement (Thornberg et al. in 2021), and pro-defending norms, such as peer pressure to defend victimized peers (Pozzoli et al., 2012). The peer norms could be expected to moderate potential links between affective relationships and future perceptions of bullying roles–perceiving someone as a bully, victim, or a defender – because the norms present forces that shape to what extent bullying, victimization, and defending are accepted in the peer group.

However, there is very limited evidence for the moderating role of classroom norms on associations between students' affective relationships and perceptions of their classmates' bullying roles. To our knowledge only a few studies have touched upon the issue. Shin (2022) found that high bullying norms in classroom are related to bullies more likely to select other bullies as friends – the study therefore suggests that classroom-level bullying norms might moderate willingness of students to ascribe certain bullying roles to their friends. Rambaran et al. (2022) found that being defended by someone whom one likes was less likely to happen in classrooms with high overall bullying occurrence – suggesting that pro-bullying classroom norms make liking defenders less likely. Finally, Romera et al. (2019) found that both higher overall pro- and anti- bullying classroom norms were linked to bullies and defenders being more popular – suggesting that strong bullying norms in classroom make both bullies and defenders to be more likely to be liked.

4.1.4 Present study

The present study builds on the argument that investigating bullying in classrooms using students' reputational peer nominations without accounting for the interdependencies with students' affective relationships of liking and disliking, may introduce a bias into the investigation. As Vörös and Snijders (2017) highlighted, avoiding an ecological fallacy necessitates differentiating tie-, individual-, and group-level processes, which calls for modelling social relationships as a complex system. In light of this argument and a recent call to focus on longitudinal development of ties in bullying contexts (Veenstra & Huitsing; 2021), the current study adopts a multiplex social network approach to understand how students' perceptions of bullying roles are shaped by their relationships. The multiplex approach allows the examination of multiple types of relationships simultaneously within the same network (Vörös & Snijders, 2017), and thus provides a crucial framework to explore how different types of relationships in-

terconnect and impact the bullying roles perceptions in classroom settings. By dissecting the bullying role nominations into ties between individual students, we can explicitly model five interactive types of ties: relationship ties of liking and disliking, along with ties representing perceptions of bully, victim, and defender roles.

Crucially, we do not attempt to conclude who bullies whom, as it was the case with several network-based studies in the past (e.g., Huitsing & Monks, 2018; Veenstra & Huitsing, 2021), and we do not attempt to arrive at an objective truth about the bullying relations among students. On the other hand, the primary objective of this study is to understand how dyad-, group-, and classroom-level processes shape students' perceptions of bullying roles, whilst controlling for the effects of these perceptions on their relationships. Compared to previous studies (e.g., Hunter et al., 2021; Salmivalli et al., 1996), we consider each individual perception as a unique tie, instead of aggregating the individual perceptions into student-level attribute, which results in the ecological fallacy, as described by Vörös and Snijders (2017). We address physical bullying which presents on the of most common and harmful forms of how bullying manifests (Olweus, 1978; Salmivalli et al., 1996). A longitudinal design of this study allows us to assess the directionality of interactions between students' relationships and their perceptions of bullying roles.

4.1.5 Hypotheses

In line with the social support theory (Colvin et al., 2002; Cullen, 1994), we expect dyad- and group-level affective relationships to influence students' perceptions of bullying roles, and we expect this influence to be moderated by classroom-level bullying norms.

The first set of hypotheses deals with the influence of dyadic affective relationships of liking and disliking on student's perceptions of bullying roles. We expect liking a classmate to lead to a lower tendency to see them as a bully, and a higher tendency to see them as both a victim and a defender. We further expect that disliking a classmate leads to a higher tendency to see them as a bully and a lower tendency to see them as a defender. We do not have a specific expectation about the association between disliking a classmate and perceiving them as a victim. The first set of hypotheses was as follows:

H1a: Liking a classmate leads to a lower tendency to perceive them as a bully.
H1b: Liking a classmate leads to a higher tendency to perceive them as a victim.
H1c: Liking a classmate leads to a higher tendency to perceive them as a defender.
H1d: Disliking a classmate leads to a higher tendency to perceive them as a bully.
H1e: Disliking a classmate leads to a lower tendency to perceive them as a defender.

The second set of hypotheses address the influence of group processes on disliking and perceptions of bullying roles. We expect that liking a classmate who dislikes another

classmate or perceives another classmate as having specific bullying roles influences one's tendency to dislike or perceive the other classmate the same way. Hence:

H2a: Liking a classmate who dislikes another classmate increases one's tendency to dislike the same classmate.
H2b: Liking a classmate who perceives another classmate as a bully increases one's tendency to perceive the same classmate as a bully.
H2c: Liking a classmate who perceives another classmate as a victim increases one's tendency to perceive the same classmate as a victim.
H2d: Liking a classmate who perceives another classmate as a defender increases one's tendency to perceive the same classmate as a defender.

The third set of hypotheses targets the moderating effect of classroom norms on the influence of affective relationships of liking and disliking on tendencies to ascribe classmates bullying, victimization, and defending roles. We expect that in classrooms with high levels of classroom moral disengagement or low levels of classroom defending norms, students are more likely to ascribe bullying to classmates that they like and less likely to ascribe victimization and defending to students that they like compared to other classroom contexts. We expect to find corresponding moderating effects, only in the opposite direction, for the links between disliking and students' perceptions of bullying roles. Hence, the main expectations were as follows:

H3a: Higher classroom moral disengagement moderates the influence of dyadic and group liking and disliking on students' perceptions of bullying roles.
H3b: Higher classroom defending norms moderates the influence of dyadic and group liking and disliking on students' perceptions of bullying roles.

4.2 Methods

4.2.1 Participants

The study's sample involved 751 early adolescents (50.6% girls) from 39 seventh-grade classrooms of 20 comprehensive elementary schools in Prague, the Czech Republic. The sample was age-homogeneous (M_{age} at Time 1 = 12.9 years, SD = 0.4) – at the beginning of the study, most students were within the 12-13 years age range, while a small number were of different ages: one student was 11 years old, four were 14 years old, and one was 15 years old. The sample was mostly ethnically homogenous with 88.1% of the participants identifying as Czech. As data from some of the classrooms did not allow for an adequate convergence of the models (described in *5.6.1 SAOM* section), the effective sample size dropped to 27 classrooms comprising 632 students.

4.2.2 Procedure

We selected 28 comprehensive elementary schools in Prague at random and invited them to participate in our study, while 20 of the schools agreed to participate. Within each of the 20 participating schools, all seventh-grade classrooms (ranging from 1 to 4 classrooms per school) were included in the sample. We collected data at two timepoints (T1 and T2) with an interval of 6 months (± 2 weeks) within the same school year 2015/2016. All data were collected using pen-and-paper questionnaires administered in classrooms over two consecutive lessons. Trained research assistants facilitated the data collection.

This research was approved by the Ethics Committee of the Institute of Psychology of the Czech Academy of Sciences No. 656/Pha/17. All parents and legal guardians gave written informed consent to participation in the research. The study comprised students who had obtained written parental consent, were present at school during the study's administration, and willingly agreed to take part in it. No incentives or compensation were given to the participants. In each classroom, two trained research assistants were present during administration to ensure privacy and emotional safety. To maintain anonymity, we did not collect any personally identifiable data – all participants were assigned numerical codes for data storage. Following the project's conclusion, the participants received leaflets with basic information about bullying and effective responses to bullying (reporting the bullying to school personnel) and contact details for relevant hotlines.

4.2.3 Measures

Affective relationships. We used relational unlimited nominations to measure two distinct types of affective relationships among the students. Following the conceptualization and established measurements of positive and negative ties between students (Cillessen & Marks, 2011), we used direct relational nominations to assess liking and disliking ties of students. The questions were constructed as "Who do you like most?" and "Who do you like least?". We assigned values of 1 if a student nominated their classmate – indicating the presence of a tie – and a value of 0 if a student did not nominate their classmate – indicating the absence of the tie.

Bullying roles perceptions. We further used reputational peer nominations to assess how students perceived their classmates' participant roles in physical bullying. We measured the perceptions of bullying, victimization, and defending using single items that assessed participant roles in physical bullying and were adapted from a self-report measure by Pozzoli & Gini (2010). Participants were asked to rate each classmate according to how often the classmate had behaved in a particular way during the previous 2-3 months. The statements were constructed as "He/she hits or

pushes some classmates" for bullying, "Some classmates attack him/her hard or hit or push him/her" for victimization, and "He/she defends classmates who are hit or attacked hard" for defending. Possible answers were as follows: never (1), sometimes (2), and often (3). We transformed the "never" value into "0" and the "sometimes" and "often" values into "1" assuming that any notion of the given behaviour among a classmate from a student's point of view indicates the student's perception of the classmate's bullying role.

The procedure assessing affective relationships and the perceptions of participant roles in bullying resulted in having five unweighted directed adjacency matrices for each classroom, each matrix representing a network with specific type of ties, together forming multiplex networks. The ties in the individual types of networks were not mutually exclusive.

Classroom moral disengagement (CMD). Classroom collective moral disengagement scale (Gini et al., 2014) was used to assess classroom moral disengagement, i.e., beliefs justifying bullying that are shared by classroom members. The originally Italian scale was validated in the Czech Republic by Kollerová et al. (2018a). The scale consists of 17 morally disengaged statements (e.g., "It is alright to beat someone who bad-mouths your family.") For each item, students rated "In your classroom, how many kids think that … [item]." Students marked their responses on the following 5-point scale: 'None,' 'About a quarter (25%),' 'About a half (50%),' 'About three quarters (75%),' and 'Everyone.' This variable was only measured at the second time point. To reduce the dimensionality of the measure, we fitted a unitary confirmatory factor analysis (CFA) model using the Weighted Least Squares – Mean and Variance Adjusted estimator, modelling the ordered nature of the items. We then computed the individual factor scores and aggregated them to the classroom level. The unidimensional factor structure had a mediocre fit to the data, with $\chi2(119) = 462$, $p < .001$; CFI = .91; TLI = .90; RMSEA = .071, 95% CI [.064, .078].

Classroom defending norms (CDN). Classroom defending norms as shared perceived peer pressure to defend victimized classmates were assessed using a 3-item measure (Kollerová et al., 2018b) introduced by the following instruction: "Classmates who are important to me think that I should …,". The instruction was followed by three items related to defending classmates who have been victimized by physical, verbal, and relational aggression. Participants expressed their agreement with these statements on a 5-point scale, ranging from "No" (1) to "Yes" (5). Data obtained at the second time point were used in the present study. Because there were only three items, we computed a unidimensional component score using the principal component analysis (PCA) instead of CFA and aggregated the individual scores at the classroom level. We do not report the model fit here because the model was just-identified (loadings of all three items ranged from $\lambda = .78$ to .92).

Student covariates. To control the effects of gender on student relationships, we also collected data on students' gender.

4.2.4 Handling missing data

In the 27 classrooms included for the analysis, there were some missing ties of all types and no missing data on gender. At T1, we had on average 21.5% of missing liking, disliking, bully, victim, and defender perception ties. At T2, we had on average 26.8% of missing liking and disliking ties, and 26.1% of bully, victim, and defender perception ties. The missing ties were treated as non-informative and dealt with a method described in detail in Huisman & Steglich (2008) as method four. In the first wave, missing entries within the adjacency matrices were assigned a value of 0, under the assumption of no ties, reflecting the common scenario of data sparsity where 'no tie' is typically the modal value. For the second wave, the last observation carried forward approach was employed for all tie variables; tie value at T1 was used to impute the T2 value. The models were based on simulations carried out over all variables as if they were complete. However, to mitigate the impact of missing data treatment on parameter estimation, only non-missing data were utilized for calculating the target statistics.

4.2.5 Analytical strategy

Stochastic Actor Oriented Models. To test the first and the second set of hypotheses and capture the interacting mechanisms of affective relationships and the perceptions of bullying roles, we used multiplex Stochastic Actor Oriented Models (SAOM; Snijders et al., 2010; Snijders et al., 2013) in *R* (R Core Team, 2020) package *RSiena* (Ripley et al., 2011). Multiplex SAOMs are network models which can take a change on one type of tie between students as a dependent variable co-evolving with other types of ties between the students while controlling for student characteristics and endogenous network mechanisms. In our case, we were interested in modelling changes on liking and disliking ties and changes on ties of perceptions of bullies, victims, and defenders conditioned on each other. SAOMs are actor-oriented meaning that tie change between the students is assumed to be the result of students' own choices about their outgoing ties. What changes students make is determined by the objective function, which contains the modelled effects capturing the hypothesized mechanisms, while how often they get to make these changes is determined by the rate function. Having two timepoints allowed us to assess the direction of the dependencies between the types of ties – for example, it allowed us to assess whether students tend to form liking towards those whom they consider defenders, or whether students tend to consider classmates as defenders if they had already formed liking towards them.

We obtained the parameter estimates and their standard errors (SEs) using the Method of Moments estimation technique. The tie change was operationalized by the evaluation function meaning that the parameter estimates were calculated on the presence of ties regardless of whether they were newly created or maintained from T1 to T2. The resulting parameter estimates are in log odds ratios (log OR). Their positive values indicate that when the network configurations embodied by the given parameter are attractive for the students, they are more likely to create or maintain ties embedded within them, whereas negative values indicate the opposite.

Prior to the analysis, we conducted pilot convergence checks to screen out classrooms where the proportion of missing data was too large to provide an admissible solution for a given model. For all models included in the analysis, we also carried out post-estimation convergence and goodness of fit (GoF) checks. Convergence issues denote situations when estimates from the model are expected to be biased due to algorithm not finding stable parameter estimates that adequately represent the observed social network dynamics. We used the criteria in Ripley et al. (2011) when assessing the convergence – the t-ratios for convergence for all model terms are recommended to be <.10, and the overall maximum convergence ratio is recommended to be <.25. If convergence of a model was not achieved in a single estimation run, we engaged in a structured, automated series of estimations. First, in three runs, the algorithm attempted to improve convergence by using estimated parameters as starting values for the next estimation run. If not successful, three additional models were estimated, which increasingly used more iterations and smaller steps (reducing the scaling parameter). We provide the full description of the estimation procedures as Supplementary material 1. GoF, on the other hand, denotes the degree to which the model represents the observed real-world network. GoF was assessed by simulating a distribution of 1,000 networks from each converged model for each classroom and subsequently comparing this distribution to the observed data with respect to indegree and outdegree distributions, geodesic distances, and triad census. The models generally showed good fit on the liking networks with minor signs of misfit in terms of indegree and outdegree distributions, and signs of misfits on disliking networks in terms of triad censuses. The misfits on disliking networks in terms of triad censuses were probably the result of not having triadic effects on the disliking networks included. However, including them along with triadic effects on liking networks resulted in convergence issues, hence, we prioritized optimization for adequate convergence over goodness of fit on disliking ties.

Meta-analysis and meta-regression. After fitting the individual SAOMs, we transformed the original effect estimates into relative importances of effects, and we aggregated them using a meta-analytical approach to get overall effect estimates over the classrooms. We used the Indlekofer-Brandes measure of relative importance for effects (Indlekofer & Brandes, 2013) to get comparable effect estimates from all

classrooms. We then employed random-effects meta-analysis in *R* package *metafor* (Viechtbauer, 2010), assuming that the observed estimates varied across the classrooms both because of real differences in the true effect sizes in each classroom and because of the sampling variability. To test the third set of hypotheses, after conducting the meta-analysis, we estimated a set of meta-regression models investigating the moderating effect of CMD and CDN which might influence the size of estimated meta-analytic effects derived from the SAOMs. We conducted the meta-regression separately for the three distinct model specifications as described in *5.7 Model specifications*. After estimating the effect in the baseline model, we cross-validated the inference regarding the presence of the effect in more complex models. Once any effect was estimated using the more comprehensive models, we always selected primarily the model with a higher sample size.

To test the third set of hypotheses and assess the moderating role of classroom bullying norms on the influence of dyadic and group liking and disliking on student's perceptions of bullying roles, we conducted a series of meta-regression analyses moderating the results extracted from the meta-analyses by CMD and CDN, aiming to explain heterogeneity of variance in effect sizes between the studies. We modelled each moderating effect separately. We conducted the meta-regression using the three different model specifications: the baseline model (n = 27), the reduced model (n = 16), and the full model (n = 8). The number of eligible studies decreased with the increasing number of estimated effects. In this paper, we report only the effect estimates relating to our hypotheses. We provide the remaining effect estimates as Supplementary material 2.

Apart from using p-values for error control, to evaluate the comparative evidence supporting the moderation effects, we employed Bayes factors (BF). Bayes factor offers insight into whether the data are more consistent with the null hypothesis (H0, effect absent, BF < 1), the alternative hypothesis (H1, effect present, BF > 1), or are inconclusive. Using a model-selection/information-criteria approach suggested by Wagenmakers (2007), we estimated BF through a BIC approximation, implicitly assuming a unit information prior. Alongside BF, we also computed the posterior probabilities for each parameter. These probabilities indicate the likelihood of the moderation parameter being different from zero, under the assumption of 1:1 prior odds for H0 and H1. We interpreted values of BF larger than 3 (or smaller than 1/3) as suggestive evidence and values larger than 10 (or smaller than 1/10) as strong evidence in favour of the respective hypothesis.

4.2.6 Model specifications

We fitted three distinct model specifications – a baseline model, a restricted model, and a full model. We fitted different specifications because the full model could not be fitted to most of the classrooms due to convergence issues. Hence, using a backward selection, we fitted the full model testing all our hypotheses, the restricted model testing our

hypothesis without the victim perceptions, and the baseline model without both the victim perceptions and the disliking ties. We could fit the baseline model to 27 classrooms, the reduced model to 16 classrooms, and the full model to 8 classrooms. We included the following effects with Figure 5 showing the diagrams for the effects:

• *entrainment of X by W* – capturing the tendency of a student to form or maintain one type of tie with another student conditioned on the existence of another type of tie with the same student. With this term, we tested the first set of hypotheses relating to the dyad-level interactions – the effects of affective relationships on perceptions of bullying roles. We further used this term to control for the possible reversed direction of the relationship by including the effects of perceptions of bullying roles on affective relationships.

• *W to agreement* – capturing the tendency of a student to form or maintain one type of tie with another student conditioned on the existence of the same type of tie towards the student from a third student with whom the first student has another type of tie. With this term, we tested the second set of hypotheses relating to the group-level interactions – the effects of liking on shared disliking and perceptions of bullying roles.

• *from W agreement* – capturing the tendency of a student to form or maintain one type of tie with another student conditioned on the existence of a shared different type of tie towards a third student from both students. With this term, we controlled for the possible reversed direction of the interactions included in the second set of hypotheses relating to the group-level interactions – the effects of shared disliking and perceptions of bullying roles on liking.

• *girl alter, girl ego, and same gender* – capturing the tendency of girls to receive or send more ties, and the tendency to form or maintain ties with students of same gender. With this term, we controlled the effects of gender on liking ties.

• *reciprocity* – controlling the tendency of students to reciprocate ties.

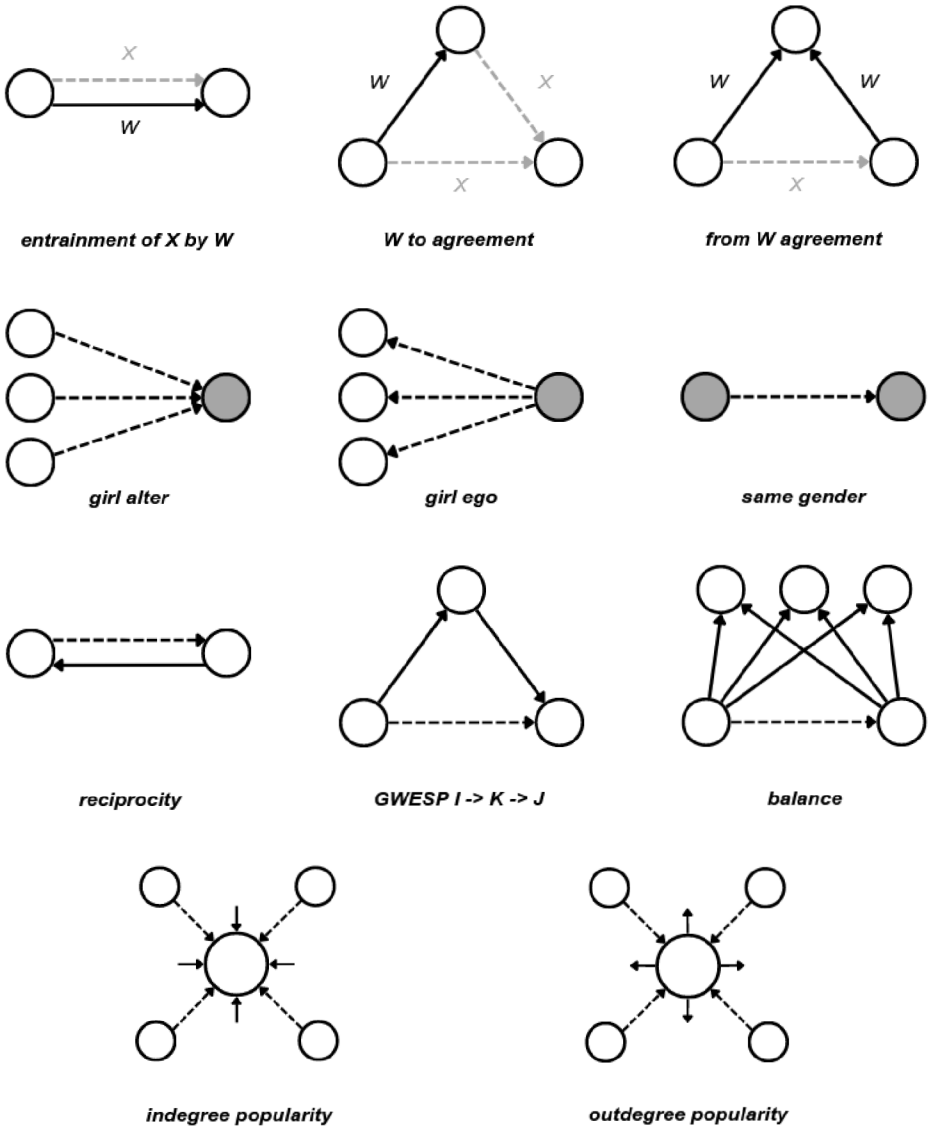
• *GWESP I -> K -> J* – controlling the tendency of students to form transitive liking ties.

• *balance* – controlling the structural equivalence with respect to outgoing ties, defined by the similarity between the outgoing ties of student A and the outgoing ties of the other students to whom student A is tied.

• *indegree and outdegree popularity* – controlling the tendency of students to receive or send disproportionately more liking ties if already receiving or sending many liking ties.

• *densities* – denoting the baseline tendency of students to form the individual types of ties.

Figure 5. Diagrams of the included effects.



4.3 Results

The results from the aggregate SAOM models show that at both dyad- and group-level, student relationships influenced their perceptions of bullying roles. Table 12 shows the overall model estimates.

At the dyad-level, we found that liking a classmate increased the likelihood of perceiving that classmate as a defender (H1c) with all three model specifications resulting in positive and significant effect estimates of *entrainment of defender perception by liking*. On the other hand, we found no evidence that liking a classmate would increase the likelihood of perceiving that classmate as a bully (H1a) or a victim (H1b) with *entrainment of bully perception by liking* and *entrainment of victim perception by liking* being non-significant. We further found that the liking-defender perception relationship is bidirectional as perceiving a classmate as a defender also increases the likelihood of liking that classmate with all three model specifications resulting in positive and significant effect estimates of *entrainment of liking by defender perception*. We did not find evidence for the effects of disliking on either perceiving that classmate as a bully (H1d) or a defender (H1e).

At the group-level, we found evidence for the influence of liked classmates on one's perceptions of bullying roles, while we found no evidence running the other direction for the influence of having shared perceptions of bullying roles on formation of new liking ties. All observed effects of perceptions of classmates whom one likes on one's own perceptions of bullying roles were significant and positive. *Liking to agreement on disliking* effect suggests that liking a classmate who dislikes another classmate increased one's likelihood of also disliking that another classmate (H2a). *Liking to agreement on bully, victim,* and *defender perception* effects suggest that liking a classmate who perceives another classmate as bully (H2b), victim (H2c), or defender (H2d) increased one's likelihood of also perceiving that another classmate as bully, victim, or defender. Controlling for the other direction of the interactions, we found no evidence for the effects of shared perceptions on relationships with all effects being non-significant.

Control effects for gender and structure confirmed the influence of gender, reciprocity, transitivity, outdegree popularity on formation of liking ties. Positive *same gender* effect suggests that students tended to like same-gender classmates. *Gender alter* and *ego on liking network* effects are not significant suggesting that neither girls nor boys tended to like more classmates or be liked by more classmates. *Reciprocity of liking* and *GWESP I -> K -> J on liking network* effects are strong, positive, and significant suggesting that formation of liking ties was mostly influenced by the tendency of students to like classmates who also like them and to like classmates who were liked by others whom the student liked as well. Negative and significant *outdegree popularity on liking* effect suggests that there was a

general tendency of students to like those classmates who did not like many others. We further found positive and significant effects of *reciprocity of disliking* and *reciprocity of bully perception* suggesting that student tended to dislike those classmates who disliked them and perceive those classmates as bullies who also perceived them as bullies.

Table 12. Overall model estimates.

	baseline model			reduced model			full model		
	log OR	**SE**	***p***	**log OR**	**SE**	***p***	**log OR**	**SE**	***p***
effects of relationships on perceptions of bullying roles									
entrainment of bully perception by liking (H1a)	-.006	.077	.936	.033	.133	.804	.178	.145	.219
entrainment of victim perception by liking (H1b)							.089	.105	.399
entrainment of defender perception by liking (H1c)	.348	.062	<.001	.306	.087	<.001	.387	.102	<.001
entrainment of bully perception by disliking (H1d)				.218	.138	.115	.223	.201	.267
entrainment of defender perception by disliking (H1e)				-.158	.095	.095	-.106	.135	.431
effects of perceptions of classmates whom one likes on one's own perceptions of bullying roles									
liking to agreement on disliking (H2a)				.398	.069	<.001	.287	.085	.001
liking to agreement on bully perception (H2b)				.570	.063	<.001	.482	.050	<.001
liking to agreement on victim perception (H2c)							.375	.057	<.001
liking to agreement on defender perception (H2d)				.150	.037	<.001	.147	.055	.007
control effects for perceptions of bullying roles on relationships									
entrainment of liking by bully perception	.046	.067	.495	.203	.110	.066	.261	.134	.052
entrainment of liking by victim perception							-.025	.178	.889
entrainment of liking by defender perception	.235	.086	.006	.337	.144	.020	.398	.172	.021
entrainment of disliking by bully perception				.218	.075	.004	.279	.101	.006
entrainment of disliking by defender perception				-.131	.118	.268	-.102	.172	.555
control effects for shared perceptions on relationships									
liking from disliking agreement				.063	.100	.528	.016	.125	.897
liking from bully perception agreement				-.022	.062	.723	-.009	.070	.901
liking from victim perception agreement							.104	.124	.401
liking from defender perception agreement				-.014	.049	.776	-.043	.060	.470
control effects for gender									
girl alter on liking network	.049	.051	.335	.073	.086	.397	.128	.107	.230
girl ego on liking network	-.022	.064	.725	.007	.083	.933	.007	.081	.929
same gender on liking network	.348	.054	<.001	.376	.096	<.001	.388	.115	.001
control structural effects									
reciprocity of liking	.826	.069	<.001	.820	.116	<.001	.742	.140	<.001
GWESP I -> K -> J on liking network	.880	.071	<.001	.928	.115	<.001	.896	.148	<.001
balance on liking network	-.003	.029	.913	-.021	.051	.682	-.014	.063	.821
indegree popularity on liking network	-.058	.040	.153	-.127	.063	.043	-.125	.081	.120
outdegree popularity on liking network	-.192	.049	<.001	-.227	.080	.004	-.188	.098	.054
reciprocity of disliking				.371	.070	<.001	.428	.115	<.001
reciprocity of bully perception	.142	.064	.026	.252	.066	<.001	.294	.091	.001
reciprocity of victim perception							.185	.115	.107
reciprocity of defender perception	-.001	.035	.977	.016	.046	.727	.056	.062	.365
basic rate parameters and densities									
density on liking	-1.466	.107	<.001	-1.414	.174	<.001	-1.470	.222	<.001
density on disliking				-1.028	.070	<.001	-1.042	.105	<.001
density on bully perception	-.595	.062	<.001	-1.233	.104	<.001	-1.219	.148	<.001
density on victim perception							-1.145	.089	<.001
density on defender perception	-.412	.059	<.001	-.500	.112	<.001	-.547	.144	<.001

Results from the meta-regression show that high CMD reduced the influence of defender perceptions of classmates whom one liked on one's own perceptions, possibly increased the influence of liking on perceiving classmate as a bully, and that high CDN possibly reduced the influence of affective relationships on bully perceptions. Table 13 shows the meta-regression results.

Starting with the moderating role of CMD (H3a), we found a significant moderation effect on *liking to agreement on defender perception*. It is negative and significant in both reduced (BF10 = 13.423) and full model (BF10 = 17.048), we therefore interpret this as a strong indication that high CMD reduced the influence of perception on defenders of classmates whom one liked. We also found some indication that a higher CMD were related to a higher tendency of students to perceive classmates they like as bullies with *entrainment of bully perception by liking* effect significant in the full model (BF10 = 3.029), but only indicative in the reduced model (BF10 = 2.835) and non-significant in the baseline model (BF10 =.225). We found no evidence that CMD would moderate any other dyad- or group-level processes.

The evidence for the moderating role of CDN (H3b) is mixed. In the full model, we found a negative and significant moderating effect of CDN on *entrainment of bully perception by liking* and *entrainment of bully perception by disliking* suggesting that in classrooms with high level of defending norms, the effects of both liking (BF10 = 5.357) and disliking (BF10 = 4.801) a classmate decreased the likelihood of perceiving that classmate as a bully. However, these results were mainly driven by a single outlier classroom in the full model comprising only eight classrooms. In the reduced and baseline models, the two effects have the same negative direction, but they are not significant. We therefore interpret this only as suggestive evidence. We further found a positive and significant moderating effect of CDN on *entrainment of defender perception by liking* in the baseline model (BF10 = 4.137) suggesting that higher pro-defending classroom norms increased the tendency of students to perceive classmates as defenders if they liked them. However, the moderating effect is not significant in the reduced and full models. We therefore again interpret this only as suggestive evidence. Finally, we found contradictory evidence for the effect of CDN on *entrainment of defender perception by disliking* effect; in the reduced model, there is an indication that higher pro-defending classroom norms were linked to lower tendency of students to perceive classmates as defenders if they disliked that classmate (BF10 = 4.861), however, in the full model, this effect was not significant and was in the opposite direction (BF10 = .405). We found no evidence that CDN would moderate any other dyad-level or group-level processes.

Table 13. Meta-regression results.

	baseline model			reduced model			full model		
	log OR	SE	BF_{10}	log OR	SE	BF_{10}	log OR	SE	BF_{10}
moderation effects of classroom moral disengagement									
entrainment of bully perception by liking	.110	.194	.225	.887	.363	2.835	1.118	.518	3.029
entrainment of victim perception by liking							0.751	.509	1.120
entrainment of defender perception by liking	-.160	.181	.284	.123	.302	.301	-.096	.429	.387
entrainment of bully perception by disliking				-.120	.497	.285	-.433	.859	.428
entrainment of defender perception by disliking				-.158	.353	.306	-.641	.522	.803
liking to agreement on disliking				-.215	.216	.445	.041	.333	.381
liking to agreement on bully perception				-.137	.208	.331	-.465	.240	2.483
liking to agreement on victim perception							-.084	.232	.404
liking to agreement on defender perception				-.346	.123	13.423	-.586	.206	17.084
moderation effects of classroom defending norms									
entrainment of bully perception by liking	-.120	.244	.217	-.647	.483	.658	-8.019	3.278	5.357
entrainment of victim perception by liking							-5.211	2.611	2.768
entrainment of defender perception by liking	.459	.181	4.137	.401	.284	.689	-2.867	2.299	.761
entrainment of bully perception by disliking				-.260	.522	.314	-8.227	3.115	4.801
entrainment of defender perception by disliking				-.724	.302	4.861	.881	2.378	.405
liking to agreement on disliking				-.095	.260	.296	-2.166	1.449	1.034
liking to agreement on bully perception				-.089	.269	.293	1.999	1.436	.996
liking to agreement on victim perception							.831	1.110	.500
liking to agreement on defender perception				-.046	.154	.290	.793	1.371	.446

4.4 Discussion

The present study investigated an understudied problem of the influence of affective relationships between students and their bullying roles perceptions. The investigation was based on social support theory (Colvin et al., 2002; Cullen, 1994), assuming that when students evaluate potential bully, victim, and defender role of a classmate, they may be influenced by their and their friends' liking and disliking of the classmate and that these associations could further be shaped by classroom norms. Previous research was missing despite the wide-spread use of peer nominations to assess students' involvement in bullying. Our study has shown that bullying roles perceptions of students may be biased by their affective relationships and moderated by classroom moral disengagement and classroom defending norms. Considering the role of affective relationships in bullying roles perceptions might therefore increase the accuracy of the peer-reported bullying screening methods. On a dyadic level, liking a classmate increased the likelihood of perceiving that classmate as a defender (see first set of hypotheses). On a group level, perceptions of bullying roles adopted by classmates whom one liked influenced one's own subsequent perceptions of this classmate including whether the classmate bullied others, was victimized, or defended others (see second set of hypotheses). At a classroom level, high classroom moral disengagement decreased the effect of perceptions of who defenders are adopted by classmates whom one likes, and classroom defending norms provided inconclusive results (see third set of hypotheses). In sum, the findings document that

perceptions of bullying, victimization, and defending are intertwined with liking and disliking among classmates and that classroom normative context enters these complex associations.

There are two plausible processes behind our finding that students liking a classmate makes them more likely to start perceiving them as a defender. Students may ascribe bullying roles to their classmates according to their own involvement in bullying, which then influence their relationships (Huitsing & Monks, 2018; Huitsing et al., 2014), and students may ascribe bullying roles according to their existing affective relationships. We found that in the case of perceiving classmates as defenders, both processes were present – students tended to like those whom they considered defenders and they also tended to ascribe the role of defenders to classmates they liked. Therefore, our results support the findings of previous research on the influence of affective relationships on perceptions of bullying roles, as documented in self-reports (Oldenburg et al., 2018; Rambaran et al., 2022), and align with the social support theory (Colvin et al., 2002; Cullen, 1994). The social support theory at the individual level was, however, supported by our findings only in case of defender roles. Being liked did not prevent students from being perceived as bullies, and being disliked did not increase the probability of being perceived as bullies.

The question is, why, on the dyadic level, we did not find influence of affective relationships on perceptions of who bullies are. One plausible explanation could be that bullying, being a more overt and often observable form of aggression, may not require a personal liking or disliking relationship to be recognised. It might be easier for students to identify bullying behaviours objectively, without their personal relationships with the involved individuals significantly influencing their perceptions. Many bullies directly use bullying to make themselves more visible and popular, which makes their behaviour more easily recognized by their classmates (Salmivalli, 2014). Unlike defending behaviours, which may be subtle or ambiguous and thus more likely to be influenced by personal relationships, bullying behaviours could be blatant enough to be recognised regardless of the observer's affective ties.

Another question is why we found a strong and significant effect of reciprocated perceptions of being a bully. Our finding points to the possibility of bidirectional antagonism, where individuals may alternate in roles as bullies and victims within a dyadic relationship or a group setting. This finding aligns with previously documented evidence of reciprocity in relational bullying nominations, which was interpreted as a sign that bullying may sometimes be bidirectional (Huitsing & Monks, 2018; Kisfalusi et al., 2020). This complexity may challenge the common narrative of a unidirectional bully-victim relationship and calls for a deeper exploration of the multifaceted interactions that constitute bullying behaviours. The bully-victim double roles are prevalent, and a portion of this phenomenon might be anchored in reality, if the victim gains confidence for a revenge, original bullies might perceive this act as

bullying not as a self-defence or equating mutual injustices (Sariçam & Çetinkaya, 2018).

Our group-level findings support the view that students form heterogeneous subgroups with different perspectives on what is happening in the classroom. The study by Huitsing and Veenstra (2012) previously revealed that the common research practice of assigning participant roles to students based on averaged received reputational nominations may be limited, as students may form heterogeneous subgroups that may bully some classmates and defend others. Specifically, it showed that some students, when nominated for defending in response to a reputational question, defended bullies rather than victims. Building upon this knowledge, our results reveal that these subgroups may have differing perspectives on who embodies the roles of bully, victim, or defender within the classroom dynamics. Our findings suggests that a shared liking between two students might lead to shared perceptions regarding the three bullying roles (bully, victim, and defender). However, the reverse doesn't hold true. This might provide some evidence validating the social support theory at the group level (Colvin et al., 2002; Cullen, 1994). Assuming students liking each other most probably belong to the same peer group, the fact they begin to share perceptions over time might indicate the presence of a conflict between opposing groups – supporting those in-group not out-group peers – rather than individuals.

Our study supports, albeit partially, the notion that classroom norms moderate the interactions between affective relationships and perceptions of bullying and defending. While most of the tested moderating effects of classroom norms were not significant, our study provided evidence that classroom moral disengagement reduced the influence of perceptions on defenders of classmates whom one liked. Given that morally disengaged classrooms present unfavourable contexts where defending is associated with higher social costs (Thornberg et al., 2021), students may be more reluctant to ascribe the defender role to a classmate, which is aligned with the results of Rambaran et al. (2022). The moderating effect of pro-bullying classroom norm leading to more likelihood of bullies selecting other bullies as friends (Shin, 2022) was not confirmed in our study and we also contradict previous research of Romera et al. (2019) that students are more willing to like bullies in classrooms with high pro-bullying norms. We further found tentative evidence that in classrooms with high pro-defending norms, students may be more inclined to ascribe the defending role to students they like, possibly because defending is a valued and accepted characteristic within these peer groups (Pozzoli et al., 2012).

4.4.1 Limitations

Our study has several limitations stemming from the sample and the instruments. First, we had a starting sample of 39 classrooms, which was further reduced to 27 classrooms due to the model convergence issues. We tested some hypotheses

on even smaller samples. It is therefore possible that we were not able to detect some smaller yet theoretically relevant effects due to the lack of statistical power. Second, we were not able to tell the extent to which the influence of affective relationships on bullying roles perceptions was due to a true bullying dynamics or due to the perception bias. As we know from previous research (Huitsing et al., 2014; Huitsing & Monks, 2018), bullying and defending do not occur at random – for example – victims of the same bullies tend to defend each other. It is therefore possible that for one student, perceiving another student as a defender might be the result of both liking that student or being defended by that student. With our instruments relying solely on peer report questionnaires, we were unable to distinguish between the two. Moreover, we relied on the three most frequently used bullying roles: bully, victim, and defender. However, student can also have other roles – Salmivalli et al. (1996), for example, described reinforcer of the bully, assistant of the bully, and outsider. Finally, we measured only physical bullying. It is, however, possible that different forms of bullying have different interactions with student affective relationships.

4.4.2 Implications

Our research has implications for future research on bullying and multiplex networks. We show that considering affective relationships between students is crucial in any relational research on bullying roles, otherwise, researchers risk having their research biased as student perceiving someone as a bully, victim, or defender may, to a large extent, depend on students' relationships. Ultimately, accounting for the perception bias might lead to provision of more targeted interventions distinguishing – for example – conflicts between peer groups – from actual bullying situations. Future researchers might utilize self-reported data about bullying roles to provide a certain cross-validation of the peer perceptions. Future researchers might also consider replicating our study using relational or verbal bullying forms and perform a sensitivity analysis with physical bullying form. Finally, we support Vörös and Snijders' (2017) argument that the use of multiplex network models is a way to avoid the risk of ecological fallacy with tie-, individual-, and group-level processes being confounded. Multiplex approach was proven crucial in disentangling the interactions between the individual types of ties and not confounding ties with student attributes. We showed that multiplex SAOMs can be useful models for small networks and complex specifications. However, at the same time, due to the complexity of the models comprising three, four, and five types of interacting types of ties, we often encountered troubles with model convergence. Future research might therefore benefit from the development of multiplex network models more robust to convergence issues.

4.4.3 Conclusion

This study aimed to better understand the associations between early adolescents' affective relationships and their perceptions of bullying roles. The main findings of the present study showed that liking a classmate heightened the likelihood of perceiving them as a defender and that students' own perceptions of bullying roles were influenced by the perceptions of students they liked. Importantly, classroom moral disengagement weakened the influence of perceptions of students that one liked on their own defender perceptions. Altogether, our insights document the interconnectedness between early adolescents' relationships and their perceptions of bullying roles.

5 Study D: Interaction dynamics in classroom group work

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Abstract: Group work in classrooms is employed by teachers across all levels of education. For group work to be effective, all students should participate equally. Why some students engage in interaction and how group size and composition influence interaction dynamics is a research gap. We employed dynamic actor-oriented models on a sample of 145 Czech lower-secondary students in 62 small groups and pooled the results from the groups with a meta-analytical procedure. We found bursty behavior resulting from endogenous structural mechanisms of reciprocity, transitivity, cyclicity, and preferential attachment. Students gave preference to initiating interactions with those they initiated interactions with before and off-task interaction contributed to the development of on-task interaction. Students strongly preferred interactions with friends. Those students who talked a lot during regular whole-classroom lessons and students with high levels of literacy tended to both initiate and receive more interactions in group work, and students similar in these attributes preferred to

interact with each other. Group size did not affect preferential attachment tendencies in interaction, but smaller groups made the effect of friendship ties on interactions stronger, and communication group norms shifted with changing group composition. Our study shows the suitability of dynamic actor-oriented models for studying interaction in education and small groups.

5.1 Introduction

Group work in classrooms is widespread and employed by teachers across all education levels. Letting students cooperate, learn from each other, and help each other to achieve a common educational goal is recognized and sometimes even mandated by educators as a desirable part of student-centered learning (Felder & Brent, 1996; Fung, 2022; Webb, 2009). For group work to be successful, all students in the group should actively participate. However, this is not an easy task. Participation in group work is usually unequal and entails free-riding – some students doing everything while others not contributing at all (Le et al., 2018; Slavin et al., 2003). Many student- and group-level factors have been hypothesized to influence student participation during group work (Webb, 2009). Yet, groups are usually arranged by the teacher without any consideration for the group composition and the potential effect the composition may have on group work (Gillies & Boyle, 2010).

Most research on what leads to active and equal student participation during group work is either qualitative or descriptive. Previous research has not considered some important unique characteristics of group work stemming from the fact that group work is wholly based on interactions. Most studies have operationalized interaction as the number of times individual students spoke (see Webb, 1991). Simply counting the number of times a student speaks and relating that number to student characteristics does not capture the nature of interaction, as it ignores their interpersonal structure. Analyses based on such observations may lead to results lacking validity because they have omitted fundamental properties of interactions, which are inherently dynamic, relational, and actor-oriented. They are dynamic because interactions occur over time and each interaction is dependent on a previous interaction; for example, interactions typically occur in a turn-taking manner such as student A addressing student B followed by student B responding to student A. They are relational because interactions necessarily occur between two or more students; each interaction can therefore be understood as a tie between a sender and one or more receivers, and over time the ties form a network of interactions that forms a structure of opportunities for further interaction. Interactions are actor-oriented because the individual actors – in our case the students – are agentic and make their own choices regarding how they interact and with whom (Stadtfeld & Block, 2017).

A stream of network models developed in recent years, including stochastic actor-oriented models (Snijders, 2001), relational event models (Butts, 2008), and, most recently, dynamic network actor models (Stadtfeld & Block, 2017), aim to capture the dynamic, relational, and actor-oriented nature of interaction. Dynamic network actor models (DyNAMs) are specifically tailored to fine-grained time-stamped data, such as observations of student interactions during group work, and they make it possible to capture mechanisms driving student choices to interact with other students within a network framework. Despite the availability of network models allowing the study of student interactions, the research employing network analysis on classroom interaction has thus far focused on whole-classroom communication only (e.g., Mameli et al., 2015; Ryu & Lombardi, 2015; Wagner & González-Howard, 2018).

In this study, we aim to provide a new viewpoint on mechanisms driving interactions between students in classroom group work by using fine-grained time-stamped data from videorecorded group works and employing network-based quantitative modelling accounting for the dynamic, relational, and actor-oriented nature of interaction. We differentiate between on-task and off-task interaction allowing us to capture the effect of off-task interaction on on-task interaction. We ask two questions: 1.) *What influences interaction dynamics in classroom group work?* and 2.) *How does group composition influence the interaction dynamics in classroom group work?*

5.2 Theory and hypotheses

5.2.1 Temporal aspects of interaction

The nature of group work depends on the individual interactions between students, particularly the order and timing of these interactions. Neglecting the temporal dimension of interaction relates to several implicit assumptions – for example, it assumes that interactions between actors do not change over time; that interactions are randomly distributed over time; and that there is no relationship between the individual interaction events (Miritello, 2013). These assumptions are, however, incorrect. Interactions in group work are not static; actors change who they initiate and end interaction with over time, and ties are therefore constantly formed and dissolved. Interactions are also not randomly distributed over time – it was shown that bursty behavior – long periods of activity separated by intense bursts of activity – is a universal feature of human interaction (Karsai et al., 2012; Miritello, 2013; Navarro et al., 2017). Generally, bursty behavior can be described as a tendency to more likely to initiate interaction if an interaction occurred shortly before (Barabasi, 2005). Hence, we expect the following:

• **H1 – general burstiness**: students tend to initiate on-task interaction if another on-task interaction was initiated recently in the group.

Moreover, individual interactions are not independent of each other; rather, the order and relative timing of interactions affect subsequent interactions. It has been established that interactions have a memory that leads to old and repeated interactions being more likely to occur over time than newly established interactions (Miritello, 2013). Just as we expect on-task interaction to stem from previous on-task interactions, we also expect off-task interaction between two students to increase likelihood of on-task communication between them. It was found that activities unrelated to the task function to support the eventual task solution among students and promote the collaborative dynamics (Langer-Osuna et al., 2020). Hence:

• **H2a – repeated interaction**: students tend to initiate on-task interaction with those groupmates that they initiated on-task interaction with before.

• **H2b – cumulative repeated interaction**: students' tendency to initiate on-task interaction with a given groupmate increases with each repeated initiated on-task interactions with that groupmate before.

• **H2c – off-task to on-task interaction**: students' tendency to initiate on-task interaction with a given groupmate increases with each repeated initiated off-task interactions with that groupmate before.

5.2.2 Relational aspects of interaction

It is also crucial to consider the relational mechanisms in interaction. Each interaction requires a sender and one or more receivers of the message. Each interaction in group work then forms some fundamental pattern – either a dyad when one actor addresses another, or an outgoing star graph when one actor addresses the whole group (Lehmann, 2019). We expect several endogenous relational mechanisms to influence interaction in group work.

Preferential attachment was found to be a frequently occurring phenomenon in all types of networks (Rivera et al., 2010). In the context of interaction networks, preferential attachment denotes the tendency to initiate interaction towards those who either initiated or received many interactions before, or to receive interaction from those who either initiated or received many interactions before. It has been argued that this is the result of a tendency of actors looking for new connections to use other actors' degree as a proxy for their suitability – in the context of group work, we might expect students to be more likely to interact with groupmates who had already initiated or received many interactions, as it shows that the student is open to communication. Hence:

• **H3a – ego type indegree preferential attachment**: students tend to initiate on-task interaction if they received many on-task interactions previously.

• **H3b – ego type outdegree preferential attachment**: students tend to initiate on-task interaction if they initiated many on-task interactions previously.

• **H3c – alter type indegree preferential attachment**: students tend to receive on-task interaction if they received many on-task interactions previously.
• **H3d – alter type outdegree preferential attachment**: students tend to receive on-task interaction if they initiated many on-task interactions previously.

Reciprocity, transitive closure, and cyclic closure also comprise universally occurring mechanisms in communication networks (Kossinets & Watts, 2006; Ten Bosch et al., 2005). In the context of interaction networks, immediate reciprocity is often interpreted as turn-taking behavior (Ten Bosch et al., 2005). Transitive closure is the tendency to initiate interaction with those who have been interacted with before by the receiver of one's previous interaction (student A addressing student C after student A addressed student B and student B addressed student C) – when one student interacts with another, it can lead to subsequent interactions among other students who were indirectly connected through the initial interaction. Finally, cyclic closure denotes the tendency to initiate interaction with those who have interacted with the sender of one's previous interaction (student C addressing student A after student A addressed student B and student B addressed student C). Cyclic closure can be seen as an indirect exchange or generalized reciprocity; once established, it was found to be self-reinforcing (Bearman, 1997). Hence, we expect:
• **H4a – reciprocity**: students tend to receive on-task interaction from a student who was the receiver of their interaction before.
• **H4b – transitive closure**: students tend to form transitive patterns of interaction.
• **H4c – cyclic closure**: students tend to form cyclic patterns of interaction.

In addition to the endogenous relational mechanisms, interaction is potentially influenced by the friendship ties between individual students. On the one hand, friendship may support collaboration and learning among group members; on the other hand, it may also lead to off-task activities (Chiriac & Granström, 2012; Myers, 2012). Although there is a lack of conclusive evidence of the impact of friendships among group members on group work activity, we anticipate that the presence of a friendship tie between two students will enhance the likelihood of on-task interaction between them. This assumption is based on the notion that the sense of another person's likeability typically increases one's inclination to engage in conversation with them. Hence, we expect:
• **H5 – interaction preference from friendship ties**: students tend to prefer on-task interactions with groupmates they consider friends.

5.2.3 Attribute-related aspects of interaction

Drawing from expectation states theory, we assume student level of vocality during regular lessons and student level of literacy to play roles in group work interaction. We understand vocality as a usual tendency of a student to speak during regular whole-classroom lessons. Expectation states theory postulates that, when given a

collective task to accomplish, individuals bring pre-existing status characteristics into group interactions, which influence the group's power and prestige structure. Some members will be more active than others, exercise more influence than others, and be rewarded more often than others (Berger & Conner, 1969; Correll & Ridgeway, 2003). Vocality and literacy are arguably important characteristics influencing student expectations and status in group work. Vocality and literacy directly impact a student's ability to communicate and articulate ideas effectively, serving as key indicators of competence, leading to higher status within the group and greater influence over group dynamics. Furthermore, students typically have preconceived notions about their peers' vocality and literacy levels well before group work commences, influencing their expectations and the eventual status dynamics within the group. These status characteristics inform members' expectations for each other's performance and contribution to group tasks, affecting how opportunities to participate and lead are distributed among group members. Expectation states theory presumes that student characteristics influence both expectations of themselves – which is also supported by evidence showing that relative student ability within a group is the predictor of their active behavior (Webb, 1991) – as well as expectations from others. Hence, we expect:

• **H6a – vocality promoting interaction activity**: students with higher levels of whole-classroom vocality tend to initiate more on-task interactions.
• **H6b – literacy promoting interaction activity**: students with higher levels of literacy tend to initiate more on-task interactions.
• **H6c – vocality promoting interaction attractiveness**: students with higher levels of whole-classroom vocality tend to receive more on-task interactions.
• **H6b – literacy promoting interaction attractiveness**: students with higher levels of literacy tend to receive more on-task interactions.

Based on the theory of homophily (Byrne, 1971; Turner et al., 1987) and previous research showing that students generally tend to prefer interactions with similar friends (Block & Grund, 2014), it is plausible to assume that students with comparable communication skills and literacy will naturally pair, valuing clear mutual understanding without the need for extended clarifications. Hence:

• **H7a – vocality homophily**: students tend to choose groupmates with similar levels of vocality when initiating on-task interactions.
• **H7b – literacy homophily**: students tend to choose groupmates with similar levels of literacy when initiating on-task interactions.

5.2.4 Group-level aspects of interaction

We expect group size to influence interaction equality among students. Groups of three have often been criticized by researchers who suggest that these groups lead to a higher probability of one of the students being excluded from active group partici-

pation, especially if one of the students does not have good relations with the other two, while the other two are friends (Cullingford, 1988). On the other hand, it was found that smaller groups generally allow a more even participation of all students (Kutnick et al., 2002; Kutnick & Blatchford, 2014). We deem preferential attachment as a proxy for general tendencies for unequal distribution of interactions, because it shows how unequal distribution of interactions stems purely from previous interactions in that group. Hence:

• **H8a – group size influencing preferential attachment**: smaller group size decreases the effect of preferential attachment on interaction.

• **H8b – group size influencing the effect of friendship ties**: smaller group size increases the effect of friendship ties on interaction.

We also expect group vocality and literacy composition to shape the dynamics of student interaction patterns within group work. Existing research provides mixed insights on the role of ability composition in group dynamics. For instance, Lou et al. (1996) found that homogeneity in group ability could enhance outcomes, but this does not consistently apply to groups with uniformly low abilities. Conversely, Webb (1991) observed that in groups of high-ability students, communication was often stifled due to a mistaken belief that all members knew how to solve a given problem. These findings suggest that both the average ability of a group and the diversity of abilities within the group may moderate the importance of the individuals' attributes. A higher average level of vocality and literacy within a group suggests that members collectively possess strong communication and comprehension skills, which could lead to more balanced participation based on their vocality and literacy as each member feels competent to contribute. On the other hand, greater heterogeneity may introduce a wider range of perspectives and problem-solving approaches, potentially enriching the group's collaborative process. This diversity also means that the influence of any single student's specific level of vocality or literacy might be diluted, as the group's dynamic becomes less about individual contributions and more about leveraging the collective skill set. Thus, we hypothesize that groups with both higher averages and greater diversity in vocality and literacy will exhibit more equitable interaction patterns, as the variance in individual attributes is balanced by the group's overall composition, reducing the dominance of specific characteristics on group interaction. Hence:

• **H9a – group average vocality and heterogeneity influencing the role of individual students' vocality on interaction**: higher average group vocality level and heterogeneity decrease the effect of individuals' vocality on interaction.

• **H9b – group average literacy and heterogeneity influencing the role of individual students' literacy on interaction**: higher average group literacy level and heterogeneity decrease the effect of individuals' literacy on interaction.

5.3 Data and methods

5.3.1 Research context

The data this research is based on were collected for a larger research project called *Collectivity in dialogic learning: An interventional study*. The main aim of the project was to determine whether an intervention led by researchers among comprehensive lower-secondary class teachers could enhance classroom communication. Half of the classrooms in the sample underwent an intervention focused on classroom dialogue. Employing collaborative group work was a part of the intervention, with each interventional classroom experiencing two lessons containing group work – our data came from these lessons. All group work took place during Czech language lessons. The group work all had a similar structure – groups were given a worksheet and everyone in the group was instructed to collaborate with each other to complete the worksheet. Each group work was supposed to take approximately ten minutes, however, the groups greatly differed in how much time they spent interacting – some were interacting for only over a minute, while others were interacting for almost thirty minutes.

5.3.2 Ethics

Oral consent from school principals and teachers and written consent from the teachers and parents of participating students were obtained. The students were able to withdraw from research at any time. All procedures were performed in compliance with Masaryk University's institutional guidelines on ethics in research.

5.3.3 Data collection

We collected data during the 2021/2022 school year. We collected data on interactions between students in groups during collaborative group work, relational data on peer friendships, and student-level attributes of talk during regular whole-classroom lessons and reading literacy levels.

For the data on interactions, two members of the research team visited the lessons and videorecorded all group work with one or two recording devices per group work making it possible to identify who was speaking, at what time, and what the content of the communication was. In each classroom, the group work took place twice during the 2021/2022 school year. We worked with a total of 806 minutes of recorded material.

We acquired the relational data denoting friendship ties between the students with a pen-and-paper sociometric questionnaire consisting of a single nomination question (Del Vecchio, 2011; Poulin & Dishion, 2008) worded as "Write the names of the classmates you are friends with. You can write as many names as you want. The

order of the names does not make any difference." A trained researcher administered the questionnaire in group settings in the classrooms during school lessons and provided the students with the necessary assistance. We collected relational data at two timepoints – at the beginning and at the end of the school year. For the purposes of this study, we used only the relational data from the beginning of the school year as all group work took place closer to the beginning of the school year and we assumed the interactions among students to be the result of their relationships and not vice-versa.

We acquired the data on whole-classroom talk with video recordings of the lessons. We recorded two consecutive Czech language lessons in each classroom at the beginning and at the end of the 2021/2022 school year, assessed the length of each student's on-task communication in seconds with the help of EduCoM – a specialized mobile application designed for bulk collection of educational communication data in classrooms (Švaříček & Chmelík, 2018), and averaged the students' talk in seconds across the two consecutive lessons. Again, for the purposes of this study, we used only the whole-classroom talk data from the beginning of the school year. Finally, we acquired the data on student literacy levels with a standardized computer-based reading literacy test by SCIO (2023) that was administered at schools at the beginning and end of the school year. The test contained 26 items covering five areas of literacy – distinguishing between opinions and judgements, distinguishing between subjective and objective statements, identifying manipulative communication in mass-media, using text as a study resource, and forming new text. Students could score anywhere from -100 to 100 points – a student would get -100 points if they answered all items incorrectly, 0 points if they did not answer any item, and 100 if they answered all the items correctly. The version with the negative scoring system was validated by SCIO and recommended for use as a measure of literacy. As with the other measures from both the beginning and end of the school year, for the purposes of this study, we used only the reading literacy score from the beginning of the school year.

5.3.4 Participants

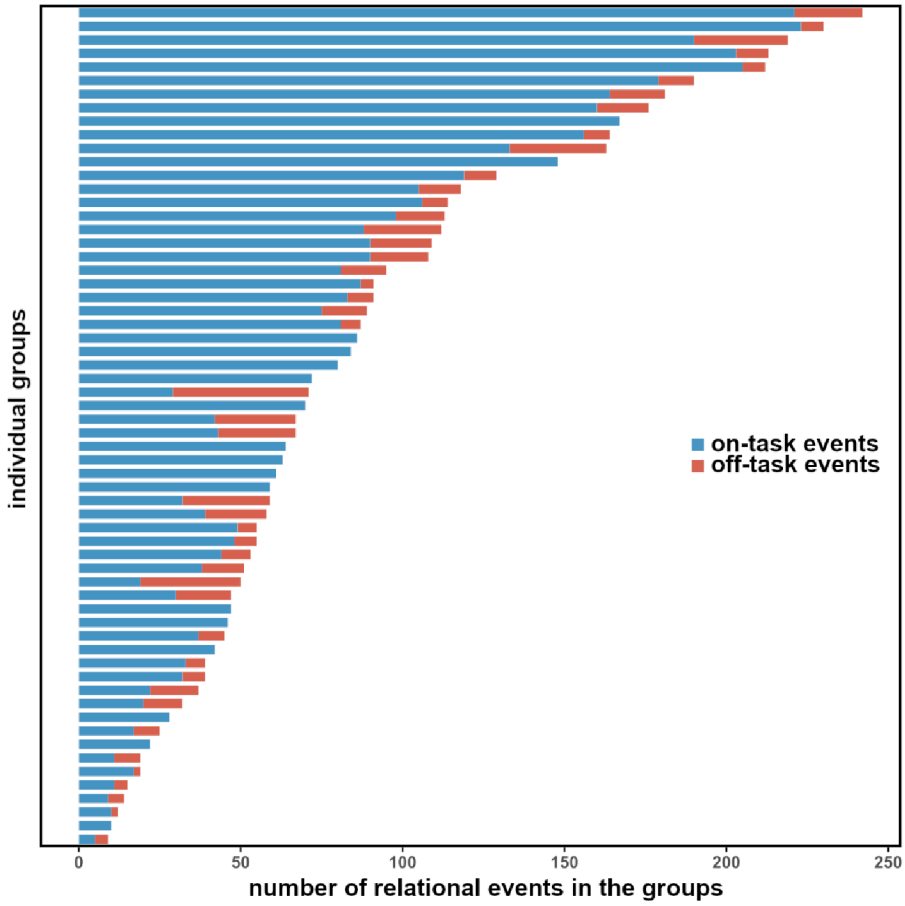
Our sample comprised 145 students in the sixth grade (age 12-13) in six different classrooms mixed into 62 groups. Most of the students were part of both group work sessions during the school year, however, neither of the groups were the same in those two group work sessions. We therefore treated the 62 groups as independent of each other. Our sample was gender-balanced with 78 (53.1%) girls and 72 (46.9%) boys. The average vocality level of the participants was 11.9 (SD = 14.6) – in other words, the students spent on average 11.9 seconds talking during whole-classroom lessons. The average literacy level of the participants was 43.5 (SD = 22.9). We had 12.4% whole-classroom talk data and 10.3% literacy data missing. We had 14

(22.6%) groups of three, 41 (66.1%) groups of four, and 7 (11.3%) groups of five students. The groups showed a large variance in the average vocality composition (mean = 10.9, SD = 7.9) and the average literacy composition (mean = 42.1, SD = 14.2).

5.3.5 Coding interaction

We transcribed the recorded classroom group work into a text. Using both the text and the recordings, we coded the interactions into time-ordered and time-stamped relational event data. The basic unit of our analysis was a relational event denoting a directed tie from one student to another – or to the whole group – embedded in time as described by Butts (2008) and by Stadtfeld & Block (2017). Each relational event contained a sender, a receiver, and a time in seconds from the beginning of the group work when the interaction occurred. Since most of the relational events were very brief (~1 second), we did not separate the beginning and the end of the relational event; instead, we only coded the beginning of the event. We coded both on-task and off-task interaction. On-task communication related to the task the group was working on – it included substantive communication relating to solving the task, but also communication around organizing students' workload. Off-task communication did not relate to the task the group was working on. We did not distinguish between the different types of interaction – e.g., questions, answers, comments. The full codebook used to create the interactional data is available as Supplementary Material S1. The coding was performed by two of the authors of this study with 10% of the material being double-coded. We calculated the interrater agreement with a Krippendorff's Alpha calculated in R (R Core Team, 2021) package icr (Staudt & L'Ecuyer, 2020) yielding an agreement of 0.872 (SD = 0.018) for the senders and 0.871 (SD = 0.019) for the receivers denoting high interrater agreement. In total, we worked with 5,333 relational events – 4,721 on-task and 610 off-task. Figure 6 shows the number of relational events by type by group. The groups showed a large variance in the number of both on-task and off-task events ($mean_{total}$ = 86.0, SD_{total} = 61.1, $mean_{on\text{-}task}$ = 76.2, $SD_{on\text{-}task}$ = 59.1, $mean_{off\text{-}task}$ = 9.8, $SD_{off\text{-}task}$ = 9.7).

Figure 6. Number of relational events in the groups.



5.3.6 Handling missing data

We imputed the missing student covariates by a multiple imputation method. We assumed the covariates to be missing at random and applied multiple imputation by chained equations with a predictive mean matching imputation technique (Little, 1988). We imputed the covariates under a fully conditional specification using the default settings of *R* package *mice* (van Buuren & Groothuis-Oudshoorn, 2011). Since multiple imputation requires each model to be calculated multiple times and our models required a significant amount of time for the estimation procedure, calculating many datasets for missing covariate imputation was prohibitive. We therefore decided to rely on the lower side of the recommended number of datasets for imputation (van Buuren, 2018) and made five datasets. We calculated the estimates in each imputed dataset separately and combined them using Rubin's rules (Rubin, 1987).

5.3.7 Analytical strategy

Network models are usually limited to estimation of parameters of a single network. Two streams of approaches emerged when dealing with multiple networks – a single-step multilevel approach and a two-step meta-analytic approach. There is inconclusive evidence about the accuracy of one approach over another. However, it was argued that the decision to choose between the two should be guided by theoretical assumptions about data-generating process – if it is assumed that the networks come from a single distribution, a single-step approach should be used; on the other hand, if it is assumed that the networks come from different contexts or clusters, a two-step approach should be used (Tolochko & Boomgaarden, 2024). Furthermore, the approach is often guided by practical aspects, such as the degree of implementation of the approaches for different models.

Here, we decided on the two-step meta-analytic approach using dynamic network actor models (DyNAMs; Stadtfeld & Block, 2017). Considering the differences in the numbers of events between the group work sessions and sampling from different classrooms and different schools, we assumed the data to come from different distributions. Also, at the time of our analysis, *goldfish.latent* package built for the single-step multilevel DyNAMs (Uzaheta et al., 2023) was not in a stage of implementation that would allow us to use it as necessary in our research.

5.3.7.1 Dynamic network actor models. The first step of our analysis consisted of fitting DyNAMs with the same specifications to each individual group work session. DyNAMs aim to capture the network nature of interaction by explicitly modeling emerging network patterns over time as decisions made by the actors about when and with whom they interact. The model aims to explain the emergence of relational events. In our case, the dependent variable of the model is the emergence of an on-task relational event in log odds ratios conditioned on a predefined set of effects based on previous events, network structure, relationships between students, and student attributes. We did not model the emergence of off-task relational events and we used them only as a trigger of the on-task events, because we did not have enough off-task events in our data allowing meaningful off-task interaction models. The DyNAMs consist of two submodels – rate and choice. The rate submodel contains effects relating to the general activity of students. The choice submodel contains effects relating to the tendency of students to choose certain groupmates for interaction (Stadtfeld & Block, 2017).

Since a nonnegligible number of the relational events contained utterances aimed at the whole group ($N_{on\text{-}task}$ = 523, 11.1%$_{on\text{-}task}$, $N_{off\text{-}task}$ = 77, 12.6%$_{off\text{-}task}$) and the DyNAMs are not currently built to allow the combination of relational events directed at specific actors along with the relational events directed at the whole group, we had to address the problem of having events directed at the whole group. We did not want to disregard them, as this would result in lower statistics for the activity of many students frequently addressing the whole group. We therefore decided to em-

ploy the following permutation method: if a student addressed the whole group, we told the model to randomly select one of the other students in the group as the receiver; we did this with all cases of a student addressing the whole group within that group session; we calculated the model with data containing the relational events addressed at students individually with all cases of events addressed to the whole group substituted; we performed the procedure 100 times; we aggregated the results of the individual models by averaging the log odds ratios and calculating root-mean-square error from the individual models' standard errors. Because of this procedure along with the mice procedure, getting estimates from one model from a single group work session took 30 minutes on average. We calculated DyNAMs in *R* package *goldfish* (Hollway & Stadtfeld, 2022).

5.3.7.1 Model specification. We fitted two distinct DyNAM model specifications – a baseline model fitted to all 62 groups and a full model fitted to 39 group. The two specifications stem from the fact that the size or composition of some groups prevented fitting the full model specification. For example, we could not include triadic terms on groups of three. We also could not include student attribute effects on groups containing students with very similar levels of vocality or literacy. The subsample of 39 groups used for the full model did not significantly differ from the other groups included in the full sample in the number of events per group ($p = 0.253$), vocality composition ($p = 0.256$), or literacy composition ($p = 0.421$).

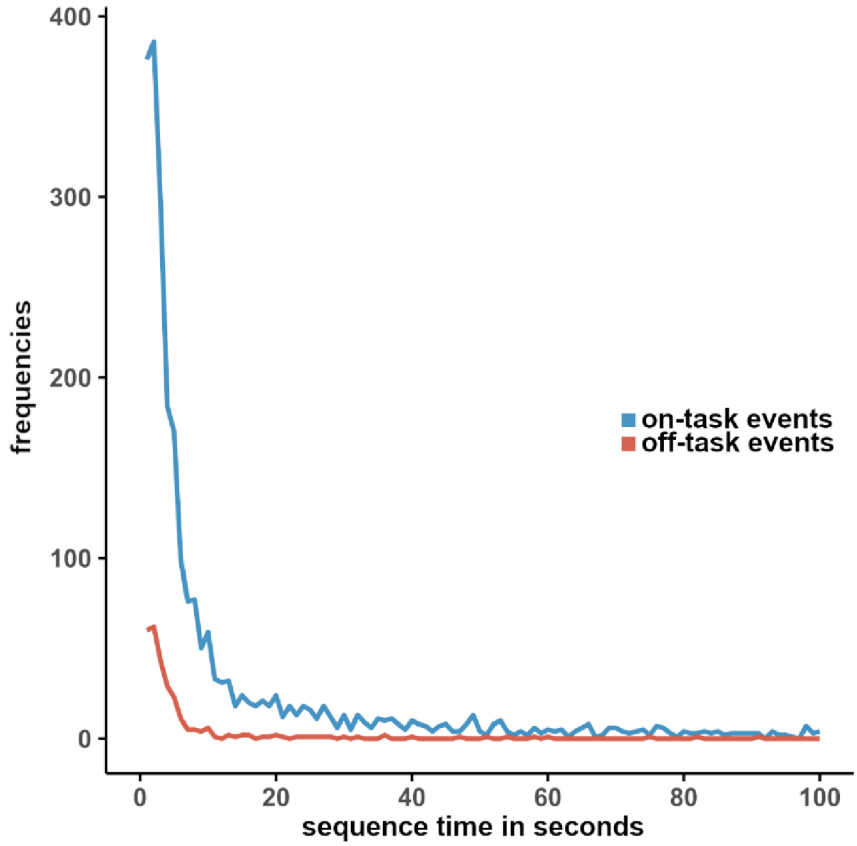
Due to the small sizes of our groups, we had to decide on the relevance of the included effects as some effects were highly collinear. We decided not to include any gender and socioeconomic status (SES) effects. The average gender homophily index on friendship ties across the sample classrooms was 0.5 and gender terms were thus highly collinear with the friendship tie effect. Student SES, on the other hand, was correlated with both vocality ($r = 0.2$) and literacy ($r = 0.2$) and in combination with the small groups, including SES in the models along with vocality and literacy resulted in model convergence issues. We gave preference to the inclusion of vocality and literacy effects due to their more direct and observable impact on group dynamics and task-related interactions.

In 22 (35.5%) groups, there was no off-task interaction and in 7 (11.3%) groups, there were either friendship ties between all group members or between none of them. Hence, in some groups, it was principally impossible to include effects testing **H2c – off-task to on-task interaction** and **H5 – interaction preference from friendship ties**. We opted not to create separate model specifications for them. Maintaining a unified model approach across groups, despite the lack of off-task interaction and varying friendship ties in some, allowed us to avoid fragmenting the data, which would reduce the overall clarity of the analysis. We conducted sensitivity analyses to test if the effect estimates were significantly different for groups that included off-task interactions and friendship ties compared to those that did not. The sensitivi-

ty analysis indicated no substantial effect of the incomplete model specification on our interpretation of the results, thereby reinforcing our decision to treat those groups uniformly within our analytical framework. Results of the sensitivity analysis are available as Supplementary Material S2.

As we worked with small networks which quickly became complete graphs, we had to decide on time windows for some effects. We set a default 20-second window for dyadic effects and a 40-second window for triadic effects as double the window for the dyadic effects as they require one event more. We based our decision on the observation of distribution of reciprocated sequence times. We defined reciprocated sequence time as the difference in times between two events, not necessarily immediately subsequent, where the second one was a reciprocation of the first one. We did not consider the strict AB-BA participation shifts occurring as two immediately following events described in Butts (2008), because our groups would sometimes split into two separate simultaneous conversations in pairs. If we worked with the strict definition of the participation shifts, we would have missed some of the actual reciprocated events as in the time, as two simultaneous conversations would be overlapping in time. Figure 7 shows the distribution of reciprocated sequence times. The distribution is long-tailed with most reciprocated events occurring within that 20-second window.

Figure 7. Distribution of reciprocated sequence times.



The baseline model is the most comprehensive specification that could be fitted to all 62 groups. Apart from intercept, the rate submodel contains the following effects:

• $ego_{bursty\ behavior}$ testing **H1 – general burstiness tendency**. It captures the probability of initiating an on-task interaction with any groupmate conditioned on an initiation of on-task event in the window of the previous 20 seconds by any student in the group. bursty behavior serves as a dynamic dummy variable, which is same for all students, but which changes in time as a rolling window of 20 seconds. If any on-task event is initiated, all students in that group are "triggered" for 20 seconds assuming that recent activity will trigger future activity and it therefore aims to capture general burstiness tendency independent of any specific connections or attributes.

• $indeg_{weighted}$ and $outdeg_{weighted}$ testing **H3a** and **H3b – ego type in/outdegree preferential attachment**. They capture the tendency to initiate on-task interaction if previously receiving/initiating many on-task interactions. We used weighted specifications for the in and outdegree terms as we wanted to capture the cumulative tendency of those who initiate and receive many interactions to initiate more interaction in future.

The choice submodel contains the following effects:

• *inertia* testing **H2a – repeated interaction**. It captures the tendency to choose a groupmate for on-task interaction if they initiated interaction towards that groupmate before – in other words, the tendency to repeat existing ties rather than create new ones.

• $tie_{on\text{-}task\ interaction\ weighted}$ testing **H2b – cumulative repeated interaction**. It captures the increased tendency to choose a groupmate for on-task interaction with each repeated initiated on-task interactions with that groupmate before.

• $tie_{off\text{-}task\ interaction\ weighted}$ testing **H2c – off-task to on-task interaction**. It captures the increased tendency to choose a groupmate for on-task interaction with each repeated initiated off-task interactions with that groupmate before. It serves as a cross-network term controlling for the effect of off-task interactions on on-task interactions.

• $indeg_{weighted}$ and $outdeg_{weighted}$ testing **H3c** and **H3d – alter type in/outdegree preferential attachment**. They capture the tendency to receive on-task interaction if previously receiving/initiating many on-task interactions. As with the rate submodel terms, we used weighted specifications aiming to capture the cumulative tendency of those who initiate and receive many interactions to receive more interaction in future.

• $recip_{window20}$ testing **H4a – reciprocity**. It captures the tendency to reciprocate on-task interactions within the window of 20 seconds of receiving it.

• $tie_{friendship}$ testing **H5 – interaction preference from friendship ties**. It captures the tendency of students to choose those groupmates as receivers of their on-task interaction whom they consider friends.

The full model tests all our hypotheses and could be fitted to 39 groups. It contains all effects included in the baseline model plus triadic and attribute-based effects. The rate submodel contains the following effects:

• $ego_{whole\text{-}class.\ talk}$ testing **H6a – vocality promoting interaction activity**. It captures the tendency of students with higher levels of vocality to initiate more on-task interactions.

• $ego_{literacy}$ testing **H6b – literacy promoting interaction activity**. It captures the tendency of students with higher levels of literacy to initiate more on-task interactions.

The choice submodel contains the following effects:

• $trans_{window40}$ testing **H4b – transitive closure**. It captures the tendency to interact in a way that forms the transitive pattern of an event i→j closing more two-paths (i→k→j).

• $cycle_{window40}$ testing **H4c – cyclic closure**. It captures the tendency to interact in a way that forms the cyclic patterns of an event i→j closing more two-paths (j→k→i).

• $alter_{whole\text{-}class.\ talk}$ testing **H6c – vocality promoting interaction attractiveness**. It captures the tendency of students with higher levels of vocality to receive more on-task interactions.

• $alter_{literacy}$ testing **H6d – literacy promoting interaction attractiveness**. It captures the tendency of students with higher levels literacy to receive more on-task interactions.

• $sim_{whole\text{-}class\ talk}$ testing **H7a – vocality homophily**. It captures the tendency to choose groupmates with similar levels of vocality when initiating on-task interactions.

• $sim_{literacy}$ testing **H7b – literacy homophily**. It captures the tendency to choose groupmates with similar levels of literacy when initiating on-task interactions.

5.3.7.3 Meta-analysis. The second step of our analysis consisted of aggregating the results from the individual DyNAMs. Pooling the estimates across the groups resulted in overall model estimates. We pooled the estimates with a random-effect meta-analysis in *R* package *metafor* (Viechtbauer, 2010), assuming that the observed estimates varied across the groups both because of real differences in the effect sizes in each group and because of the sampling variability.

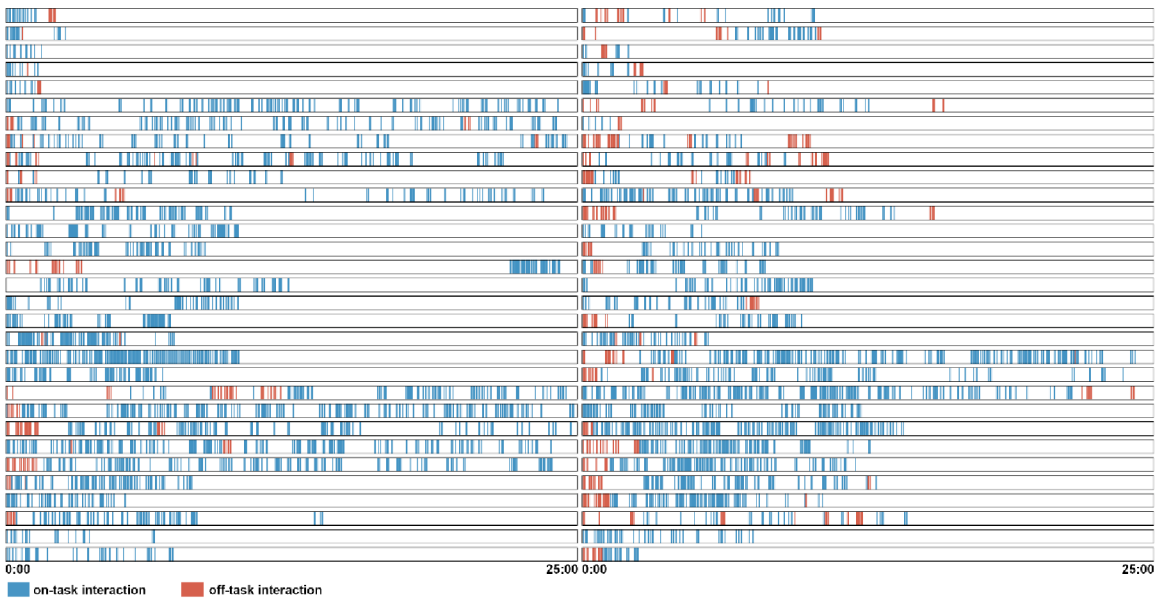
5.3.7.4 Meta-regression. The third step of our analysis consisted of fitting meta-regression models with group size and composition as moderator variables. Meta-regression allows for the investigation of the relationships between group-level variables and effect sizes across multiple models fitted to individual groups. It seeks to understand the heterogeneity in effect sizes by examining how they are influenced by external factors. To test **H8a – group size influencing equality of interaction** and explore whether smaller group size is related to weaker preferential attachment tendencies, we used group size as a moderator variable for the *indeg* and *outdeg* effects. A negative coefficient for group size would indicate that in smaller groups, interaction among students is less centralized around a small number of students and the interaction is therefore more equal. To test **H8b – group size influencing the effect of friendship ties** and explore whether smaller group size increases the effect of friendship ties on interaction, we used group size as a

moderator variable for the $tie_{friendship}$ effect. We used the baseline model to test the moderating role of the group size as it could be fitted to all 62 groups. To test **H9a – group average vocality and heterogeneity influencing the role of individual students' vocality on interaction**, we used the mean, SD, and the interaction between the two as moderator variables for the $ego_{whole\text{-}class.\ talk}$, $alter_{whole\text{-}class.\ talk}$, and $sim_{whole\text{-}class.\ talk}$ effects. To test **H9b – group average literacy and heterogeneity influencing the role of individual students' literacy on interaction**, we used the mean, SD, and the interaction between the two as moderator variables for the $ego_{literacy}$, $alter_{literacy}$, and $sim_{literacy}$ effects.

5.4 Results

Figure 8 shows the event timelines across the groups. Three striking patterns are apparent. First, interaction in all groups exhibit burstiness – the events are not evenly distributed in time, they occur in clusters of high-activity periods split by low-activity periods with no interaction. Second, on-task and off-task interactions do not mix – there are periods of on-task interactions, periods of off-task interactions, but not periods of combined on- and off-task interactions. Third, off-task interaction periods often precede on-task interaction periods. Most group work sessions start with a period of off-task interactions followed by one or more periods of on-task interactions.

Figure 8. Event timelines across the groups. Each tick denotes a single relational event in time.



5.4.1 What influences interaction dynamics in classroom group work?

Table 14 shows the pooled DyNAM estimates with their associated standard errors (SE) and p-values. Neither the baseline nor the full model shows a significant $ego_{bursty\ behavior}$ effect, thus providing no evidence for the general tendency of burstiness in a sense of having increased activity due to occurrence of recent previous activity in the group. The observed burstiness seen in Figure 8 is therefore caused by other mechanisms. Both models show positive and significant *inertia* and $tie_{on\text{-}task\ interaction\ weighted}$ effects, suggesting that students tend to prefer repeated on-task interactions with the same groupmates, and that tendency increases with each repeated initiated on-task interactions with that groupmate before. Both models also show a positive and significant $tie_{off\text{-}task\ interaction\ weighted}$ effect – although borderline significant in the full model – suggesting that off-task interaction leads to on-task interaction. Except for the $indeg_{weighted}$ effect in the choice submodel and $outdeg_{weighted}$ effect in the rate submodel in the full specification, the *indeg* and *outdeg* effects are positive and significant, suggesting that those who initiate and receive many on-task interactions are more likely to initiate future on-task interactions, and those who initiate many on-task interactions are more likely to receive future on-task interactions. This results in interaction-wise active and/or popular students being engaged in interactions disproportionately more than others. The models further show positive and significant $recip_{window20}$, $trans_{window40}$, and $cycle_{window40}$ effects, suggesting that students tend to reciprocate on-task interaction and form both transitive and cyclic patterns of on-task interaction. Both models show a positive and significant $tie_{friendship}$ effect, suggesting that students prefer initiating on-task interactions with groupmates they consider friends. In the full model, all *ego* and *alter* effects are positive and significant, suggesting that students who are vocal in whole-classroom lessons and students with higher levels of literacy are more likely to initiate and receive on-task interaction in group work. Both *sim* effects are also positive and significant, suggesting that students tend to choose groupmates with similar levels of vocality and literacy when initiating on-task interactions.

Table 14. Pooled DyNAM estimates.

	baseline model (62 groups)			full model (39 groups)		
	log(OR)	SE	p	log(OR)	SE	p
rate submodel						
intercept	-2.245	0.371	<0.001	-1.309	0.550	0.017
$ego_{\text{bursty behavior}}$ (H1 – general burstiness tendency)	0.106	0.079	0.177	0.134	0.091	0.138
$indeg_{\text{weighted}}$ (H3a – ego type indeg. pref. attach.)	0.039	0.007	<0.001	0.068	0.013	<0.001
$outdeg_{\text{weighted}}$ (H3b – ego type outdeg. pref. attach.)	0.029	0.004	<0.001	-0.005	0.013	0.732
$ego_{\text{whole-class. talk}}$ (H6a – vocality promoting interact. activity)				0.020	0.006	<0.001
ego_{literacy} (H6b – literacy promoting interact. activity)				0.005	0.001	<0.001
choice submodel						
inertia (H2a – repeated interact.)	0.596	0.079	<0.001	0.502	0.031	<0.001
$tie_{\text{on-task interaction weighted}}$ (H2b – cumulative repeated interact.)	0.079	0.015	<0.001	0.079	0.031	0.012
$tie_{\text{off-task interaction weighted}}$ (H2c – off-task to on-task interact.)	0.213	0.081	0.009	0.447	0.265	0.092
$indeg_{\text{weighted}}$ (H3c – alter type indeg. pref. attach.)	0.031	0.030	0.301	-0.032	0.088	0.714
$outdeg_{\text{weighted}}$ (H3d – alter type outdeg. pref. attach.)	0.118	0.015	<0.001	0.166	0.027	<0.001
$recip_{\text{window20}}$ (H4a – reciprocity)	1.038	0.104	<0.001	1.140	0.150	<0.001
$trans_{\text{window40}}$ (H4b – transitive closure)				0.342	0.110	0.002
$cycle_{\text{window40}}$ (H4c – cyclic closure)				0.616	0.074	<0.001
$tie_{\text{friendship}}$ (H5 – interact. preference from friendship ties)	0.448	0.068	<0.001	0.912	0.244	<0.001
$alter_{\text{whole-class. talk}}$ (H6c – vocality promoting interact. attract.)				0.068	0.011	<0.001
$alter_{\text{literacy}}$ (H6d – literacy promoting interact. attract.)				0.018	0.008	0.021
$sim_{\text{whole-class talk}}$ (H7a – vocality homophily)				0.153	0.080	0.055
sim_{literacy} (H7b – literacy homophily)				0.045	0.010	<0.001

5.4.2 How does group composition influence interaction dynamics in classroom group work?

Table 15 shows the results of the meta-regression models. The models do not support the hypothesis that the size of the group would have any effect on the preferential attachment in interaction, with group size not being a significant moderator for any of the *indeg* and *outdeg* effects. The models also do not support the hypothesis that the group average literacy or heterogeneity would have any moderating effect on $ego_{literacy}$, $alter_{literacy}$, or $sim_{literacy}$ effects. On the other hand, the models suggest that larger group size is related to a lower $tie_{friendship}$ effect. It supports our hypothesis that in groups of three, the effect of friendships on preference for initiating interactions is higher than in larger groups and that a student without any friend is more likely to be excluded from interaction in groups of three. The models further provide tentative evidence that a higher average student vocality level in group is related to a lower $ego_{whole\text{-}class.\ talk}$ effect, hence, lower tendency of vocal students to be more active in initiating on-task interactions. The models also provide tentative evidence that a higher heterogeneity of student vocality in group is related to a lower $sim_{whole\text{-}class.\ talk}$ effect, hence, lower tendency of students to choose groupmates with similar levels of vocality when initiating on-task interactions.

Table 15. Meta-regression results.

	log(OR)	SE	p
rate indeg$_{weighted}$ (H8a – group size and equality)			
intercept	0.073	0.051	0.147
group size	-0.009	0.013	0.491
rate outdeg$_{weighted}$ (H8a – group size and equality)			
intercept	0.052	0.038	0.175
group size	-0.006	0.010	0.552
choice indeg$_{weighted}$ (H8a – group size and equality)			
intercept	0.138	0.215	0.522
group size	-0.027	0.053	0.613
choice outdeg$_{weighted}$ (H8a – group size and equality)			
intercept	0.236	0.104	0.023
group size	-0.030	0.026	0.254
choice tie$_{friendship}$ (H8b – group size and effects of friendships)			
intercept	1.455	0.541	0.007
group size	-0.241	0.129	0.061
rate ego$_{whole\text{-}class.\ talk}$ (H9a – group av. vocality and heterogeneity)			
intercept	0.061	0.019	0.001
group average vocality	-0.002	0.001	0.098
vocality heterogeneity	-0.003	0.003	0.246
group average vocality*heterogeneity	0.000	0.000	0.245
choice alter$_{whole\text{-}class.\ talk}$ (H9a – group av. vocality and heterogeneity)			
intercept	0.280	0.169	0.097
group average vocality	-0.010	0.008	0.214
vocality heterogeneity	-0.013	0.027	0.614
group average vocality*heterogeneity	0.001	0.001	0.666
choice sim$_{whole\text{-}class.\ talk}$ (H9a – group av. vocality and heterogeneity)			
intercept	0.545	0.300	0.070
group average vocality	-0.004	0.022	0.847
vocality heterogeneity	-0.081	0.047	0.087
group average vocality*heterogeneity	0.003	0.002	0.138
rate ego$_{literacy}$ (H9b – group av. literacy and heterogeneity)			
intercept	0.030	0.030	0.310
group average literacy	-0.001	0.001	0.485
literacy heterogeneity	-0.001	0.002	0.744
group average literacy*heterogeneity	0.000	0.000	0.794
choice alter$_{literacy}$ (H9b – group av. literacy and heterogeneity)			
intercept	-0.067	0.123	0.585
group average literacy	0.003	0.003	0.396
literacy heterogeneity	0.010	0.011	0.358
group average literacy*heterogeneity	-0.000	0.000	0.313
choice sim$_{literacy}$ (H9b – group av. literacy and heterogeneity)			
intercept	0.060	0.116	0.605
group average literacy	0.000	0.003	0.885
literacy heterogeneity	0.001	0.015	0.941
group average literacy*heterogeneity	-0.000	0.000	0.799

5.5 Discussion and conclusion

In this study, we explored the interaction dynamics of lower-secondary students in collaborative group work sessions. We addressed the gap in the literature stemming from the fact that interaction in group work has never been considered in its realistic nature: dynamic, relational, and actor-oriented. We employed a recent addition to the actor-based network model family – DyNAMs – suited for the study of fine-grained time-stamped interactional data.

We found that interaction in group work is largely influenced by an array of endogenous structural mechanisms. These include reciprocity, transitivity, cyclicity, and preferential attachment. We also found interaction in group work to be influenced by the interaction repetition, with students giving preference to initiating interactions with those they initiated interactions with before, including both on- and off-task interactions. Hence, off-task interaction also contributed to development of on-task interaction. While we observed strong patterns of bursty behavior in our data, modelling burstiness *per se* as a mechanism influencing event formation yielded non-significant results. Hence, the observed burstiness in the groups was probably caused by the windowed reciprocity, transitivity, and cyclicity effects, as these stem from recent previous interactions and lead to new interactions. We further found interaction in group work to be largely influenced by friendship ties between students, with students giving strong preference to initiating interactions with those they consider friends. We found evidence that those students who talk a lot during regular whole-classroom lessons and students with high levels of literacy tend to both initiate and receive more interactions in group work, and students similar in these attributes prefer to interact with each other. Finally, we found tentative evidence that the vocality composition of the groups moderated the effects of unequal student interaction based on their level of vocality. We found that higher average group vocality was related to lower tendency of vocal students to be more active in initiating interactions and higher group vocality heterogeneity was related to lower tendency of students to choose groupmates with similar levels of vocality when initiating interactions.

The strong presence of the structural endogenous mechanisms in interaction mirrors our expectations and previous research of interpersonal and communication ties (Kossinets & Watts, 2006; Le et al., 2018; Rivera et al., 2010; Slavin et al., 2003; Ten Bosch et al., 2005). Our results suggest that while many aspects might influence interaction in group work, the endogenous mechanisms influence it the most. The presence of the temporal mechanisms in interaction including the preference for repeated on-task interactions and the influence of off-task interactions on on-task interactions also mirror our expectations and previous research on group dynamics (Miritello, 2013; Langer-Osuna et al., 2020). Taken together, our findings show that ignoring the relational and dynamic nature of small group interaction in educational

settings leads to neglecting a substantial portion of the mechanisms driving group interactions.

The strong preference of students to interact with friends makes the inconclusive results found in previous literature more conclusive. Previous research found that friends in group work frequently engage in off-task activities (Chiriac & Granström, 2012; Myers, 2012). While this might be true; we found friendships ties to enhance on-task communication as well. The question is how our finding relates to the previously described tendency of students to exclude students with whom they do not have good relationships (Cullingford, 1988). We believe our findings support this thesis. If there is a group of four students and three of those students consider each other friends, our strong positive estimate of friendship ties suggests that those three students will give strong preference to interaction with each other, while the fourth student will remain excluded. The results of our meta-regression model further support the thesis that a student is most likely to be excluded from interaction if they are without friends in groups of three. In a more equal scenario – a group of four in which two of the students consider each other friends, while the other two are not friends with anyone in the group – the two students who are not friends with anyone are also more likely to be excluded from interaction because they are less likely to communicate with the two students who are friends as well as less likely to communicate with each other. In a scenario with two pairs of friends, students may end up interact mostly within the friendship pairs, with the group virtually operating as two groups.

Our findings related to the effects of student attributes support expectation states theory (Berger & Conner, 1969; Correll & Ridgeway, 2003) suggesting that pre-existing status characteristics influence group work dynamics. Furthermore, our findings suggest that certain groups of students tend to be disadvantaged in group work by actively engaging in communication less and these groups of students are those who are already disadvantaged in education. Both silent (Sedova et al., 2019) and low-literacy (Meneghetti et al., 2006) students have worse academic performances than their vocal and high-literacy counterparts. If we accept the proposition that those who actively engage in group work most are those who benefit from group work most, we may interpret our findings as indicating that group work acts as another mechanism through which disadvantaged students in education get more disadvantaged, while those who are already successful accumulate even more advantages.

Our findings related to the effect of group size and composition in interaction dynamics generally do not support earlier findings. We found little support for the thesis that smaller groups allow more even participation of all students (Kutnick et al., 2002; Kutnick & Blatchford, 2014). However, it is important to note that we operationalized even participation as low preferential attachment tendencies, which differs from measures used in other studies. Our approach to even participation empha-

sizes the effect of cumulative advantage of active and popular students in time, rather than the raw distribution of contributions. Also, we modelled only the differences among groups of three, four, and five students; we are therefore unable to capture any effect of group size if group size becomes significant with a larger number of students.

Our findings related to the effect of group vocality composition on equality of interaction suggest that communication group norms may shift with changing group compositions. When the average group level of vocality is high, the effect of vocal students to initiate more interactions is less pronounced. At the same time, when the group comprises students with a diverse range of vocality levels, the effect of vocality homophily is less pronounced. This pattern may be attributed to the diffusion of expectations across members when overall group vocality is high, diluting the influence of any single vocal student. In such settings, the collective confidence to speak up may encourage even the typically less vocal students to participate more actively. Conversely, in groups with a diverse range of vocality levels, students may be more likely to modulate their participation to match their peers, which could diminish the vocality-based homophily.

5.5.1 Limitations

Our study has limitations stemming from the sample characteristics and from the study design. Our models are based on a non-representative sample of students from the Czech Republic, which makes generalizations of our findings difficult. Furthermore, because our groups were small, often had students with collinear characteristics, and because we applied the DyNAMs to the groups individually, we were unable to fit the full model testing all our hypotheses to all groups. We were also unable to model the effects of demographic student characteristics, as including them made model convergence impossible. Finally, when dealing with interactions addressed to the whole group, we had to rely on a workaround involving the permutation method, as DyNAMs are not currently able to work with both dyadic and multicast interactions. It may be argued that interactions aimed at the whole group are qualitatively different than dyadic interactions, however, we treated them as qualitatively same as incorporating multiplex network structures into DyNAMs in currently not implemented and beyond the scope of this paper. Having an extension to DyNAMs making it possible to model both dyadic and multicast interactions would therefore be beneficial for modeling of many real-world situations.

5.5.2 Implications

Our study has several implications for practice. The strong effect of friendship ties on interaction in group work implies that when teachers form groups, they should not mix friends with non-friends together in the same group as those who are not friends with others in the group are at the risk of being excluded from the interaction. We

therefore recommend forming either groups comprising only friends or groups comprising only non-friends. Moreover, the moderating role of group vocality composition on equal interaction implies that it may be more beneficial to form groups so that they contain a diverse range of vocality levels.

Our study has several implications for future research. We show that DyNAMs are a very useful tool for the study of real-world interaction between students. We show that DyNAMs are suitable to be fitted to groups ranging from three to five actors. In combination with the established meta-analytical procedures from social network models, we show that DyNAMs can be used to get effect estimates from several groups independently, with the results pooled to get overall estimates. We therefore believe that DyNAMs have the potential to serve as a strong analytical tool for the study of interaction in group work and for the study of interaction in whole-classroom settings. Given that structural endogenous mechanisms seem to influence interaction in group work more than any relational or attribute effects, any research aiming to explore interaction in group work should account for them, as the results may otherwise be invalid. Finally, because the size and composition of the groups prevented us from fitting the full model specification to all groups, in the future, it might be useful to get estimates from multiple groups using a multi-level framework with random-effects parameters (Uzaheta et al., 2023), and to compare the estimates from the meta-analytical framework with the estimates from the multi-level framework.

6 General discussion

In this thesis, I set to justify the assertion that any student attribute that seeks to explain certain social characteristics should not be considered as merely individual, nor modeled or interpreted as such. In line with the principles of analytical sociology (Hedström, 2005), I explored the mechanisms that underpin the formation of peer relations and the influence of relations on students. In the four distinct studies using social network analysis, built on data from Czech schools, I showed that peer relations and interactions are formed not only by an array of individual-level student attributes, but also by the mechanisms stemming from wider structural contexts. Simultaneously, I showed that both immediate and indirect peer relations have power to influence students' perceptions about their peers.

The key substantive findings of this thesis can be summarized as follows:

- The endogenous structural mechanisms of reciprocity, transitivity, cyclicity, and, in smaller degree, preferential attachment, have a strong impact on formation of both positive and negative peer relations, and on emergence of interactions between students. Hence, disregarding the structural part of peer relationships leads into missing key mechanisms of formation of peer relations.
- Gender homophily is an omnipresent mechanism in formation of positive peer relations, with an opposite mechanism operating in formation of negative relations.
- When classrooms are ethnically heterogeneous, ethnic homophily is also a formative mechanism behind positive peer relations. Ethnicity-based popularity and activity are also formative mechanisms behind positive peer relations, with Czech students being more popular and more active in forming peer relations.
- SES popularity is another mechanism behind formation of both positive and negative peer relations, with high-SES students being more popular and less excluded. SES homophily also operates in some classrooms, but its presence is not universal.
- Affective relations among students influence their perceptions of bullying roles, so that students are more likely to perceive peers as defenders if they like them. Not only do direct peer relations influence the bullying roles perceptions, but also the perceptions of peers who are liked by a given student influence the student's own perceptions.
- Several classroom-level factors have a significant impact on mechanisms behind formation of peer relations and the influence of peer relations on students. Notably, ethnic composition influences students' tendencies for formation of inter-ethnic relations, classroom moral disengagement influences

tendencies of students to perceive peers as defenders if they like them, and classrooms with high levels of reciprocity alleviate the effects of SES on peer relations.

• Interactions are dynamic, relational, and actor-oriented. They emerge from a combination of past interactions, structure of peer relations and previous interactions, and actor (student) choices grounded in their attributes.

Together, the substantive findings provide a multifaceted insight into the formative mechanisms behind peer relations and interactions in schools. But there are also several key points stemming from the thesis beyond the substantive findings that deserve a reflection.

This thesis showed that **social reality cannot and should not be reduced to summative measures nested in individuals**. Social reality stems from individuals, but also from the structures that the individuals are embedded in. Considering both the individuals and the structures ensures alignment of social theory with methods. It is more demanding to incorporate the relational perspective in social research – from data collection to data analysis – however, it is also more rewarding and more informative. It is therefore only logical to aim for the more valid representations of social reality in research to advance and empower social sciences.

An overarching theme underlying this thesis was the issue of structure and agency. Through the four studies, my research adds to the knowledge about how these two fundamental aspects interact and influence each other within educational settings. One of the key findings across all articles is that structural mechanisms such as reciprocity, transitivity, and preferential attachment exert an exceptionally high influence on the formation of relations and interactions among students. This pervasive influence suggests that structure is a key aspect of social reality at the micro-level, shaping the dynamics of peer relationships in ways that are often predictable and consistent. The strong impact of these structural factors underscores the importance of considering the broader social context when examining individual behaviors and relationships within schools.

Despite the clear influence of structural mechanisms, **my research also attempted to account for the role of agency**, particularly in the last two studies, by explicitly modelling actors' choices. Agency, however, proves to be a highly elusive phenomenon, challenging to detect and demonstrate within the framework of social network analysis. This raises important questions about the nature of agency and its visibility in empirical studies. If agency manifests as random noise that our models cannot fully explain, it might suggest that what we perceive as individual actions could actually be the result of other structural or attribute-based mechanisms that we have yet to identify. On the other hand, agency might be embedded within the very structural terms we use, such as reciprocity and transitivity. The ability to predict certain behaviors based on these structural factors does not necessarily negate the

presence of human agency; rather, it might indicate that agency operates within and is constrained by these structural boundaries.

Each study provides unique insights into the interplay of structure and agency. The first article reveals that the wider effect of SES significantly influences the formation of peer relationships. Low-SES students face higher structural constraints, necessitating greater levels of agency to overcome these barriers. Similarly, the second article highlights the role of ethnicity in shaping social integration, with non-Czech students needing to exhibit more agency to navigate and transcend the structural obstacles related to their minority status. The third article illustrates how peer relations and group dynamics influence perceptions of bullying, with perpetrators who maintain positive relationships with classmates finding it easier to manipulate these dynamics to their advantage, thus constraining the victims' ability to be recognized and supported. The fourth article demonstrates that interaction dynamics in classroom group work are influenced by prior interactions, student relations, and individual choices, suggesting that while students' agency may present, it is deeply intertwined with and often constrained by existing structural factors.

This thesis showed the **usefulness of social network analysis in educational research** and the need for the development of SNA frameworks tailored to issues in educational research. The predecessors of SNA were often applied in educational contexts (Moreno, 1934) and several seminal papers developing SNA drew from data in education (i.e., Block et al., 2019; Goodreau et al., 2009; Snijders, 2017). There are ongoing attempts to proliferate SNA into educational research and show its added value (Carolan, 2013; Froehlich et al., 2020; Grunspan et al., 2014), and I have attempted to contribute to this effort in the Czech context myself (Lintner, 2020). Yet, SNA has still not found its firm place in mainstream educational research. Hence, due to a relatively small research community, many unique challenges stemming from the nature of network data in education remain. These comprise, for example, challenges linked to collection of sensitive data among vulnerable populations, analysis of many small networks, and handling missing data.

Consequently, **this thesis opens up the issue of model development and computational efficacy in SNA research**. The four studies comprising this dissertation showed that the state-of-the-art network models are computationally very demanding and may frequently suffer from convergence issues. For these reasons, the models may not be perceived as useful by some researchers, due to the issues related to their practical applicability. It is therefore important to continue the development and optimization of the network models (e.g., Oliveira et al., 2022; Snijders, 2011), so that they are not only theoretically relevant, but also widely applicable, and accessible to a wide group of researchers.

Despite the challenges related to development of SNA in educational research, this thesis showed that **social network analysis in education can provide tangible findings relevant for practice**. It is not only the concrete recommendations for

practice stemming from this work, but also rich feedback my colleagues and I received during our research from teachers, school psychologists, and school directors, who received invaluable information about relations among students in their schools and classrooms. Whenever we could, we shared the results from our analyses with those needing them most. We often provided tailored classroom-based reports for the individual teachers and psychologists, who wanted to use our insights to improve relations among their students. Their invaluable feedback and some of the changes we witnessed after we completed our research proved us right to believe that SNA should be incorporated into practical solutions for schools, for example, in the form of user-friendly software solutions for school personnel, allowing a real-time monitoring of peer relations, with automatized algorithm-based analytics.

This thesis also showed the **importance of transdisciplinarity in contemporary research**. All four studies in this thesis drew from related disciplines of sociology and psychology and they would not be complete had the insights from the other disciplines not been included. The focus on the emergent mechanisms behind social relations and interactions opens the possibilities of shared language between the disciplines, with the potential to explore universal patterns of human relations and interactions.

Finally, **this thesis opens new avenues for research** by addressing several critical areas where further exploration can deepen our understanding of peer relations and their impact on students. One significant avenue is the challenge of disentangling structure and agency in network research. The findings from this thesis indicate that both elements are intricately linked, making it difficult to isolate their individual effects. Mixed-methods social network analysis could offer a solution by combining quantitative data with qualitative insights, allowing researchers to capture the nuanced ways in which individual choices interact with broader social patterns. This approach could help to clarify how students' decisions and actions are shaped by and contribute to the structural context of their peer networks.

The first article in this thesis highlighted the significant influence of family SES on peer relationships. While it established a clear association, it did not elucidate the causal mechanisms through which SES impacts these relationships. **Future research should focus on uncovering these pathways, exploring how SES influences social dynamics at a more granular level**. This could involve examining the role of parental involvement, access to resources, and social capital in shaping students' peer relations. Understanding these mechanisms would provide a more comprehensive picture of how SES affects social interactions in educational settings. Conversely, **future research should focus on trajectories of low-SES students who were able to overcome the constraints associated with their socioeconomic background**. Investigating the resilience and strategies employed by these students can offer valuable insights into the factors that facilitate their social inte-

gration and success. By identifying the protective factors and supportive environments that enable low-SES students to thrive, educators and policymakers can develop targeted interventions to mitigate the adverse effects of socioeconomic disadvantage on peer relationships.

The second article suggested that an increased proportion of Ukrainian students reduced their integration in social networks. However, these findings were in contrast to many other studies and did not explain the causal mechanisms behind this relationship. **Future research should investigate how classroom composition influences students' perceptions of threat and safety**, potentially through the lens of social identity theory (Tajfel & Turner, 2004) and intergroup relations (Messick & Mackie, 1989). This line of inquiry could explore how different compositions create varying social climates that either facilitate or hinder the integration of diverse student groups. Conversely, future research should examine individual cases where Ukrainian students successfully socially integrated. Understanding the protective factors and effective integration strategies in these cases could provide valuable insights into fostering a more inclusive and supportive school environment for all students.

The third article opened up new questions about the real extent of bullying within peer networks. While it showed how affective relations can protect bullies from being perceived as such, it did not address how these relationships might also serve as protective factors in actual bullying incidents. **Future research should focus on how positive peer relationships can mitigate bullying and how interventions aimed at fostering these relationships can reduce the prevalence and impact of bullying**. This could involve longitudinal studies tracking the effectiveness of such interventions over time and their impact on the social dynamics within classrooms.

The fourth article demonstrated that interactions in classroom group work are influenced by a combination of previous interactions, existing peer relationships, and individual student attributes. This finding underscores the dynamic and relational nature of classroom interactions, suggesting that interventions aimed at improving group work dynamics need to consider these factors. **Future research should explore the specific strategies teachers can use to facilitate positive interactions in group settings**, such as structuring groups to balance social and academic strengths.

In conclusion, this thesis has demonstrated that peer relations and interactions within educational settings are shaped by a complex interplay of structural mechanisms and individual agency. Through the application of social network analysis and the exploration of various contextual factors, I have highlighted the significant impact of structural elements, while also acknowledging the elusive nature of agency within these dynamics. The findings underscore the necessity of integrating both structural and individual perspectives to fully understand social phenomena in schools. This

work not only advances theoretical insights but also provides practical implications for improving student relationships and well-being. Ultimately, **this thesis advocates for a more nuanced and comprehensive approach to studying social interactions, one that recognizes the inseparable connection between individuals and the structures they inhabit**.

Deviations from published articles

This thesis exhibits some deviations from the published articles. In Study A, the original word “propinquity” was changed into “propensity”, with the former being incorrect. In Study A and Study B, the original wording "log odds” was changed into “log odds ratios”, with the former being incorrect. Also, the table and figure numbers differ from the published articles.

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Appendix A: List of publications

Articles

Lintner, T., Diviák, T., & Nekardová, B. (2024). Interaction dynamics in classroom group work. *Social Networks*, *79*, 14-24. https://doi.org/10.1016/j.socnet.2024.05.002

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