# Teaching Practices, Prosocial Giving, and Friendship Networks *

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**Abstract**

We investigate the effects of a semester-long student-centered teaching program on prosocial giving and network homophily by conducting pre- and post-intervention friendship surveys and dictator game experiments. Using a difference-in-differences method, we show that the intervention promotes prosocial giving to indirectly connected peer students, strengthens class and gender homophily in friendship, and reduces average distance among indirectly connected students. By structurally estimating a network formation model, we infer that the program also reduces costs of making friends of both genders in the same class. Our findings offer novel micro-level insights on the connection between teaching practices and social capital and networks.

**JEL Classification:** C83; D85; Z13

**Keywords:** Friendship network, teaching practices, dictator game experiment, social capital

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# 1 Introduction

School education is important for individuals to accumulate human capital and build social capital and networks. Because social connections made in school can affect various outcomes including academic achievement (Fletcher et al., 2020), health behavior and outcomes (Fletcher and Ross, 2018; Narr et al., 2019), criminal activity (Billings et al., 2019), and economic outcomes in markets (Cohen et al., 2008; Conti et al., 2013), it is essential to understand what shapes social capital and networks in school.

A prominent form of social capital and networks in school is friendship networks. One pedagogical tool of influencing friendship connections among students is how they are taught in the classroom. Compared to practices in which teachers primarily lecture and ask students questions, teaching practices stimulating student group work provide students with more opportunities to engage with their peers as part of learning in the classroom. Such student-centered interactions can promote friendship connections among students and their prosocial behavior. In this paper we investigate this hypothesis by exploiting the introduction of a student-centered teaching program, called project-based learning (henceforth, PBL).

The PBL program was introduced for one semester during the 2016 academic year to seventh graders in six middle schools by the Daegu Metropolitan Office of Education (henceforth, DMOE) in South Korea. The program trained and encouraged teachers to switch from conventional lecture-oriented classes to student-centered teaching practices in which students work in groups and do projects together, and thereby stimulating interactions among students in a classroom. For comparison purposes, the DMOE carefully selected six control schools that were located in proximity to PBL treatment schools and not practicing any similar kind of the PBL program.

Before and after the PBL intervention, we conducted a school-wide friendship nomination survey among all 7th graders across 12 middle schools, totaling 2,589 students. Every student was asked to nominate up to 10 friends from the entire list of students in the same grade at the school. Additionally, we administered an incentivized dictator game experiment with a representative sample of 1,130 students from the same schools. Each student was asked to divide endowed money between self and a randomly matched student whose name and student ID was revealed to the individual. Students repeated this decision with 10 randomly matched students. By using friendship network information and giving behavior from the dictator game experiment, we confirm the findings in the literature that donations in dictator games tend to decrease in social distance (Hoffman et al., 1996; Leider et al., 2009; Goeree et al., 2010).

Using the difference-in-differences method, we find the following effects of PBL. First, PBL increases overall prosocial giving by 23 percent compared to that in the baseline control schools. This PBL effect is driven by increased giving to indirectly connected students (i.e., those with friendship network distance greater than 1), showing a 26 to 36 percent increase from the control and baseline across different distances. In contrast, we find no significant PBL effect on giving to directly connected students (i.e., nominated friends).

Second, the PBL program strengthens class and gender homophily in friendship networks. It increases significantly the proportion of same class friends and the proportion of same gender friends in the same class, while the proportion of different gender friends in the same class remains unchanged. However, these PBL effects on class and gender homophily in friendship contribute to the reduction of average distance among indirectly connected students of different gender in the same class.

To infer the PBL effects on costs of friendship formation, we structurally estimate a network formation model with costly linking, following the economics tradition of network formation (Jackson and Wolinsky, 1996; Bala and Goyal, 2000). Assuming that the flow benefits of linking are represented by the observed inverse distance pattern of giving over friendship network distance, we estimate the homophily-dependent distributions of linking costs by matching the observed homophily patterns and infer the PBL effects on them. The PBL program significantly decreases the average linking cost for same gender and same class peers, explaining the positive PBL effect on friendship homophily in this group. In addition, PBL decreases the average linking cost to students of different gender in the same class. This effect does not necessarily lead to an increase in friendship connection in the corresponding group because PBL reduces average distance among indirectly connected students in that group, which results in the increased benefits from indirect connection and thus dilutes an incentive of direct linking.

Our paper contributes to several strands of literature. First, we contribute to the literature documenting the connection between teaching practices and social capital (e.g., Dewey, 1994; Algan et al., 2013; Choi et al., 2021). Specifically, Algan et al. (2013) find a positive correlation between the degree of student-centered teaching practices and student beliefs about cooperation.

We add to this literature by exploiting a quasi-experimental education intervention on teaching practices and presenting causal evidence on the impacts of this intervention on prosocial giving, homophily networks, and costs of friendship formation in school. Second, our paper is closely related to the experimental literature of documenting prosocial behavior in social networks (Hoffman et al., 1996; Leider et al., 2009; Goeree et al., 2010). In addition to confirming the documented relationship between giving and social distance, we provide evidence that this relationship can be influenced by an education intervention. Lastly, we contribute to the empirical literature of network homophily (Shrum et al., 1988; Pearson et al., 2006; Jackson, 2010; Jackson et al., 2023) by adding novel evidence on the cultivation of network homophily in school through teaching practices.

# 2 Intervention and Data Collection

## 2.1 The PBL Program in South Korea

The DMOE in Daegu, the fourth most populous city in South Korea, implemented the PBL program with six middle schools in 2016.[1] The program was designed to encourage middle schools to switch from traditional lecture-based teaching to horizontal student-centered teaching for seventh grade students (the first-year students of middle school in South Korea).[2]

The DMOE requested teachers in the six treatment schools to implement PBL-type classes[3] during the fall semester of 2016. Specifically, the teachers were required to implement at least two in-class group projects, each of which was required to last for five or more class hours. To assist teachers in running PBL-type classes, the DMOE offered a four-day (or 30-hour) training workshop on how to design and prepare PBL-type classes approximately two months prior to the

[1] Prior to this program, the DMOE conducted a similar pilot program at two middle schools in Daegu in 2015. We refer to Choi et al. (2021) for the detail of the pilot program and the evaluation of its effects on student cooperation.

[2] Algan et al. (2013) show, using the Trends in International Mathematics and Science Study (TIMSS), that the teaching practices in South Korea are much more based on conventional lecture-based classes than those in Nordic countries (Denmark, Norway, and Sweden) and Anglo-Saxon Countries (Australia, United States, and Great Britain). Thus, the PBL intervention in the context of South Korea is quite relevant in this regard.

[3] PBL can be defined as learning that focuses on group projects in which students investigate solutions through asking questions, debating ideas, and communicating with other students. In a typical PBL class, the teacher initially introduces the project that students need to address in the group. This consists of providing the background information, the main question of the project, and the instructions on the specific tasks that students need to accomplish. Then, students develop a group plan for the project including brainstorming ideas, collecting information, and assigning different roles and tasks among group members. Finally, their end product is presented to other students (Helle et al., 2006).

fall semester of 2016, as well as provided ongoing consultation and coaching services throughout the semester. Table A.1 in the Appendix summarizes the timing of the training and consultation programs.

For the representativeness of the sample, the DMOE selected one treatment school from each of the six different school districts within the city, and a control school was matched within the same district. The control schools where no PBL program was offered were chosen to be of the same gender type (single-sex or co-ed at both school and classroom levels) as their matched treatment schools. Therefore, we have two schools (one treatment school and one control school) per district, to be as similar as possible to each other in terms of gender structure and geographic location.[4] The school type distribution for 12 schools is presented in Table A.2 and the location of six treatment schools and six control schools is shown in Fig A.1 in the Appendix. As will be shown later, this effort of selecting sample schools guarantees that there is no statistical difference in almost all observed characteristics and pre-intervention outcomes between PBL treatment schools and control schools. Additionally, teachers or students themselves did not volunteer or self-select into either treatment or control groups, which further removes concerns for potential selection bias.

Prior to the implementation of the PBL program in the 2016 fall semester, we visited each of the 12 schools and conducted the baseline study for the seventh graders (aged 12−−13). The endline study was conducted four months later in December 2016 at the end of the fall semester. Both baseline and endline studies were undertaken with parents' written consent. The ethical aspects of this study has been approved by KDI School Research Ethics Review Committee (KDIS-IRB-2016-01).

There are important considerations regarding the structure of middle school classes in South Korea and the PBL intervention. First, South Korean middle school students remain in their homeroom throughout the day, with teachers rotating between classes to deliver instructions. Consequently, the results in this study reflect the effects of the PBL intervention under a fixed composition of classmates. Second, while class allocation in South Korean middle schools is random, the gender composition within a class (i.e., single-sex vs. co-ed) can be determined at the school level. Given that the impact of PBL may vary between co-ed and single-gender

[4] The average distance between a treatment school and its matched control school is approximately 1.2 kilometers.

classrooms, we present the results for co-ed schools separately. Third, when assigning students to groups for projects, teachers were advised to randomly group students within each class. This strategy ensured that students engaged with a diverse set of classmates in PBL sessions.

### 2.2 Survey and Experiment

The baseline and endline studies consisted commonly of three parts; 1) a friendship survey, 2) a dictator game experiment, and 3) questionnaires about students' family backgrounds and cognitive and noncognitive skills. We implemented the same set of surveys and experiments in both baseline and endline studies to facilitate empirical analysis. We conducted a friendship survey with all registered 7th graders in the 12 schools, but due to budget constraints, the remaining two parts were conducted with students in four randomly selected classrooms in each school. Four classrooms randomly selected in the baseline study were selected again in the endline study. Students used individual laptops to complete each part, and it was strictly enforced that they could not talk to each other during the study. We randomized the order of these three parts across classes to control the order effects.

At the beginning of the 2016 fall semester, 2,749 students who were registered in the 12 schools participated in the baseline friendship survey. Among them, 2,589 students (94.1%) completed the friendship survey in the endline study. For the dictator game experiment and questionnaires, we randomly selected four classrooms in each school, resulting in 1,239 students in the baseline study. Among them, 1,130 students (91.2%) also participated in the endline study.

The most frequent reasons for dropout are transfer to other schools and sick leave. Overall, the attrition rate between control and treatment schools is comparable: 6.6% for the control schools and 5.2% for the treatment schools. There is no significant difference in dropout rate between the control schools and the treatment schools (see Appendix A.4).

**Friendship survey.** We asked each student to list up to 10 close friends from the entire list of registered 7th-grade students in the school. The names of friends in a school were grouped by class. When students clicked on a class, they could see all the students' names for that class. Add and delete buttons are next to the student list, allowing them to easily choose and change their close friends list. Appendix A.2 presents the instructions we used and a sample screen for this part.

**Dictator game experiment.** Every student in four randomly selected classrooms in each school participated in 10 rounds of a dictator game with randomly matched students from their school. In each round, students were given 2,000 KRW (approximately 2 USD) and were asked to allocate the money between themselves and a randomly matched recipient whose name and student ID were displayed on the decision screen. In this regard, the student playing the role of the dictator knows the identity of the recipient but the recipient does not know the identify of the dictator whom they are matched with. Appendix A.3 presents instructions and screenshots for the experiment. At the end of the study, we randomly selected one round for payment and participants accordingly received a voucher that can be used in a convenient store in the school. We did not tell students which round was selected for their payments and strongly recommended students not to reveal the amounts they gave as the dictator. In the endline dictator game experiment, students faced the same set of recipients as in the baseline experiment in a random order.

**Questionnaires.** We asked students about their background information–gender, height, and weight–and their family backgrounds, including their parents' age and education level, as well as their birth order in the family. To assess cognitive skills, we designed five math questions and allotted 15 minutes for students to solve them. For noncognitive skills, we used the Rosenberg self-esteem scale (Rosenberg, 1965) and the Big-5 personality test (Gosling et al., 2003).

### 2.3 Balance Test

Table 1 summarizes the balance test results, assessing whether the baseline characteristics and outcome variables of the control schools differ significantly from those of the treatment group. Column (1) presents the results for all 12 schools, while column (2) focuses on the 6 coed schools. The "Control" column reports the mean and standard deviation (in brackets) for the control schools, while the "Treated" column shows the difference in means relative to the control schools, with corresponding p-values in parenthesis.

In Panel A, we present the balance test results for the mean giving share and the number of friends. In column (1), students in the control schools give an average of 25.7% of their endowment to their randomly matched friends, and the difference from that in the treatment

Table 1: Descriptive Statistics and Balance Test

| | (1) | | (2) | |
|---|---|---|---|---|
| Sample | All 12 schools | | 6 co-ed schools | |
| | Control | Treated | Control | Treated |
| N | 535 | 595 | 224 | 281 |
| *A. Prosocial giving & Friendship* | | | | |
| Mean dictator giving share | 0.257 | -0.011 | 0.226 | 0.013 |
| | [0.227] | (0.663) | [0.203] | (0.750) |
| Number of friends | 8.856 | -0.159 | 8.576 | 0.197 |
| | [1.503] | (0.886) | [1.536] | (0.750) |
| *B. Individual characteristics* | | | | |
| Female | 0.422 | 0.020 | 0.473 | 0.029 |
| | [0.494] | (0.873) | [0.500] | (0.188) |
| Height (cm) | 162.064 | 0.614 | 161.460 | 0.426 |
| | [7.480] | (0.564) | [7.265] | (0.562) |
| Weight (kg) | 52.520 | 0.909 | 52.438 | 0.039 |
| | [10.443] | (0.580) | [10.618] | (0.844) |
| *C. Family background* | | | | |
| Mother's age | 43.772 | 0.164 | 43.875 | -0.099 |
| | [4.042] | (0.688) | [4.911] | (0.812) |
| Father's age | 46.290 | 0.194 | 46.451 | -0.252 |
| | [3.681] | (0.655) | [4.266] | (0.562) |
| Mother college or above | 0.566 | 0.092 | 0.536 | 0.103 |
| | [0.496] | (0.212) | [0.501] | (0.312) |
| Father college or above | 0.615 | 0.052 | 0.609 | 0.103 |
| | [0.487] | (0.524) | [0.499] | (0.656) |
| Birth order | 1.634 | -0.081 | 1.679 | -0.152 |
| | [0.657] | (0.223) | [0.666] | (0.156) |
| *D. Cognitive & Non-cognitive skills* | | | | |
| Math score (scale 0-5) | 2.721 | -0.061 | 2.469 | 0.026 |
| | [1.577] | (0.839) | [1.547] | (0.875) |
| Selfesteem (scale 1-4) | 3.164 | -0.035 | 3.184 | -0.067 |
| | [0.495] | (0.235) | [0.505] | (0.031) |
| Big 5: outgoing (scale 1-5) | 3.598 | -0.057 | 3.614 | -0.133 |
| | [1.006] | (0.712) | [1.044] | (0.531) |
| Big 5: agreeableness (scale 1-5) | 3.322 | 0.058 | 3.397 | 0.007 |
| | [0.746] | (0.270) | [0.711] | (0.844) |
| Big 5: conscientiousness (scale 1-5) | 3.408 | 0.002 | 3.455 | -0.059 |
| | [0.875] | (0.972) | [0.889] | (0.531) |
| Big 5: stability (scale 1-5) | 3.016 | -0.053 | 3.067 | -0.062 |
| | [0.825] | (0.449) | [0.846] | (0.688) |
| Big 5: openness (scale 1-5) | 3.544 | 0.013 | 3.578 | -0.112 |
| | [0.872] | (0.880) | [0.882] | (0.344) |

Notes: This table presents descriptive statistics and balance test results from the baseline survey. Column (1) includes all 12 schools, while Column (2) focuses on the 6 coed schools. The "Control" column reports the mean and standard deviation (in brackets) for the control schools, while the "Treated" column shows the difference in means relative to the control schools, with p-values in parenthesis. The p-values were calculated using the wild cluster bootstrap method (5,000 repetitions), clustered at the school level. Math scores reflect the number of correct answers out of five math questions. Self-esteem is the average score of 10 items from the Rosenberg Self-Esteem Scale (4-point Likert scale). Big 5 Personality traits are based on the Ten Item Personality Inventory (TIPI) using a 5-point Likert scale.

schools is not significant at the 10% level. Likewise, in column (1), the average number of friends of students in the control schools is 8.856, which is comparable and not significantly different from that in the treatment schools. The patterns are similar for 6 co-ed schools.

In Panels B and C, we show the balance test results for students' gender, height, and weight, as well as for their family background. We confirm no significant differences between control and treatments schools in terms of these background variables at the 10% level. In Panel D, we compare students' cognitive skills using math test and non-cognitive skills using Big 5 personalities and self-esteem. No significant differences were found, except for self-esteem in the sample of 6 coed schools.

Overall, the findings in Table 1 suggest that the treatment and control groups are largely comparable prior to the intervention in terms of individual characteristics and key outcome variables of interest.

# 3 Results

In this section, we examine the impacts of the PBL program on the giving behavior of students in the dictator game and the homophilous behavior of friendship formation. For causal inferences on the effects of the PBL program, we use the following difference-in-difference regression with controlling individual characteristics and school and time fixed effects.

$$\mathrm{Y}_{ijst} = \beta_0 + \beta_1 \mathrm{PBL}_{st} + \beta_2 X_{it} + \gamma_s + \delta_t + \varepsilon_{ijst}, \tag{1}$$

where $Y_{ijst}$ represents the outcome of interest for student $i$ and their schoolmate $j$ in school $s$ at time $t$. For instance, in the context of the dictator game, $Y_{ijst}$ is the share given by student $i$ (the dictator) to student $j$ (the recipient) in school $s$ at time $t$. $\mathrm{PBL}_{st}$ is a treatment variable that equals 1 if the PBL program was implemented in school $s$ at time $t$. $X_{it}$ includes control variables for student $i$'s background characteristics at time $t$, such as gender, height, weight, family background, math scores, and non-cognitive skills. $\gamma_s$ denotes school fixed effects, accounting for any time-invariant characteristics of school $s$. $\delta_t$ represents time fixed effects that account for any time-specific effects common across all schools. $\varepsilon_{ijst}$ is an error term, clustered at the individual student level.

## 3.1 PBL Effects on Giving Behavior

We begin by presenting the overall effect of the PBL program on giving in dictator games. We find that the PBL program increases giving share by 5.8 percentage points in the sample of all 12 schools (6.7 percentage points in the sample of 6 co-ed schools), corresponding to a 23 percent increase (29 percent increase) compared to the average giving share in the baseline and control schools.[5]

One major finding from the experimental literature of other-regarding behavior (Hoffman et al., 1996; Leider et al., 2009; Goeree et al., 2010) is that donations in dictator games tend to decrease in social distance: the dictator tends to give more money to the recipient in a closer social relationship. Using the data of friendship networks, Goeree et al. (2010) further show that giving amounts follow a simple inverse distance law.

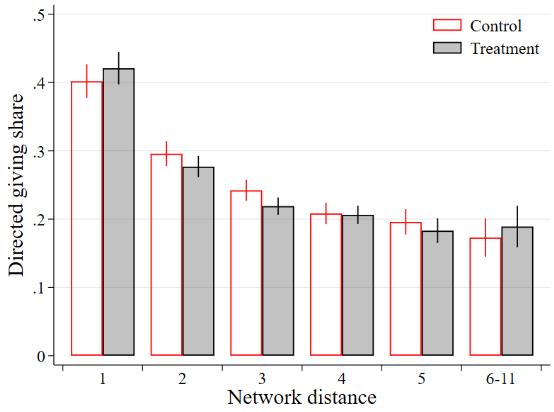
We first replicate this finding with our baseline data of dictator games and friendship survey. Figures 1(a) and 1(b) show the mean amount given for each (geodesic) distance ranging from 1 to 6 and over (we pooled the data for distances 6 and greater due to small samples) for each of the control schools and the treatment schools with all 12 schools and 6 co-ed schools, respectively.[6] As in Goeree et al. (2010), we find that offers decline with network distance: giving share is around 0.4 in distance 1, slightly below 0.3 in distance 2, and falls below 0.2 in distance 6 and over. As evident, there is no significant difference of giving share by distance between the control schools and the treatment schools in the baseline data.

We next turn to the same relationship between giving share and network distance in the endline study. Figures 1(c) and 1(d) present the endline results for all 12 schools and for 6 co-ed schools, respectively. We compute the mean giving share (with 95% confidence intervals) by network distance with the endline data of dictator games and friendship survey.

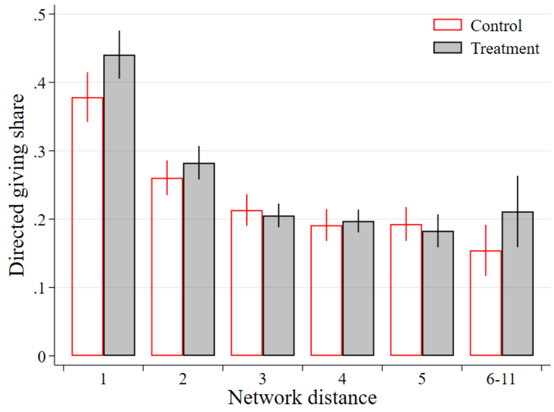
In contrast to the baseline patterns, we observe higher giving shares for each distance greater than one in the treatment schools than those of the control schools. For instance, the giving share to a recipient of distance 2 (i.e., a friend's friend) in the treatment schools is higher by about 6 percentage points than that of the control schools for all 12 schools as well as for the 6 co-ed schools. Such a significant gap in giving share remains to be present for more distantly

[5] In Appendix D.1, we show the difference-in-differences regression results for the PBL effect on giving share.

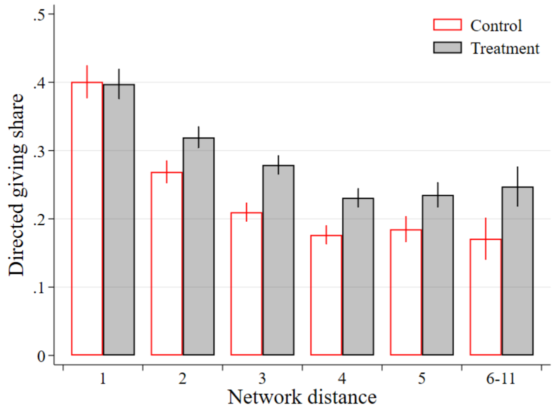
[6] Geodesic distance is the shortest path between two students in a network. In the baseline data, the distribution of distances is as follows: 12.2% for distance 1, 22.0% for distance 2, 27.1% for distance 3, 21.0% for distance 4, 10.9% for distance 5, 5.8% for distances 6-11, and 1.0% for undefined distances.



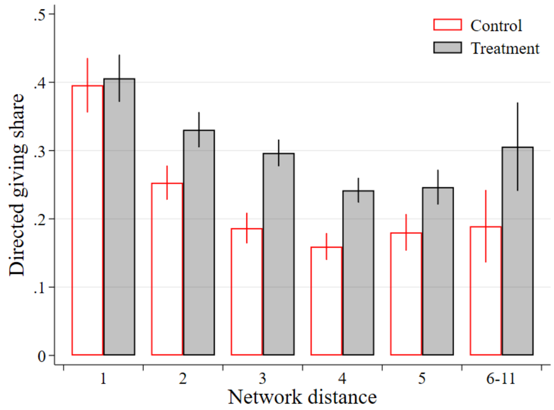

(a) Basline: All 12 schools



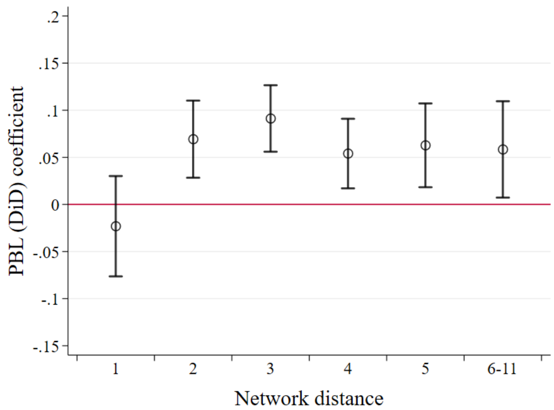

(b) Baseline: 6 co-ed schools



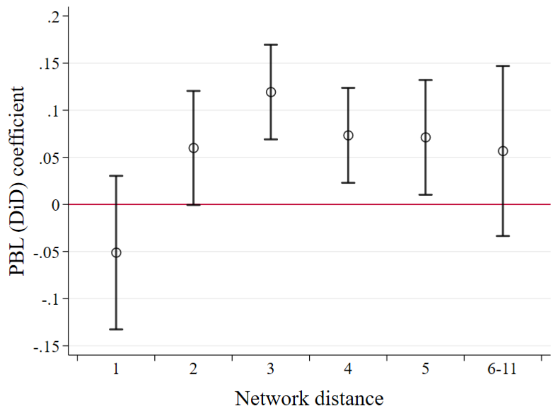

(c) Endline: All 12 schools




(d) Endline: 6 co-ed schools




(e) DiD: All 12 schools




(f) DiD: 6 co-ed schools

Notes: In panels (a) and (b), the horizonatal axis of the graph represents the baseline network distance, while the vertical axis represents the dictator giving share at the baseline. The bars represent the empirical mean of giving shares in control and treatment, respectively. The line shows the 95% confidence interval using standard errors clustered by individual level. Similarly, in panels (c) and (d), we show the corresponding figures with the endline data. Panels (e) and (f) show the PBL (difference in difference) regression coefficients using Eq (1) on giving share by network distance. The plot displays regression coefficients, with 95% confidence intervals indicated by the lines.

Figure 1: Giving Share by Network Distance and PBL Effects

connected recipients. On the other hand, no significant difference in giving shares is observed for distance one (direct friends) between treatment and control groups.

Figures 1(e) and 1(f) report the coefficient estimates on the PBL effects with 95% confidence interval by endline network distance, using Eq (1), for all 12 schools and 6 co-ed schools.[7] They confirm that the PBL effect is not significant for direct friends (distance one) in both all 12 schools and 6 co-ed schools. In both samples, for all distances greater or equal to two, we find a significant increase in giving share in the treatment schools at the 5% significance level, except for the case of distances greater than and equal to 6 in six co-ed schools (significant at the 10% level). The coefficients of PBL range from 0.054 to 0.089 (0.053 to 0.109), indicating a 26 to 36 (33 to 51) percent increase compared to the corresponding average giving share in the baseline and control schools.

### 3.2 PBL Effects on Friendship Homophily and Networks

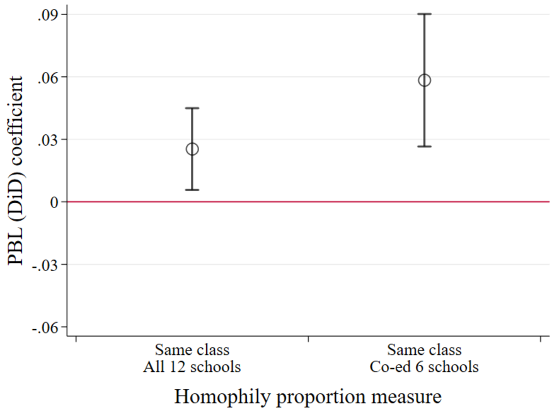
We examine the effects of the PBL program on network homophily. Because the PBL program was implemented at the classroom level, we investigate the PBL effects on within-class friendship connections compared to those between different classes in the sample of all 12 schools. We hypothesize that the PBL intervention increases the tendency to form friends in the same class. In addition, gender homophily is a widely observed pattern in friendship at school and in other social networks (McPherson et al., 2001; Shrum et al., 1988; Jackson et al., 2023). We thus consider the PBL effects on gender homophily with the sample of 6 coed-classroom schools.

We measure homophily of class and gender, respectively, with the proportion of same class friends and the proportion of same gender friends among all nominated friends.[8] In the baseline data of all 12 schools (6 co-ed schools), the proportion of same class friends is 57.1% (46.5%) in the control schools and 57.3% (50.5%) in the treatment schools. For gender homophily, in the baseline data of co-ed 6 schools, the proportion of same-gender friends is 94.8% in the control schools and 93.4% in the treatment schools.[9]

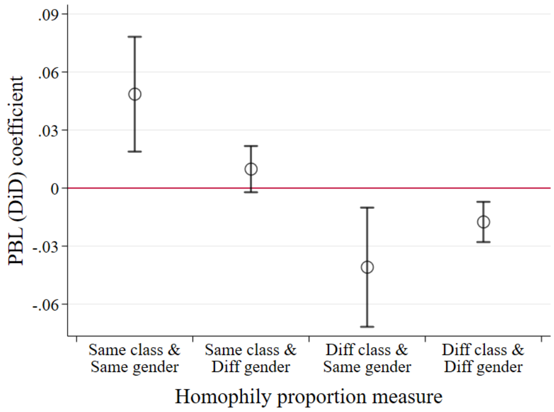
[7] The full regression results are reported in Table D.1 in Online Appendix. As a robustness check, we also present regression results using baseline network distance and report consistent PBL effects in Online Appendix B.2.

[8] Since the proportion measure depends on the number of friends they have, we show the distribution of the number of nominated friends in Appendix B.3. We find that PBL does not significantly change the number of nominated friends.

[9] Shrum et al. (1988) used a sample of students from grades 3-12 in the US and found around 82-85% gender homophily across different races. Jackson et al. (2023) reported around 75% gender homophily in a sample of Caltech undergraduates.




(a) Class




(b) Class and gender

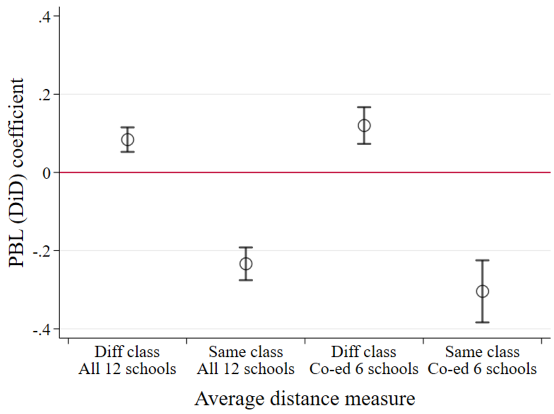
Notes: In Panel (a) and (b), the graphs show the PBL regression coefficients using Eq (1) on homophily measures with 95% confidence intervals, using standard errors clustered at the individual level. In Appendix B.1, we have baseline balance test results and show homophily measures are well-balanced in the baseline. We have a full regression table in Online Appendix D.2.

Figure 2: PBL Effects on Network Homophily

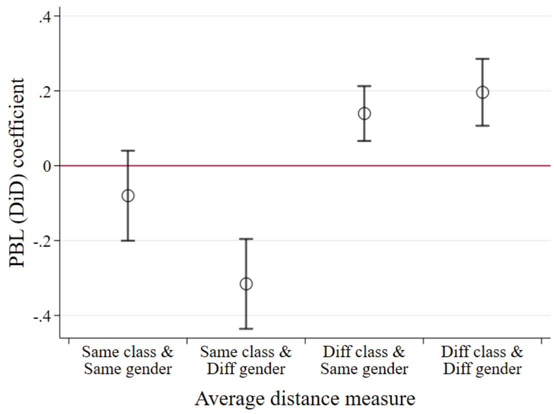
To estimate the PBL effects on these measures of network homophily, we run the same regressions as in Eq (1) in which the dependent variables are homophily proportions of interest. Figure 2 shows the coefficient estimates of the PBL effects across class homophily and gender homophily with 95% confidence intervals. In Appendix D.2, we report the regression table used for the coefficients plot.

Figure 2(a) shows that the PBL program significantly increases the proportion of same class friends by 0.025 in the sample of all 12 schools, which amounts to 4.4 percent increase from the proportion of same class friends in the baseline control schools. Similarly, the PBL program increases the proportion of same class friends by 0.058 in the sample of 6 co-ed schools. This amounts to 12.3 percent increase from that in the baseline control schools. Both coefficients are significant at the 5% level.

In Figure 2(b), we find that the PBL program increases the proportion of same class and same gender friends by 0.049 in the sample of 6 co-ed schools, which amounts to 11.1 percent increase relative to the baseline control proportion of same class and same gender friends (0.444). On the other hand, the PBL program decreases the proportion of same gender friends from different classes by 0.041, amounting 8.1 percent decrease relative to the corresponding proportion in the baseline control schools (0.504). It also decreases the proportion of different gender friends from different classes by 0.017, which corresponds to 54 percent reduction from the same proportion




(a) Class




(b) Class and gender

Notes: In Panel (a) and (b), the graphs show the PBL regression coefficients using Eq (1) on average distance with 95% confidence intervals, using standard errors clustered at the individual level. In Online Appendix B.1, we have baseline balance test results and show average distance measures are well-balanced in the baseline. We have a full regression table in Online Appendix D.3.

Figure 3: PBL Effect on Average Distance

in the baseline control schools (0.030). All these coefficients are significant at the 5% level.

These PBL effects on class and gender homophily in friendship connection have associated effects on social distance with indirectly connected students. To see such effects, we examine the effects of the PBL program on average distances between indirectly connected students in each homophily group. In computing average distance for each homophily group, we exclude directly connected friends (3.31%) and pairs of students who are not connected (0.21%). We use the same regression specification as in Eq (1).[10]

Figure 3(a) shows the PBL coefficient estimates on average distance with same class and different class in all 12 schools and in 6 co-ed schools. In the sample of all 12 schools, the PBL program reduces average distance to indirectly connected students in the same class by 0.234, corresponding to a 7.5 percent decrease from the control and baseline average distance (3.111), and increases it in different classes by 0.084, which is a 2.2 percent decrease from the control and baseline average distance (3.793). These patterns are consistent, and the size of the coefficients is comparable in the sample of 6 co-ed schools.

In Figure 3(b), we present the PBL effects on average distance across gender and class homophily in the sample of 6 co-ed schools. The PBL program significantly reduces average

[10]The regression results are reported in Appendix D.3. For robustness check, we include unconnected pairs by assigning a large number in the regression analysis and find a consistent result in Online Appendix B.4.

distance to indirectly connected, different gender students in the same class by 0.316, which amounts to a 7.6 percent decrease compared to that of the the baseline control schools (4.133). For peers in different classes, the PBL program increases average distance regardless of their gender.

We summarize the PBL effects on friendship homophily and networks. First, the PBL program fosters class and gender homophily in direct friendship connections. Second, it reduces average distances to indirectly connected peers in the same class, particularly to those of different gender, and increases average distance to peers in different classes regardless of their gender.

## 4 Inferring the PBL Effects on Costs of Friendship Formation

We have shown that the PBL program promotes giving to indirectly connected peer students, strengthens class and gender homophily in friendship, and reduces average distance among indirected connected students. In this section, we consider a network formation model enabling us to estimate the PBL effects on costs of making friends. Because the PBL intervention promotes in-class interactions among peer students, we hypothesize that the program lowers the costs of corresponding friendship connections. For the purpose of addressing this question, we follow the tradition of the economics of networks (e.g., Jackson and Wolinsky, 1996; Bala and Goyal, 2000; Currarini et al., 2009; Hsieh and Lee, 2016; Mele, 2017) in which friendship networks result from cost-benefit analysis of linking and equilibrium restrictions on individual behavior.[11]

We use the observed relation between giving share and social distance as a proxy to measure the benefits of link formation at the individual level. The inverse distance pattern of giving is then interpreted as a representation of flow benefits of linking, decayed over social distance.[12] Given the assumption that the benefits of making friends are represented by altruistic giving, our exercise focuses on the formation of altruistic friendships rather than opportunistic friendships in school. Previous studies (Blum, 1980; Eisenberg and Miller, 1987; Eisenberg et al., 2013) indicate that altruism is an important source of friendship formation and prosocial behavior. We believe that altruistic motivations (e.g., helping other students without the consideration of

[11]This cost-benefit comparison approach is particularly useful for explaining why certain properties emerge in empirical networks (e.g. Jackson and Rogers, 2007; Shin, 2021).

[12]It is commonly assumed in economics models of network formation (e.g., Jackson and Wolinsky, 1996; Bala and Goyal, 2000).

rewards) are one important source of making friends.

## 4.1 A Conceptual Framework

Suppose there are $N$ students in a school. The friendship network is represented by an $N \times N$ adjacency matrix $g$. $g_{ij}$ represents the component at row $i$ and column $j$ of the adjacency matrix. Specifically, the entry $g_{ij} = 1$ if individual $i$ nominates individual $j$ as a friend, and $g_{ij} = 0$ otherwise. We consider a directed network $g$ and $dist_{ij}(g)$ represents the geodesic distance from $i$ to $j$ given a directed network $g$. For the notation, $g_{-ij}$ refers to the adjacency matrix with $g_{ij} = 0$, while keeping everything else in $g$ the same. Similarly, $g_{+ij}$ refers to the adjacency matrix with $g_{ij} = 1$, while every other component remains the same as in $g$.

We first define individual $i$'s utility from $j$ in directed network $g$ as follows.

$$u_{ij}(g) = \delta \times dist_{ij}(g)^{\gamma} - c \times \mathbf{1}\{g_{ij} = 1\} \tag{2}$$

The first part in Eq (2) corresponds to the flow benefit from either direct connection (i.e., friendship) or indirect connection from $i$ to $j$. $\delta > 0$ measures the value for friends ($dist_{ij}(g) = 1$) and $\gamma < 0$ captures exponential decay of flow benefit as the network distance increases.[13] The second part in Eq (2) represents the cost of making a friend with individual $j$. While the benefit from $j$ comes from direct or indirect connection, the linking cost applies only to direct connection ($g_{ij} = 1$).

Individual $i$'s utility in network $g$ is then defined as the sum of utility from all other individuals in the network as $\Pi^i(g)$:

$$\Pi^i(g) = \sum_{j \in N \setminus \{i\}} u_{ij}(g) = \underbrace{\sum_{j \in N \setminus \{i\}} \delta \times dist_{ij}(g)^{\gamma}}_{= B^i(g)} - \underbrace{\sum_{j \in N \setminus \{i\}} c \times \mathbf{1}\{g_{ij} = 1\}}_{= C^i(g)} \tag{3}$$

where $B^i(g)$ denotes the sum of the benefits from network $g$ and $C^i(g)$ the sum of linking costs in network $g$.

For those who are not directly connected ($j \in \{k \in N | g_{ik} = 0\}$), individual $i$ forms a link to $j$ if $\Pi^i(g_{+ij}) > \Pi^i(g)$. For those who are directly connected ($j \in \{k \in N | g_{ik} = 1\}$), individual $i$

[13] This parametric functional form is also used in Goeree et al. (2010).

removes the link to $j$ if $\Pi^i(g_{-ij}) > \Pi^i(g)$. In Nash equilibrium network $g$, every individual has no incentive to deviate from their linking decisions.

### 4.2 Estimation Method

Our estimation exercises proceed with the following two steps for each of the baseline and endline data in the control schools and the treatment schools. First, we estimate $(\delta, \gamma)$ for the flow benefit function of friendship connection.[14] Second, we estimate the homophily-dependent distributions of the costs of making a friend of the same or different gender in the same class or in a different class for the sample of co-ed 6 schools (only in the same or different class for the sample of all 12 schools). We assume that the cost of making a friend in homophily type $\tau$, $c_\tau$, follows Gamma distribution with shape parameter $\alpha_\tau$ and scale parameter $\beta_\tau$. A random cost of linking to a student with type $\tau$ is drawn independently and identically from the Gamma distribution with parameters $(\alpha_\tau, \beta_\tau)$. In the method described below, we estimate the homophily-dependent distributions of linking costs, $(\alpha_\tau, \beta_\tau)$, that minimize the probability of deviating from the observed network.

Specifically, for the observed network $g$ for a school, we compute the probability that individual $i$ can deviate from their linking decisions in the observed network, denoted by $P_i(g, \{\alpha_\tau, \beta_\tau\}_\tau)$. To do that, for each friend $j$ with type $\tau$ ($j \in \{k|g_{ik} = 1\}$), the probability of deleting the link to $j$ is given by $Pr\{B^i(g) - B^i(g_{-ij}) < c_\tau\}$. Similarly, for each $j$ with type $\tau$ who is not a friend of $i$ ($j \in \{k|g_{ik} = 0\}$), the probability of forming a link to $j$ is given by $Pr\{B^i(g_{+ij}) - B^i(g) > c_\tau\}$.

After computing all the deviation probabilities of $i$ across all $j \in N \setminus \{i\}$, we construct individual $i$'s average deviation probability from network $g$ as $P_i(g, \{\alpha_\tau, \beta_\tau\}_\tau)$.[15] Based on these individual average deviation probabilities, we construct the natural logarithm of individual deviation probability from the observed network $g_s$ for each school $s$ with student size $N_s$ and

[14] In Appendix C.1, we report the estimated parameters $\delta$ and $\gamma$, using the following regression specification:

$$\text{Share}_{ijt} = \delta \times dist_{ijt}^{\gamma} + \varepsilon_{ijt} \tag{4}$$

[15] As an objective function, we use the individual average deviation likelihood instead of the deviation probability of each cell in the adjacency matrix $g_{ij}$ because the latter overrepresents schools with larger student populations. For example, if School A has 100 students, there are $100^2$ cells in the adjacency matrix, whereas School B with 200 students would have $200^2$ cells, potentially overrepresenting the likelihood for School B.

estimate $\{\alpha_\tau, \beta_\tau\}_\tau$ to minimize the sum of these probabilities across schools.

$$\min_{\{\alpha_\tau,\beta_\tau\}_\tau} \sum_s \sum_{i \in N_s} \ln\left(P_i(g_s, \{\alpha_\tau, \beta_\tau\}_\tau)\right). \tag{5}$$

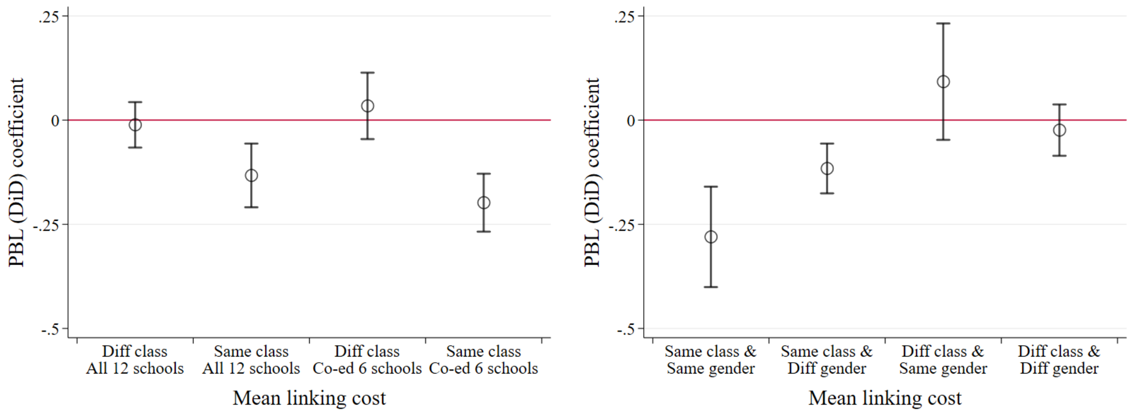
In Appendix C.2, we report the estimated parameters across class and gender homophily groups for each of the baseline and endline data in the control schools and the treatment schools. The mean cost of making friends varies depending on the homophily groups, with same class and same gender having the lowest estimated cost, followed by different class and same gender, then same class and different gender, and finally, different class and different gender having the highest estimated cost.

### 4.3 PBL Effects on Costs of Friendship Formation

Using the estimated cost distributions, we compute the mean linking cost for each homophily type for each of the baseline and endline data in the control schools and the treatment schools. We then estimate the PBL effect on linking cost by computing a difference-in-differences change in mean linking cost for each homophily type. For comparison across different homophily types, we normalize the DiD cost estimate level by the average linking cost of the control schools in the baseline for each homophily type.

Figure 4(a) shows the PBL coefficient estimates on mean linking cost with respect to class homophily for all 12 schools and for co-ed 6 schools. For peers in the same class, the PBL program significantly reduces the mean linking cost by 16% in the sample of all 12 schools. Similarly, there is a 22% reduction in the corresponding mean linking cost in the sample of co-ed 6 schools. On the other hand, the PBL program does not change significantly the linking cost to peers in a different class. This reduction in the cost of linking to students in the same class explains the increase in class homophily in friendship as shown in Figure 2(a) even though PBL does not change the benefits of linking to them (i.e., giving share in distance 1) as in Figure 1.

Figure 4(b) presents the PBL effects on mean linking cost across class and gender homophily in 6 co-ed schools. For students of different gender in the same class, there is around 12% decrease in the mean linking cost. For peers of same gender in the same class, there is even a larger reduction in the mean linking cost, a 26% decrease. These effects are statistically significant at the 5% level. On the other hand, we do not find any significant change in the




(a) Class

(b) Class and gender

Notes: Panel (a) shows the coefficients of the PBL intervention after running a difference-in-difference regression based on all 12 schools. Panel (b) shows the coefficients of the PBL intervention using co-ed 6 schools. In Online Appendix C.2, we have estimated parameters. The dots represent the estimated coefficient values. The bars represent 95% confidence intervals constructed using 1,000 bootstrap estimations. In Online Appendix D.4, we have a detailed regression result.

Figure 4: PBL Effect on Normalized Linking Cost

linking cost to students in a different class, regardless of their gender. The reduction in the cost of linking to students of same gender in the same class explains the increase in same class and same gender homophily in friendship as shown in Figure 2(b).

One puzzling aspect of the findings is that although the cost of linking to students of different gender in the same class significantly decreases, we do not observe any significant increase in the corresponding homophily in friendship (see Figure 2(b)). This can be explained by the finding that the PBL program reduces average distance to indirectly connected students of different gender in the same class (see Figure 3(b)), which results in the increased benefits from those indirectly connected students. It would then weaken an incentive to form a direct link to peers of different gender in the same class.

## 5 Conclusion

Exploiting the introduction of the project-based learning program for one semester to 6 middle schools in South Korea, we evaluated the effects of a student-centered teaching pedagogy program on prosocial giving and friendship networks among students. We found that the PBL program enhances prosocial giving to indirectly connected peers, fosters class and gender friendship homophily, and reduces average distance in friendship networks.

Because our endline study was implemented right after the intervention, we are unable to examine the long-run consequences of students being exposed to student-centered teaching practices. This would be an intriguing avenue for further research. In addition, in our study, the intervention of the PBL program lasted only for one semester in the treatment schools and we found some significant changes in prosocial giving and friendship networks. Evaluating the effects of a longer-lasting pedagogical change would be another important topic for future research. Despite these limitations of the intervention and the study design, our findings provide novel micro-level insights to the connection between teaching practices and social capital (Dewey, 1994; Algan et al., 2013).

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