

The Role of Classroom Seating Arrangements in Friendship Formation and Persistence

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Abstract

This research study aims to analyze the differences existing between teacher-assigned seating and free seating in classrooms in terms of their impact on students' friendship formation across a semester. The goal is to bridge the literature on seating arrangements, spatial propinquity, and friendship networks for teenagers. Through a social network analysis of friendships in a classroom at the beginning and end of a semester in addition to the seating maps at play, it is possible to test how different seating influences adolescent social structure. This innovative way of tackling spatial propinquity in schools not only has the potential to improve our understanding of high school friendship structures and how they relate to classrooms but also to increase our knowledge of the effects of seating assignments in high schools, a practice that is widespread in the United States. This study analyzes 410 student respondents in 24 American high school classrooms longitudinally across a semester. The results were unexpected: when students choose their seats, the formation of friendships tends to be more influenced by seating proximity, and these friendships tend to be less racially homophilous than when teachers choose seats.

Keywords

Classrooms, Seating assignment, Social networks, Spatial propinquity

Introduction

Research suggests that up to 94% of teachers in the United States assign their students seats in at least some portion of their class, implying the assignment of seats is the most popular type of teacher intervention nationally (Wasnock, 2010). Moreover, it has been reported that students who sit close together tend to have similar learning engagement (Gao et al., 2022). Assigned seating is widely believed to increase student performance, but little is known about the effects of this practice on friendships, even though friends can be crucial for teenagers' mental health, academic achievements, and well-being during high school.

The goal of this paper is to study how seating arrangements (assigned by teachers or decided by

students) affect adolescent friendship networks in American high school classrooms. There are three subparts to that goal: (a) investigating the extent to which *changes* in the friendship networks across a semester can be accounted for by seating, (b) comparing how this varies by *type* of seating, namely *teacher-assigned* (TA) or *student-chosen* (SC), and (c) studying what governs friendship *formation and persistence* across a semester in a classroom. This study is inspired by research on spatial propinquity, which suggests physical proximity is a determinant of friendship formation. Here, the conditions for which this is true in high school classrooms and the relationship of this effect with homophily are investigated.

In Figure 1, one can see the visualization of the research question in a specific classroom, denoted

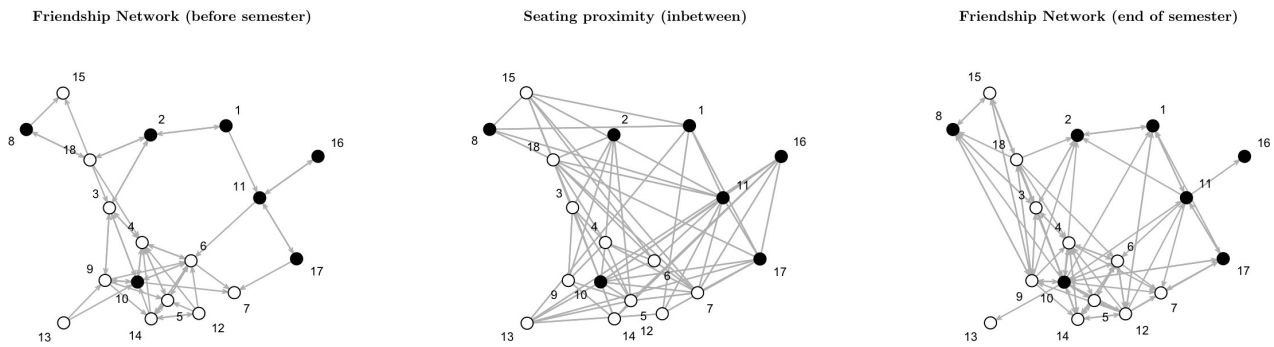


Figure 1: A visualization of the research question with classroom number 4 (TA). Here, white nodes represent White students and black nodes represent Black students. The friendship network, before the semester, is compared to the friendship network at the end of the semester, taking into consideration the seating arrangement in between. (Node positions are maintained across three pictures). TA, teacher-assigned.

classroom number 4. The changes in the friendship networks across the semester can be compared in terms of the seating map proximity: the data collected allow for the question of whether the new friendships formed were likely a result of the seating proximity and how this differs by seating type.

Literature Review

Network theory has elucidated the processes by which structural features of friendship within groups are determined, and the impact this has on its members. Teenagers in high school are naturally a target of many studies since secondary school is a rare moment in one's life in which friendships are extremely contained in one physical space, and constantly changing. There is rich literature on friendship networks in schools, ranging from how they develop, to how they are sustained (e.g., Baerveldt et al., 2008; Ball and Newman, 2013; Currarini et al., 2010; Değirmencioglu et al., 1998; Hallinan and Smith, 1989; Kandel, 1978; Liu and Chen, 2003; McFarland, 2001; McFarland et al., 2014).

Recently, with advances in computational methods, the formation and dissolution of ties in social networks across time have been amply studied (see Fowler and Christakis, 2008; Klärner et al., 2016; Snijders, 2001; Wölfer et al., 2015). Despite scholars now investigating how *temporal* shifts impact network structures, there have not been enough efforts to bridge the *spatial* features of locales with the network structures of the people who integrate them. The area of spatial propinquity within psychology devotes itself to studying how physical spaces impact the opportunities people have to meet, and how these

can result in friendships (Al-Homoud and Tassinari, 2004; Hipp et al., 2014; Small and Adler, 2019). Exemplary cases in the literature include Eagle et al.'s (2009) work in inferring friendship networks from mobile phone data, Takhteyev et al.'s (2012) effort to map the geography of Twitter networks, and Lane's (2016) ethnographical work in Harlem (Eagle et al., 2009; Lane, 2016; Takhteyev et al., 2012).

Altogether, these scholars have shown physical proximity can be defining for forming friendships, whether that proximity comes about in the membership in the same workgroup (Hogg and Tindale, 2001; Segal, 1974) or in living within a certain distance from each other (Festinger et al., 1950; Latané et al., 1995; Nahemow and Lawton, 1975). The effects of physical spaces on friendship have also been shown to be more long-lasting than previously anticipated, even in the case of classroom seating (Back et al., 2008). However, although seating charts are one of the most predominant forms of teacher-led interventions in classrooms, the effects of this practice on friendship networks remain mostly unstudied.

Psychologists and educators have explored how differences in seating arrangements in classrooms impact productivity, albeit most without keeping social networks in mind (Weinstein, 1979). The social order of classrooms and the school more broadly are shown to be impacted by micro-interactions in small group discussions, hallway encounters, and teacher-led interventions (Hamm and Hoffman, 2022). One study, from 1976, discussed how the participation rates and GPAs varied when students were assigned seats in alphabetical order in opposition to SC seating (Wulf, 1976). In the latter case, there was significantly

more classroom participation. Studies from Byrne in 1955 and 1961 have investigated alphabetical seating, demonstrating that the formation of friendships with nearby acquaintances seems to be a reliable phenomenon (Byrne, 1961; Byrne and Buehler, 1955; Frank et al., 2013). Moreover, studies in developmental psychology have shown that the physical distance between classmates is associated with likeability and popularity and that the experimental manipulation of proximity led to higher likeability ratings (Van den Berg and Cillessen, 2015; Van den Berg et al., 2012). These studies indicate that different seating arrangements in classrooms can have many nuanced changes for the longer-term friendship network social structure. So far, modeling the effects of potential seating arrangement changes on friendship selection has been promising (Radó and Takacs, 2019).

Network analysis allows the scholar to differentiate term-wide changes likely generated by *seating* from changes that occurred from expected friendship network structures (such as mutuality and triadic closure). Work needs to be done to investigate which conditions of physical proximity affect homophily. Studies found downstream effects of random assignment of roommates of different races on students' racial attitudes and beliefs (Baker et al., 2011; Boisjoly et al., 2006; Camargo et al., 2010; Carrell et al., 2019; Corno et al., 2019; Van Laar et al., 2005). The importance of this issue for discrimination is salient; however, there is no current consensus on how seating assignments impact racial homophily. Studies have shown that peers can influence one's grades or racial prejudice (Moody, 2001), but seating impacts on homophily seem to vary. On one hand, a study published in 2010 conducted on the seating assignments for training in a police academy demonstrated random seating assignments *increased* interracial friendships between police officers (Conti and Doreian, 2010). In contrast, a study with Hungarian schoolchildren showed benefits of new seating arrangements seemed to be *restricted* to interracial peers (Keller and Takács, 2019). Another Hungarian study of middle schoolers conducted randomizing seating and found that seating next to a stranger increased the probability of a mutual friendship from 15% to 22% and that friendships of the same gender were more likely (Rohrer et al., 2020). Although scholars have studied randomly or alphabetically assigned seating, albeit, without a network-wide approach, SC seating has not been studied as a possible root of social structure changes. The impact of seating arrangements that are *naturally* driven could also be interesting for tie formation and dissolution, and both types of seating

should be compared thoroughly to investigate spatial propinquity and network attributes in classrooms.

Research Design

Data and Sample

The dataset studied encompasses 24 classrooms in different schools in the United States, with a total of 410 student respondents.¹ Data collection occurred during the 1996–1997 school year and the resulting data have been analyzed and expanded in McFarland (2001) and McFarland et al. (2014). However, the work conducted in these papers was focused on popularity and hierarchical triads, and the impact of seating arrangements has not yet been tested. The richness of this dataset is unprecedented, due to the rare information about the seating proximity network among students in addition to the sociocentric network data.

The data sampled are not representative of the United States high schoolers. Asian and Latino students represent <4% of the sample, meaning they are underrepresented in comparison to the US population, whereas White and Black students represent 81.6% and 12.4% of the sample, respectively, meaning White students are slightly overrepresented and Black students are slightly underrepresented in comparison to the US population. Differences in income were not considered in the analysis due to the fact most students are lower-middle class. It is important to note, however, that the average household income per capita of White students was \$2004 higher than non-White students (so racial effects found might have some effect from income as well). This purposive sample was collected in the Midwest and meant to include *rural* and *urban* schools.

¹ Note that these 410 respondents represent 437 nodes since a portion of the students were enrolled in more than one of the classes studied (but since we are treating classrooms as isolated networks, these are separate “observations”). In this sample, since some of the classes studied were in the same school, 62 students shared at least 2 classes with at least 1 other student. These 62 students represented 222 directed ego–alter pairs of students who shared more than one class together in the second semester (only 4 of which were between students who shared 3 classes, and the rest were between students who shared 2 classes). However, all 222 of those pairs were between students who were already friends prior to the start of the second semester. Since it turned out that sharing more than one class together in the second semester was fully correlated with being friends before the start of the second semester, due to collinearity, this was not considered as a covariate in the STERGMs analysis (since the effect should be accounted for since the model accounts for friendships prior to the semester).

This study focuses on High School students (9th grade through 12th grade). Seating arrangements are the manner students can be put in the classroom geographically when it comes to seating. In this dataset, seating arrangements take the form of a seating configuration that is converted into a seating network (where students are connected to other students if they are at a talking distance to them). Friendships are self-reported by students in surveys, in which they are asked to name students they are friends with. For that reason, friendships are *unidirectional* (Alex might consider Ben to be their friend, but Ben might not list Alex as a friend, yielding a unidirectional friendship edge).

From the friendship data, network structures are formed, and these are analyzed before the semester begins and at the end of it, with additional information on the seating networks. Homophily is the likelihood a person will form a connection (in this case, friendship) with another person based on sharing attributes. In this study, it is operationalized by the probability that a student with characteristic X befriends another student with characteristic X (whether that is the same race, gender, or grade). Moreover, triadic closure (how likely two students are to become and stay friends if they share a friend) and mutuality (how likely mutual friendships are to form and persist) were studied. The classroom data are divided into two categories: SC and TA². Out of the 24 total classrooms studied, there are 13 classrooms with SC seating and 11 TA classrooms. The TA category contains alphabetical, random, or other types of assignments by teachers.

More information on the types of classrooms included in this study such as class name, aimed grade, seating type, number of respondents, number of missing longitudinal data, percentage non-white, percentage woman, and percentage not in the aimed grade level for the class is included in Table 6. Classes were often heterogeneous in terms of the grades, gender, and race of the students who composed them. Moreover, it is important to note that these data were collected in the 1996–1997 school year and that institutional support was given to conduct the study, so students were prompted during class time with the survey on their friendships to get a higher response rate. Classrooms were chosen based on being significantly sized and being at different times such that they did not overlap (to allow for class observation). The participant response rate for the classrooms studied was high as the minimum response rate for any classroom was 80% and the

maximum was 100%, with 92.5% being the average³ (full details are on Table 6). Data on the previous friendships of students were collected in the last weeks of the first semester (the studied semester was the second one of the academic year). Four months later, at the end of the second semester, friendship data were collected again.

Variables and Measures

The dependent variable in this study is the formation and persistence of friendships across high school classrooms using Separable Temporal Exponential Family Random Graph Models, or STERGMs (as in Krivitsky and Handcock [2013]). Due to their temporal aspect, STERGMs consider tie *formation* and *persistence* as two separate processes such that we can understand one controlling the other. The key independent variables examine the effect of network and social attributes at different levels of analysis, namely the node level, dyad level, and network level. The variable of edge formation and persistence was added as the constant term of the traditional regression models, and race, gender, and grade variables as controls. The descriptions and definitions of the variables in the STERGM are shown in Table 1.

Edges

The variable edges must be included in building network models based on the exponential-family random graph models (Krivitsky and Handcock, 2013). The edges variable indicates the number of edges in the network, which is used to measure density. The effect of doing this is equivalent to a *constant term* in traditional regression models (Broekel and Bednarz, 2018).

Mutuality

The mutual term in the STERGM measures how much more likely mutual ties are to be formed or maintained in comparison to non-mutual ties.

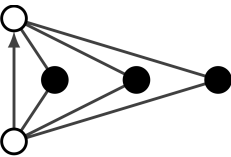
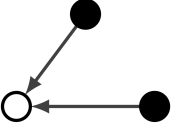
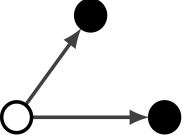
Homophily

The nodematch terms in the STERGM capture if there is homophily by gender, grade, or race in the formation of ties.

2 Note that teachers' choice of assigning seating can be tied to disciplinary motivations, which is an important confounding variable to consider.

3 The high response rate, in addition to the fact that the measures used in this paper (such as in-degree and homophily) are largely robust to missing data and that participants missing should be at least pseudorandom, implies this should not bias the results presented here significantly (Smith and Moody, 2013).

Table 1. STERGM terms tested for the formation and for the persistence of ties. Note that not all terms were tested for all networks due to size or other constraints (for instance, racial homophily could not be tested for white-only networks).

Variables	STERGM term	Diagram	Definition
Edges	edges		The number of edges in the network.
Mutuality	mutual		Probability of bidirectional edge to be formed or maintained.
Homophily	nodematch		Probability of formation and persistence of edges within nodes sharing the same attribute (in this case, gender, race, and grade).
Seating proximity	edgecov(seating)		Sum of seating proximity for all edges in the network.
Triadic closure	gvesp.fixed.0.5		Geometrically weighted edge shared partners. Tests if students form (and keep) edges when they share many common friends.
In-degree	nodeifactor		Differences in in-degree by nodal attribute (in this case, gender, race, and grade).
Out-degree	nodeofactor		Differences in out-degree by nodal attribute (in this case, gender, race, and grade).

Seating Proximity

In this study, seating proximity was operationalized through a seating proximity network constructed from original data from ethnographic observations and assignment of a score by the primary researcher⁴ who originally collected the data. Seating proximity scores were normalized such that students had a tie with other students if they were near enough to interact in the classroom and did not have a tie if they were not. These classrooms had very varied compositions (classical grid, pair-seating, circles, etc.). In this data collection, 75.8% of the student pairs were attributed a score of zero (these two students cannot talk to each other), while 9.3% of the student pairs were attributed the maximum score of two (these two students can easily talk to each other, which is the case when students are sitting next to each other with their desks connected). The other 14.9% were attributed a score from 0 to 2 based on their layout being permissible to talk (0.5 was given to students

who were diagonal to each other or similarly far but reachable, 1 if one of the students was sitting in the back of another student, and 1.5 if the students were next to each other but not connected). This allowed for the formation of a unidirectional seating proximity network as a covariate in the analysis.

Triadic Closure (also Called Structural Embeddedness)

This is measured with a geometrically weighted shared partner (GWESP), calculating the tendency to form a triangle structure (Krivitsky and Handcock, 2013). Triadic closure using GWESP is calculated as follows⁵:

$$v(y, \theta_i) = e^{\theta_i} \prod_{i=1}^{n-2} \{1 - (1 - e^{-\theta_i})^i\} EP_i(y) \quad (3.1)$$

⁵ Note that in Eq. [3.1] the term $EP_i(y)$ refers to the number of edges in y between two nodes with i neighbors in common. See (Broekel and Bednarz, 2018) for another use of this measure.

⁴ Professor Daniel McFarland.

In-Degree and Out-Degree

The nodefactor term in the STERGM captures differences in and out of degree by the nodal attribute of interest (in this case, gender, race, and grade).

Other Independent Variables

Race, gender, and grade were self-reported by students. Race was dichotomized for the sake of convergence into white and non-white, gender is dichotomized as female and male, and grade includes 9th, 10th, 11th, and 12th grade.

Results

Descriptive Analysis

Before analyzing the factors governing the formation and persistence of friendships within a semester across different types of seating arrangements, it is important to verify the conditions of the classrooms were sufficiently near for comparison. The number of students in TA and SC classrooms was similar: while TA seating classrooms had a mean of 19.5 and a median of 19 students, SC seating classrooms had a mean of 17.2 and a median of 18 students. The network densities before the semester were also similar, with 0.188 for TA seating classrooms and 0.183 for SC seating classrooms. Moreover, both types of seating had at least four classrooms each that were racially heterogeneous (>30% non-white students) allowing for some limited comparison in racial homophily. We thus conclude that these classrooms were similar enough for the effect of the seating types to be compared, albeit with reservations.

When assessing the racial assortativity of the seating map of classrooms, we see that SC seating tends to generate *more* racially homophilous seating, as would be expected (see Figure 2). This result makes the findings in Section “Results by Type of Seating” stronger since this effect is *reversed* for the formation of friendships. On the other hand, teacher-chosen seating has *less* racially homophilous seating, which is expected, but as we will analyze in Section “Results by Type of Seating” it leads to *more* racially homophilous friendship formation.

Table 2 summarizes the structural characteristics of each of the 24 networks, including the number of nodes and the number of edges before the semester and at the end of the semester, in addition to the changes in network density, mean distance, mean degree, and centralization. Almost all networks had increases in density and mean degree. The average

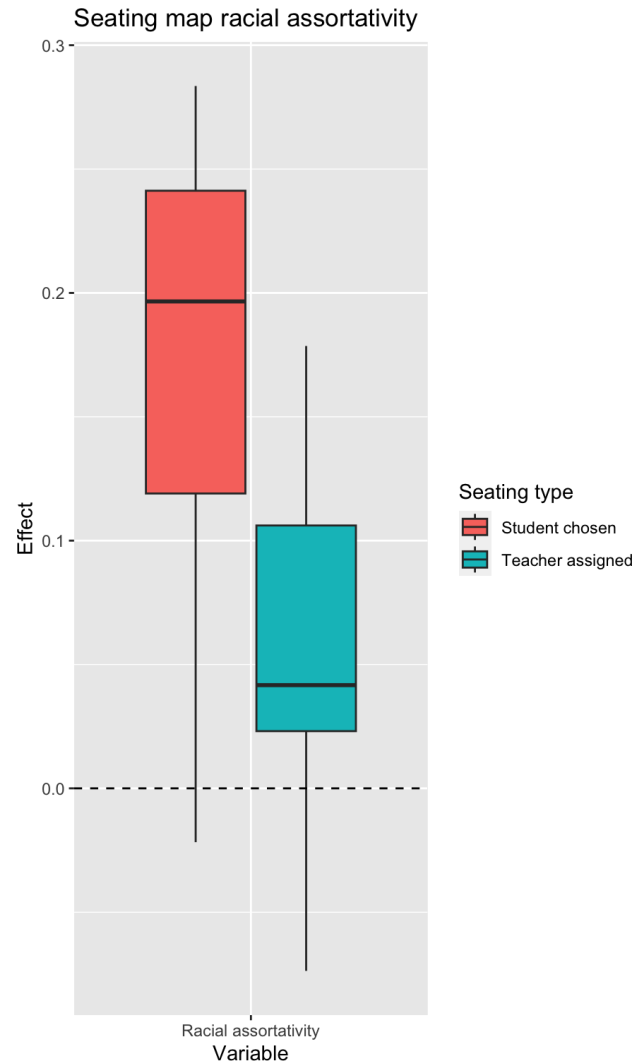


Figure 2: Seating networks racial assortativity

increase in density was by a factor of 0.1122 and the average increase in mean degree was by a factor of 3.9635. Clearly, in every type of seating arrangement studied, sharing a class in a semester increases the friendship ties between high school students significantly, and students end up with more total friends in the end and are better connected to the rest of the network.

In Figure 3, we can see that network density and mean degree increased significantly across the semester, with similar slopes in SC and TA classrooms. This shows that both types of classrooms have a significant increase in the formation of friendships, yielding a good basis for comparison. However, *in-degree* centralization consistently increased in TA seating classrooms and this effect did not appear in

Table 2. Network attributes changes.

Class	Type	<i>n</i>	<i>e</i> (S1)	<i>e</i> (S2)	Δ density	Δ mean dist.	Δ mean deg.	Δ centralization
1	TA	14	35	47	0,0659341	-0,146808	1,714286	0,051282
2	TA	14	64	96	0,152381	-0,323341	4,266667	0,0357142
3	TA	17	49	99	0,1838235	-0,93939	5,882354	0,1083334
4	TA	18	55	91	0,117647	-1,075059	3,999999	-0,03308823
5	TA	24	72	142	0,1268116	-0,765732	5,83333	0,04940714
6	TA	24	89	185	0,173913	-0,722117	8,000003	-0,04743086
7	TA	22	70	142	0,1558441	-1,420978	6,545454	0,07142858
8	TA	18	65	88	0,0751634	-0,283273	2,555556	0,0569852
9	TA	24	97	201	0,1884058	-0,744438	8,666667	0,0158103
10	SC	20	51	104	0,1394737	-0,493138	5,3	0,06871347
11	SC	18	67	131	0,2091504	-0,591145	7,111116	-0,0183823
12	SC	13	35	53	0,1153846	0,004831	2,769231	0,030303
13	SC	24	82	165	0,1503623	-1,26794	6,916667	0,01284585
14	SC	11	20	36	0,1454545	0,253086	2,909091	-0,0277777
15	SC	8	14	19	0,0892857	-0,209184	1,25	0,13095238
16	SC	16	50	54	0,0166667	0,463289	0,5	-0,0095238
17	SC	18	57	82	0,0816994	-0,608628	2,777778	0,0202206
18	SC	22	79	110	0,0670995	-0,898577	2,818182	0,0154762
19	SC	18	47	72	0,0816993	-0,281671	2,777778	-0,01286769
20	SC	15	41	77	0,1714286	-0,767532	4,800003	0,02472531
21	SC	26	70	96	0,04	-1,1696	2	0
22	SC	14	37	30	-0,038462	-0,637253	-1	-0,0673077
23	TA	19	77	121	0,128655	-0,32748	4,631577	0,0212418
24	TA	20	60	81	0,0552632	-0,826451	2,1	-0,001462

SC, student-chosen; TA, teacher-assigned.

n represent number of nodes (respondents) and *e* represent number of edges. Centralization is calculated with in-degrees.

Δ = valueend of semester 2 – value before semester 2 (positive values are increases and negative values are decreases).

SC classrooms. It might be that the effect of more friendship formation *due to seating* (as we will see in Section “Results by Type of Seating”) decreases the *hierarchy* of SC social structures.

Table 3 summarizes the changes in gender, race, and grade homophily in each classroom. Note that although the change is overwhelmingly a decrease in homophily of all types, this must be understood in the context of a big increase in average degree and network density as we have seen in Figure 3. Moreover, although there is a decrease, homophily is positive in almost all networks, even at the end of the

semester. The average gender assortativity before the semester is 0.2562, which decreases to 0.1231 at the end of the semester. Racial assortativity also goes from an average of 0.4925 to 0.2197, while grade assortativity goes from 0.49254 to 0.21966.

Generally, all forms of assortativity *decrease* across the 24 classrooms throughout the semester. This seems to be a natural process in the formation of more ties and the development of familiarity over time. The slopes for gender and grade assortativity seem similar for student-chosen and teacher-chosen classrooms. However, for SC seating classrooms, the

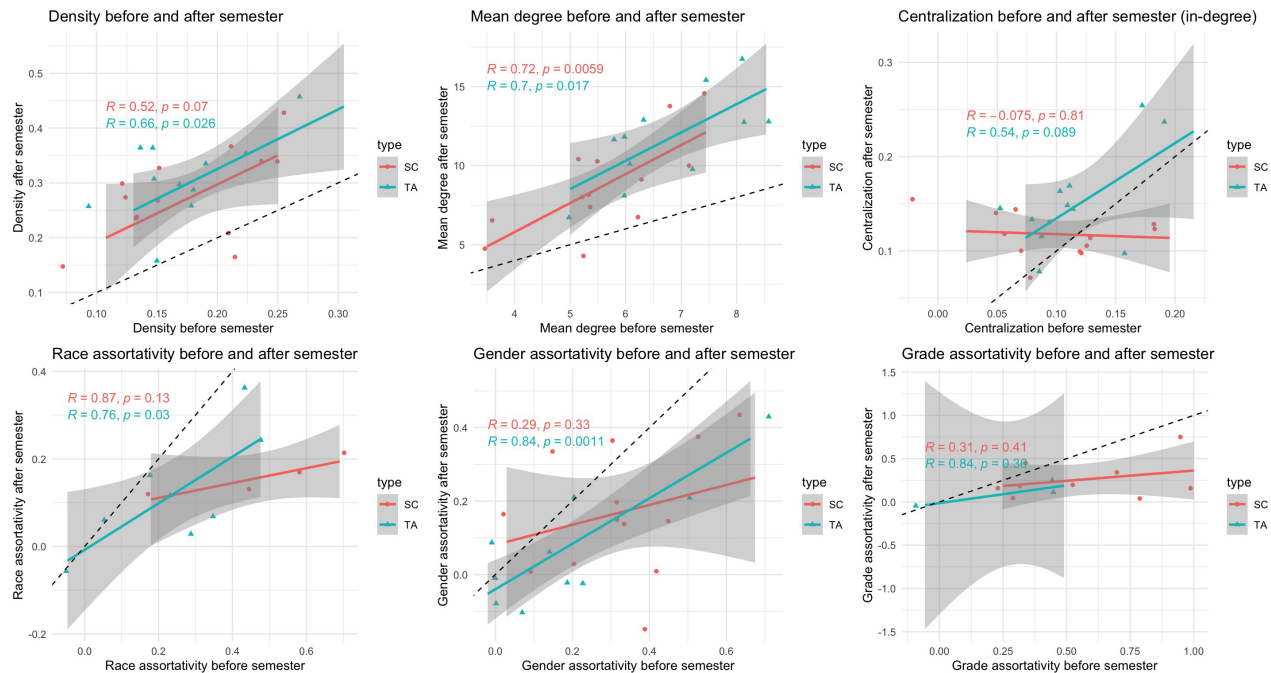


Figure 3: Differences between before and after semester network statistics: of network density, mean degree, mean distance, race assortativity, gender assortativity, and grade assortativity, with slopes, correlation coefficients, and p -values for the sake of comparison. SC, student-chosen; TA, teacher-assigned.

decrease in racial assortativity across a semester is starker than in teacher-chosen seating classrooms. This is an interesting effect, especially taking into consideration that in student-chosen seating, the seating map was substantially more racially homophilous (see Figure 2). Hence, although the seating maps had more racial segregation when students chose their seating, this seating configuration resulted in less racially homophilous friends than teacher-chosen seating classrooms, which were less racially segregated. This counterintuitive finding sediments the context for the found results of less racially homophilous friendships being formed in SC seating classrooms, as we will discuss in the Section “Results by Type of Seating.”

Friendship Formation and Persistence STERGM Analysis

While Table 4 describes the statistically significant results of the STERGMs in classes with teacher-assigned seating, Table 5 describes the statistically significant results of the STERGMs in classes where students chose their seating. The positive beta coefficient indicates the promotion of network relationships in formation/persistence, and the

negative coefficient indicates the suppression of network relationship formation/persistence.

All STERGMs converged and had appropriate goodness of fit (see Figure 5 for the respective Goodness of Fit plots). We can see that the general formation of new ties is governed by various social and network factors while the persistence of ties is way less prevalent and has fewer governing factors. Moreover, while some factors seem to govern tie formation in almost all networks, such as mutuality, some seem very specific to the conditions of each network (such as some grades or a given gender or race having higher in or out degrees than others). We can also see that the formation of *new edges* was significantly below the random threshold, while the effect of *persistence* of edges was not significant in most networks (indicating perhaps that the friendships between students prior to the semester were not of a strong nature).

Results by Type of Seating

By performing an analysis of the coefficients found in the STERGMs of the 24 classrooms, we can have a better notion of the overall trend by type of seating arrangement. In Figure 4, we can see the comparison

Table 3. Network assortativity changes.

Class	Type	Δ gender assortativity	Δ race assortativity	Δ grade assortativity
1	TA	-0,12992152	-0,1138759	NA
2	TA	-0,2800093	-0,0044844	NA
3	TA	0,010200081	-0,27768636	NA
4	TA	0,07025436	0,0120824	NA
5	TA	-0,21661889	-0,0863014	NA
6	TA	-0,19435523	-0,28064122	NA
7	TA	-0,05244456	NA	-0,1888698
8	TA	-0,2323466	NA	0,01198873
9	TA	-0,14999934	-0,223815	NA
10	SC	-0,450792526	-0,4044041	NA
11	SC	-0,17527807	-0,059338	NA
12	SC	-0,1508002	-0,349391	-0,2033669
13	SC	-0,079262478	-0,4754838	NA
14	SC	0,2349064	NA	-0,8430588
15	SC	-0,5266441	NA	-0,74261296
16	SC	-0,1831539	NA	0,1267994
17	SC	-0,3295782	NA	-0,1149261
18	SC	-0,239163	NA	-0,0921452
19	SC	0,0296049	NA	-0,3941588
20	SC	-0,1588119	NA	NA
21	SC	-0,1311118	NA	-0,1616417
22	SC	0,13544486	NA	-0,2851677
23	TA	-0,006702639	-0,00981007	NA
24	TA	0,0101957	NA	-0,3874417

SC, student-chosen; TA, teacher-assigned.

Δ = valueend of semester 2 – valuebefore semester 2 (positive values are increasing and negative values are decreasing). Note that NA values are present due to the lack of more than two nodes in the network of a different race/grade (assortativity was not calculated if that was the case)

of estimates found across SC seating classrooms and teacher-chosen seating classrooms.

The findings were as follows. Seating seemed to govern tie formation for classrooms in which students chose their own seating but not for classrooms where students were assigned to their seats. This could indicate that when students are allowed to choose their own seating, they are more likely to form friendships with the students around them than if they are given a seating arrangement.

Moreover, seating does not seem to govern the persistence of friendships in either type of seating arrangement. Racial homophily was significant for

tie formation in TA seating, whereas for SC seating, homophily was not a governing factor of tie formation. Note that this is especially surprising given that SC seating yields a more racially homophilous seating map as we saw in Figure 2. Since both groups had an absolute decrease in racial assortativity, this might be somehow impacted by the difference in seating assignments. The reasons for this effect are unclear, but the data suggest that student-chosen seating presents more racially heterogeneous friendship formation than teacher-chosen seating. There was no clear trend in gender homophily, as in some classrooms we found signs of friendships forming

Table 4. Results of STERGM formation and persistence for teacher-chosen classrooms.

Class	Type	Formation (estimate, p-value)	Persistence (estimate, p-value)
1	TA	edges (-4.6697, < 1e-04 ***), racial homophily (1.5218, 0.00391 **), triadic closure (0.01252*)	
2	TA	edges (-4.66039, 0.000298***), non-white outdegree (0.99882, 0.028678*), mutuality (2.16343, 0.000236***)	edges (1.15196, 0.087114+), seating (2.27947, 0.032804*)
3	TA	edges (-2.53740, <1e-04***), mutuality (1.51807, 0.000251***), triadic closure (NA, 0.095127+)	edges (5.54313, 0.003879**), girl outdegree (-1.87382, 0.024540*)
4	TA	edges (-4.756824, <1e-04***), mutuality (1.325573, 0.008302 **), triadic closure (NA, 0.000146***)	
5	TA	edges (-3.43292, <1e-04 ***), non-white indegree (0.40454, 0.0890+), girl indegree (0.50478, 0.0483 *), mutuality (1.81821, <1e-04 ***), triadic closure (0.40458, 0.0233 *)	
6	TA	edges (-2.87312, <1e-04 ***), non-white outdegree (0.62196, 0.00597 **), mutuality (1.54773, <1e-04 ***), triadic closure (0.51810, 0.06822+)	mutuality (1.69691, 0.00669 **)
7	TA	edges (-3.45125, <1e-04 ***), mutuality (1.20579, 0.000859 ***), triadic closure (0.90554, 0.000117 ***)	edges (1.62969, 0.055371+)
8	TA	edges (-3.23157, <1e-04 ***), 11 grader outdegree (-1.81279, 0.0908+), mutuality (2.16172, <1e-04 ***)	triadic closure (0.83281, 0.0105+)
9	TA	edges (4.3701, < 1e-04 ***), seating (0.4754, 0.02471 *), non-white outdegree (0.8559, 0.00311 **), mutuality (2.5804, < 1e-04 ***), triadic closure (1.2353, 0.00538 **)	
23	TA	edges (-5.06002, <1e-04 ***), non-white indegree (-0.83548, 0.014202 *), non-white outdegree (1.58795, <1e-04 ***), mutuality (1.38504, 0.001826 **), triadic closure (1.40902, 0.000776 ***)	edges (1.53861, 0.078322+), racial homophily (-1.15963, 0.063901+), mutuality (1.46604, 0.048401 *), triadic closure (0.58833, 0.032323 *)
24	TA	edges (-4.63762, <1e-04 ***), gender homophily (0.87172, 0.00820 **), 9th grader indegree (1.18034, 0.01947 *), girl outdegree (0.68859, 0.03343 *), triadic closure (0.95337, <1e-04 ***)	triadic closure (1.33068, 0.00343 **)

AA, alphabetically assigned, RA, randomly assigned, OS, other seating; TA, teacher-assigned.

*p < 0.10; **p < 0.05; ***p < 0.01; ****p < 0.001.

Table 5. Results of STERGM formation and persistence for SC classrooms.

Class	Type	Formation (estimate, p-value)	Persistence (estimate, p-value)
10	SC	edges (-3.94281, < 1e-04***), gender homophily (-0.66842, 0.01785*), mutuality (2.35829, < 1e-04***), triadic closure (0.69331, 0.00367**)	
11	SC	edges (-4.3457168, <1e-04 ***), mutuality (1.7479738,<1e-04 ***), triadic closure (1.0083759, 0.0231 *)	seating (2.2146689, 0.0740+)
12	SC	edges (-2.03702,0.03316 *), mutuality (1.83455, 0.00444 **)	triadic closure (1.50379, 0.05099+)
13	SC	edges (-3.85863, < 1e-04***), mutuality (1.57682, < 1e-04***), triadic closure (1.00728, 0.000146***)	mutuality (3.11584, 0.001632**)
14	SC	gender homophily (2.2956, 0.00223 **) girls outdegree (-1.8065, 0.01609 *) seating (1.1260, 0.06051+)	
15	SC	grade homophily (-2.7301, 0.0258 *)	
16	SC	edges (-4.27543, <1e-04 ***), grade homophily (1.77210, 0.0270 *), mutuality (1.40598, 0.0450 *)	mutuality (2.71069, 0.0107 *)
17	SC	edges (-3.400596, < 1e-04 ***), 11 grader indegree (-1.999271, 0.04689 *), triadic closure (0.891412, 0.00687 **)	
18	SC	edges (-3.93163, < 1e-04 ***), seating (-0.77997, 0.031878 *), mutuality (1.41718, 0.001916 **), triadic closure (0.97603, 0.035833 *)	triadic closure (0.68382, 0.035833 *)
19	SC	edges (-4.02308, <1e-04 ***), gender homophily (0.58180, 0.0784 +), mutuality (2.00926, <1e-04 ***) triadic closure (0.59734, 0.0108 *)	gender homophily (1.64543, 0.0572+), mutuality (2.16391, 0.0440 *)
20	SC	edges (-1.05228, 0.0117 *), girl outdegree (-0.84408, 0.0323 *)	
21	SC	edges (-3.86354, <1e-04 ***), gender homophily (0.86038, 0.0128 *), grade homophily (1.69354, <1e-04 ***)	
22	SC	edges (-3.549671, 0.000752 ***), girl outdegree (1.532272, 0.064955 +)	grade homophily (-2.967090, 0.023639 *)

Table 6. Descriptive characteristics of the classrooms studied, including the name of the class, aimed grade, seating type, number of respondents, number of missing longitudinal data, percentage non-white, percentage woman, and percentage not in the aimed grade level for the class.

Class	Name	Aimed grade	Type	Respondents	Missing	Non-white (%)	Woman (%)	Not in aimed level (%)
1	Biology	10th	TA	14	2	35,7	64,28	7,1
2	Biology	12th	TA	14	0	35,7	64,28	0
3	English	12th	TA	17	3	52,9	58,8	0
4	English	10th	TA	18	1	38,8	72,2	0
5	Trigonometry	10th	TA	24	1	37,5	54,1	0
6	English	10th	TA	24	3	41,6	54,1	0
7	Chemistry	10th	TA	22	1	0	50	18,1
8	Chemistry	10th	TA	18	0	5,5	50	5,5
9	AP English	12th	TA	24	1	37,5	79,1	0
10	Discrete Mathematics IB	12th	SC	20	2	55	55	0
11	Calculus IB	12th	SC	18	3	33,3	27,77	0
12	Algebra II	10th	SC	13	0	46,1	61,5	15,3
13	US History II IB	12th	SC	24	3	41,6	79,1	0
14	Precalculus	12th	SC	11	0	0	63,6	27,3
15	Precalculus	12th	SC	8	2	12,5	62,6	75
16	Biology II	12th	SC	16	0	5,5	68,7	31,2
17	Trigonometry	10th	SC	18	2	5,5	55,5	22,2
18	Chemistry	10th	SC	22	3	4,5	50	31,8
19	Physics	12th	SC	18	3	5,5	66,6	22,2
20	Calculus	12th	SC	15	1	6,6	60	0
21	Geometry	10th	SC	26	2	7,6	50	50
22	Algebra B	10th	SC	14	2	0	50	35,7
23	Biology	10th	TA	19	0	42,1	63,1	0
24	Geometry	10th	TA	20	1	0	45	45

and persisting more frequently among the same or different genders. The lack of pattern in gender homophily is expected for high school students.

The largest effect found was that of mutuality: mutual friendships tend to persist more than non-mutual ones, across all classes. Mutuality seems to govern tie formation in every type of classroom to a large extent (meaning mutual friendships are much more likely to form than non-mutual ones). Likewise,

triadic closure seems to play an important role in tie formation and persistence in every type of classroom, but to a lesser extent than mutuality.

Discussion

In disagreement with the literature suggesting that TA seating is effective for increasing diverse friendships (such as Conti and Doreian, 2010; Rohrer et al., 2020),

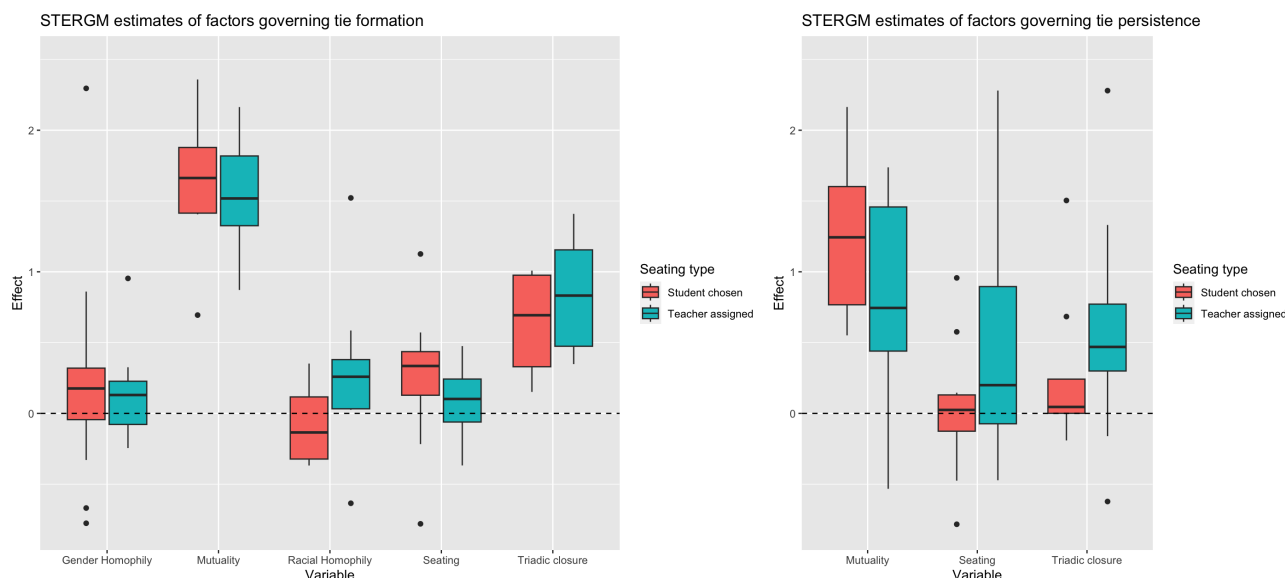


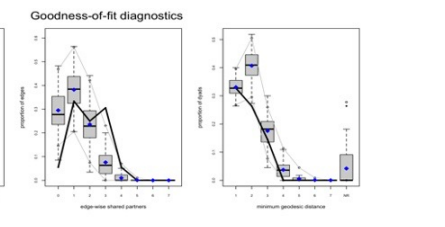
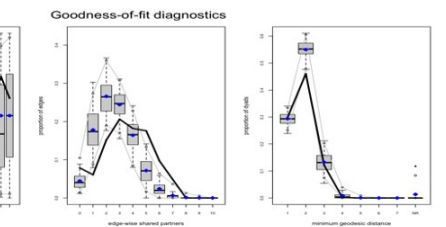
Figure 4: Results comparing the STERGM estimates of factors governing tie formation (right) and persistence (left). The results are separated by seating type (SC or TA). SC, student-chosen; TA, teacher-assigned.

we found that in classrooms where students chose their seats, friendship formation tends to be *more diverse*. Moreover, unlike Byrnes's findings (1955, 1961), alphabetically assigned seating proximity did not seem to significantly govern the formation of new friendships. The opposite happened since we found a significant effect of seating proximity impacting the formation of new friendships when students were free to choose their seating. This might be due to the documented effect which describes students who seem to interact more with their surrounding peers in SC seating (Wulf, 1976). Perhaps it is the case that SC seating is conducive to students forming more friendships with those around them with less homophilous patterns.

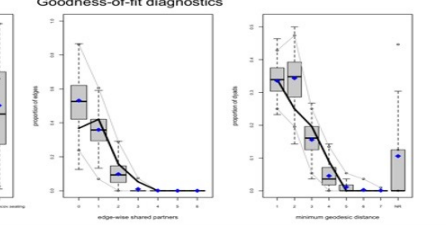
The trend for a strong decrease in racial homophily and more friendship formation due to proximity in free-choice seating classrooms might be due to a list of factors: (a) perhaps students feel that others who sit next to them willingly are more likely to want to interact with them, (b) perhaps students need peers they already know to talk and meet new peers in the first place, (c) perhaps due to the ubiquity of alphabetical map assignment, students in these classes might know their peers in TA seating, whereas the natural stochasticity of free seating provides unfamiliar faces, or yet (d) perhaps when students select their own seats, they select people who they are not yet friends with but who they are open to becoming friends with. It is necessary to further investigate to

discover which of these scenarios is taking place (taking into consideration it is more likely more than one). Finally, mutuality and triadic closure seemed to be essential for forming and maintaining friendships across a semester in any classroom, a result which is consistent with the literature (McFarland et al., 2014).

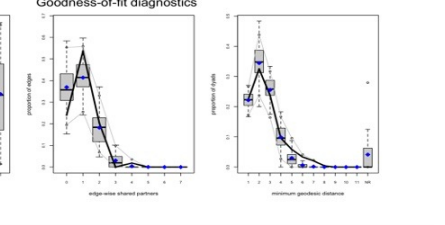
Since this dataset is a convenience sample from the Midwest with only 410 respondents, its generalizability is limited. In order to discover whether these trends hold across the United States, it would be ideal to randomly sample school districts in the United States and perform a similar analysis taking into consideration the type of seating assignment, friendships prior to a semester starting, the seating proximity network, and other factors that have not been taken into consideration here (such as the content of the class or the number of meeting times per week). Although the causal impact of this effect is better assessed with an experiment, the factors that lead teachers to assign seating in the first place might be causing this phenomenon. Moreover, this investigation (and particularly the findings on racial homophily) would entail a more diverse sample than the one analyzed here, and the effect of racial homophily could be tested in areas with more racial diversity. It would thus be necessary to test the effect of racial homophily without dichotomizing race, in broader multiracial classroom contexts. The effects found here were likely specific to the relationship of mostly White and Black students and the relationship



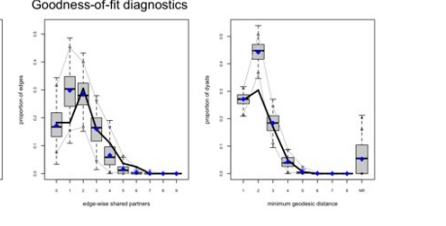
Goodness-of-fit diagnostics



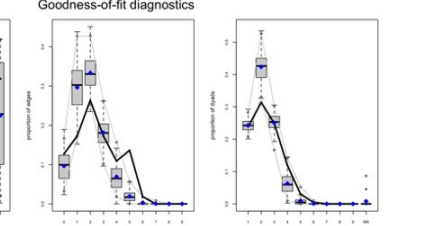
Goodness-of-fit diagnostics



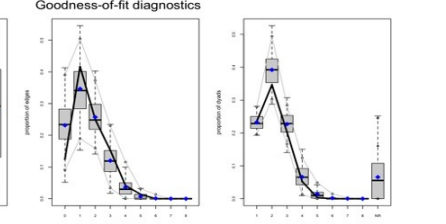
Goodness-of-fit diagnostics



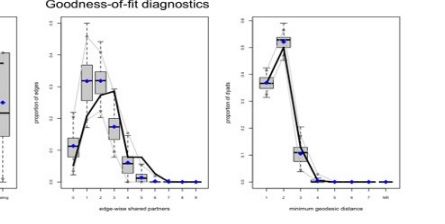
Goodness-of-fit diagnostics



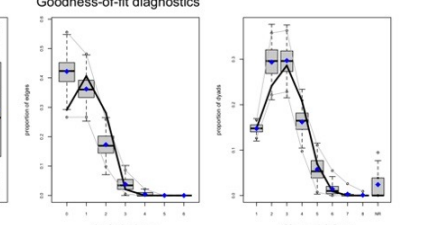
Cardiorespiratory fitness



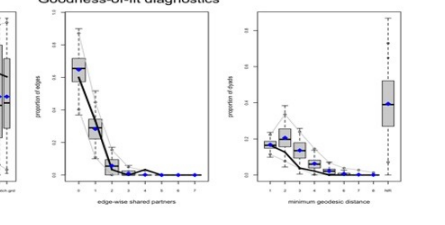
Goodness of fit diagnostic



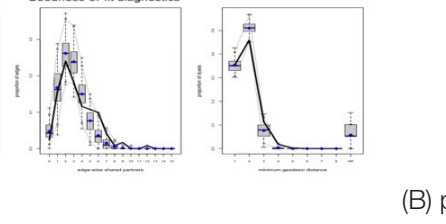
Goodness-of-fit diagnostics



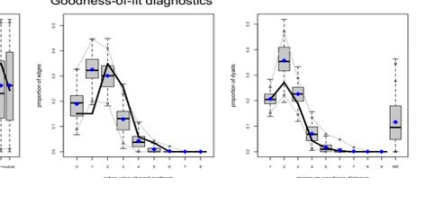
Goodness-of-fit diagnostics



Goodness-of-fit diagnostics



Goodness-of-fit diagnostics



(B) part II

Continued Figure 5: Goodness of fit tests for the 24 networks.

between classroom seating and homophilous friendship formation differs for Latino or Asian students. It is also important to note that a complete network study of a whole High School would provide a better estimate of whether friendships are persisting or forming due to proximity in seating or due to other factors (such as extracurriculars, or sharing other classes).

Another limitation of these findings is that the collection of this data was in the late 1990s, when the diffusion of cellphones and social media platforms in high schools had not yet occurred. Although some studies have attempted to describe the effect of technologies such as group chats, messaging apps, and social media on high school friendship dynamics (Davel, 2013; Lam, 2023), new research and data-collection efforts are required to test how these tools have changed the ways in which adolescents form and maintain friendships with their classmates and peers. In particular, it is crucial to test how online social network effects and in-person social network effects interact. In a study conducted in rural Japan, Maejima (2020) showed how online interactions with classmates were more gender heterogeneous than in-person interactions. More data on both in-person and online friendships among high schoolers should be collected to understand the ways online messaging and social media can further intensify or help attenuate racial homophily among high schoolers. More broadly, there needs to be an investigation into how online spaces and online proximity can be studied alongside physical proximity and spatial propinquity in multidimensional networks. A new iteration of this study in contemporary classrooms should strive to tackle these questions.

To further scrutinize the findings presented here, it is also necessary to reflect on what could be other confounding variables of SC versus teacher-chosen seating assignments. We should assess whether there is a correlation between the amount of talking in a classroom and the type of seating, or more broadly if there is a correlation between the type of class teachers allow for free choice seating and the type of class students tend to form friendships in. However, the hypothesis of the relationship between the type of seating and formation of friendships by the amount of talking seems unlikely to be causing the effect in this sample since we found the number of new friendships formed was extremely similar across different seating types. If the effect found in this study is present when taking a larger and more representative sample of classrooms, the hypothesis of a causal relationship between free-choice seating and less homophilous friendship formation would be strengthened.

Research Ethics

This research on human subjects has been approved by an IRB. This study has therefore been performed in a way that is consistent with the ethical standards articulated in the 1964 Declaration of Helsinki and its subsequent amendments and Section 12 ("Informed Consent") of the ASA's Code of Ethics. All human subjects gave their informed consent prior to their participation in the research and adequate steps were taken to protect participants' confidentiality. Moreover, the author has had the proper non-medical human subjects CITI training to handle the data.

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