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Haste Makes No Waste: Peer Effects of a Speed Competition on Math Score

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Haste Makes No Waste: Peer Effects of a Speed Competition on Math Score

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This study investigates the peer effects of a speed competition on educational outcomes in self-learning at the right level program for primary school students in Bangladesh. Specifically, we examine the peer effects of speed of problem-solving (time) on math scores (score) using students' daily progress record over eight months. The unique setting of the program allows to address the identification challenges such as the direction of causality and the reflection problem. The results show a significant peer effect of classmates' speed on improving one's own time. Furthermore, we find that the faster the classmates of similar abilities, the higher one's own math scores. This suggests that the speed competition among students with similar abilities leads to improving their learning quality without negatively affecting others. These findings will contribute to shaping an effective learning environment by incorporating positive peer pressure on learning quality.
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Peer effects, both positive and negative, in educational settings have been of great interest to educators as well as parents. There is an extensive literature focusing on peer effects through learning outcomes such as test scores and grades (Hoxby, 2000; Sacerdote, 2001; Zimmerman, 2003; Kang, 2007; Figlio, 2007; Ding and Lehrer, 2007; Carrell, Fullerton and West, 2009; Ammermueller and Pischke, 2009; Carrell and Hoekstra, 2010; Duflo, Dupas and Kremer, 2011; Arcidiacono et al., 2012; Burke and Sass, 2013; Angrist, 2014; Lu and Anderson, 2015; Feld and Zölitz, 2017).[1] However, few studies have focused on the peer effect through speed competitions, and no research has been conducted on its effect on learning outcomes such as scores and grades. Problem-solving speed in an educational setting is a real-time signal of competitiveness, and we frequently see a "racing" environment in a high-stake screening mechanism in higher-quality educational institutions. However, in a learning environment, speed competitions among peers could have either positive or negative impacts on one's own learning outcomes. For example, speed competitions among peers may work as an incentive to invest more effort and maintain high motivation to achieve higher learning outcomes. On the other hand, it could have negative impacts by inducing careless errors due to excessive time pressure and anxiety.[2]

In fact, peer pressure in general works in a complicated manner, either to enhance a positive norm or hide effort (Bursztyn and Jensen, 2015; Bursztyn, Egorov and Jensen, 2019). Furthermore, the literature on competition orientation by gender suggests that there may be an opposite effect across gender: competition might motivate males to perform better but could discourage females (Gneezy and Rustichini, 2004; Niederle and Vesterlund, 2007; Gneezy, Leonard and List, 2009; Niederle and Vesterlund, 2010, 2011; Boschini, Muren and Persson, 2012; Booth and Nolen, 2012; Balafoutas, Kerschbamer and Sutter, 2012; Buser, Niederle and Oosterbeek, 2014; Lee, Niederle and Kang, 2014; Dreber, von Essen and Ranehill, 2014; Bursztyn, Fujiwara and Pallais, 2017; Niederle, 2017; Shurchkov and Eckel, 2018; Yagasaki and Nakamuro, 2018; Yagasaki, 2019; Gneezy, Leonard and List, 2009; Ito, Kubota and Ohtake, 2020). As our sample is relatively young, primary school third- and fourth-graders, gender norms may or may not have any influence on their attitudes toward competition. In short, this is open to empirical examination.

In this study, we examine the peer effect of speed competitions in an educa-

[1] See Epple and Romano (2011) for a review of the peer effects literature.

[2] Outside of the education literature, there exist some studies that examine the peer effect where the speed itself is an outcome of interest. For example, for cash registers or fish processing, speed is used as a signal of productivity because the quality can be easily monitored and there exists clear punishment for low-quality services or production in these settings (Mas and Moretti, 2009; Park, 2019). Mas and Moretti (2009) shows that others are stimulated and their productivity increases in the presence of a high-productivity person. The author concludes that "social pressure can partially internalize free-riding externalities that are built into many workplaces." Park (2019) finds that workers higher on the conscientiousness scale exhibit less productivity decline even if they are next to their friends. This suggests the peer effect on speed may vary depending on an individual's personality, which may be applicable to a student's non-cognitive ability, such as self-esteem. Sports economics also have examined peer effects through speed competitions, such as Yamane and Hayashi (2015).

tional context. Using the unique setting of an individualized self-learning program conducted among the primary school goers in Bangladesh, we focus on the potential compatibility or trade-off between speed and learning quality. Our study leverages a randomized control trial (RCT) design that investigates the effectiveness of a globally popular method of self-learning at the right level (developed by the Kumon Institute of Education Co., Ltd.) on improving both the cognitive and non-cognitive abilities of pupils (Sawada et al., 2019).[3] One of the unique features of a Kumon session is that one can observe who finishes the daily assignment faster than oneself, as students are individually working on their own level of worksheets and turn them in on completion to the graders in the front row of the classroom.[4] In this setting, we can examine the peer effect of problem-solving speed on a students' learning outcomes on two dimensions: the speed of problem-solving (time) itself and the math score (score). We hypothesize that the students working on problem-solving in the same classroom might have been competing on speed, which through visible peer pressure may affect the learning outcome (measured through the score) negatively or positively. The problem-solving speed is the time to submission, which is a highly visible behavior in the classroom. Therefore, the faster students' speed works as an exogenous shock to the slower students because they do not know the peers' submission timing until someone stands up and walks toward the front row. Furthermore, the faster student's behavior unidirectionally affects the slower students and not the other way around because of the time flow. This set-up helps in the causal identification of the effect of a faster peer's behavior on the rest of the classmates who are still working on the assignments. This set-up also allows us to avoid Manski's reflection problem (Manski, 1993).[5] For control variables, we use student fixed effects, which control for all the time-invariant observable and unobservable characteristics as well as day fixed effects.

Based on the preliminary results, we find positive peer effects in a speed competition on the problem-solving time for everyone in a class, whether they are faster or slower. Furthermore, we find positive peer effects of a speed competition on scores for students who are similar in abilities. Specifically, the students who are faster than the median of a class score higher when the fastest peer finishes earlier. On the other hand, the scores of the students who are slower than the median of a class are not affected by the speed of the fastest peer. Rather, their scores improve when the median speed of the class becomes faster. The competition is most likely to occur sequentially in time, meaning that the faster students are competing against the fastest peer and slower students are competing only

[3]The intervention is eight-month long daily sessions of the Kumon method of learning (hereafter Kumon). Sawada et al. (2019) finds substantial improvement in cognitive ability measured by mathematics test scores and catch-up effects on non-cognitive ability measured by a pupil self-esteem measure; these are consistent with a longer-term impact found in take-up rates and scores on a national-level primary school completion exam.

[4]Ten worksheets are the daily assignment during the 30 minutes of a Kumon session.

[5]Appendix C discusses the reflection problem from both the theoretical and empirical viewpoints.

against the peers slightly faster than them but not the fastest.

The remainder of the paper is organized as follows. In Section 2, we outline the setting of the data collection, followed by a description of the data. Section 3 presents the empirical approach, followed by results in Section 4. Section 5 concludes the paper.

I. Setting

The RCT study included 34 randomly selected BRAC primary schools consisting of third- and fourth-graders, of which 17 schools were offered the Kumon intervention (Sawada et al., 2019). The intervention consisted of a 30-minute session on Kumon study prior to the beginning of the regular lessons. The intervention lasted for eight months, from August 2015 to April 2016. We studied the detailed daily record data of Kumon sessions in these 17 intervention schools.[6]

For the intervention schools, the Kumon Institute of Education Co., Ltd provided an intervention package consisting of mathematics materials and an instructor's manual with sheets for the BRAC teachers.[7] The full material set consists of i) mathematics worksheets with questions of various levels of difficulty (Figure 1), and ii) a notebook to record everyday progress, including the level of the worksheet that a student worked on, time spent until submission, number of repetitions required before achieving a full score on the worksheet, and number of worksheets that they finally completed (Figure 2).[8] The starting level was adjusted to the students' ability based on the initial diagnostic test regardless of their age or grade, so that students could solve all problems correctly by themselves in a certain time. Each student solved a total of ten worksheets from sheets No. 1 to No. 10 during the Kumon session each day. Once they completed the ten worksheets, they brought them for grading.[9] The session ended when students either achieved a full score, or continued trying till the end of the designated time frame to correct wrong answers until they achieved a full score.

During the administration of the Kumon program, the BPS teachers did not provide lectures; they simply observed students' progress. They only intervened when students were stuck on the same worksheet or could not find the right answer after many attempts. They adjusted the level of worksheets in such cases. The BPS teachers also provided guidance when advanced students proceeded to entirely new materials beyond the regular curriculum. The marking assistants

[6]For further details of the experimental design, please refer to Sawada et al. (2019).

[7]BRAC field staff were assigned to assist and follow up on BPS teachers. Three days of preparatory training for BPS teachers and field staff were held prior to launching the program to familiarize teachers with the concepts and procedures of the learning method. In addition, three follow-up training sessions were held during the implementation period. Two marking assistants were provided for each class to support the grading and recording of worksheets during the Kumon sessions. BPS teachers monitored students and determined the level of worksheets for students to work on.

[8]All the materials, including numbers, were provided in the Bengali language, which is the medium of instruction for BPS teachers and students.

[9]There is some variation in the number of sheets per day as shown in Figure A1. We discuss how we address these observations in Footnote 10.

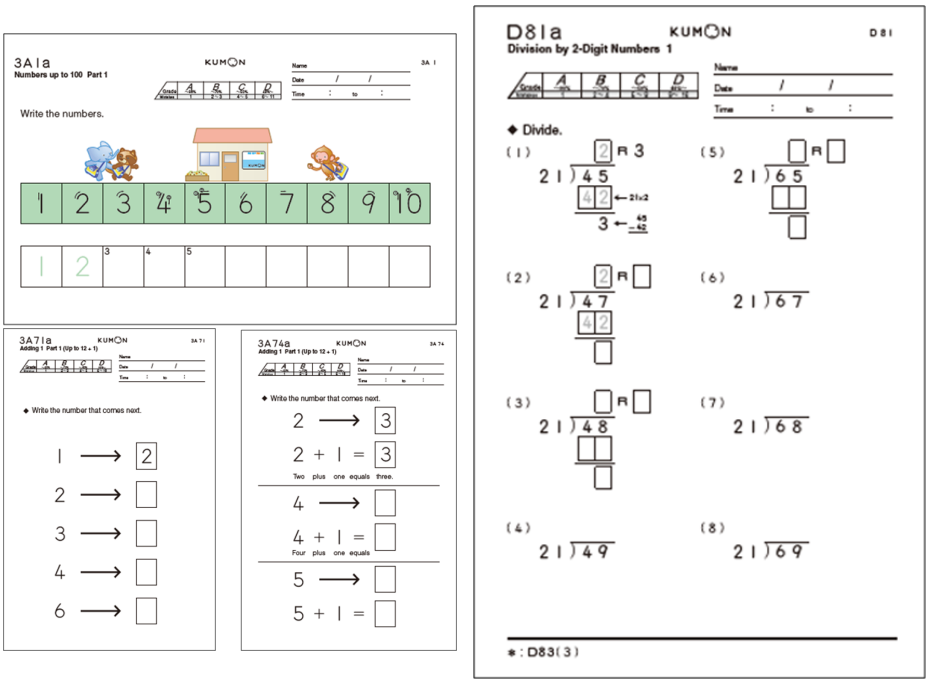

Figure 1. An Example of Worksheets

helped the teachers with grading and recording the worksheets.

II. Data

In this study, we use the daily record of the time students spent until submitting ten worksheets and the marks indicating the repetitions required before achieving a full score on the worksheet. We focus on the first three months of daily records because the number of worksheets solved by students during the Kumon session is universally ten during this time.[10]

Table 1 shows the descriptive statistics of the variables used in the estimation. Panel A highlights some of the key demographics of the sample, where the sample size is 335 students. Panel B summarizes the descriptive statistics of the daily records. The average time is about 12 minutes with a 5 minute standard deviation. This is the time to submit the ten worksheets to the marking assistants, so students may spend additional time resolving the problem if they did not score full marks. The likelihood of obtaining a full score is above 75 percent even on the last three worksheets when students tend to get more challenging, which we

[10]See Figure A1 in Appendix A. From the fourth month until the end, there were some variations in the number of worksheets solved per student. We excluded these five months of records from this analysis.

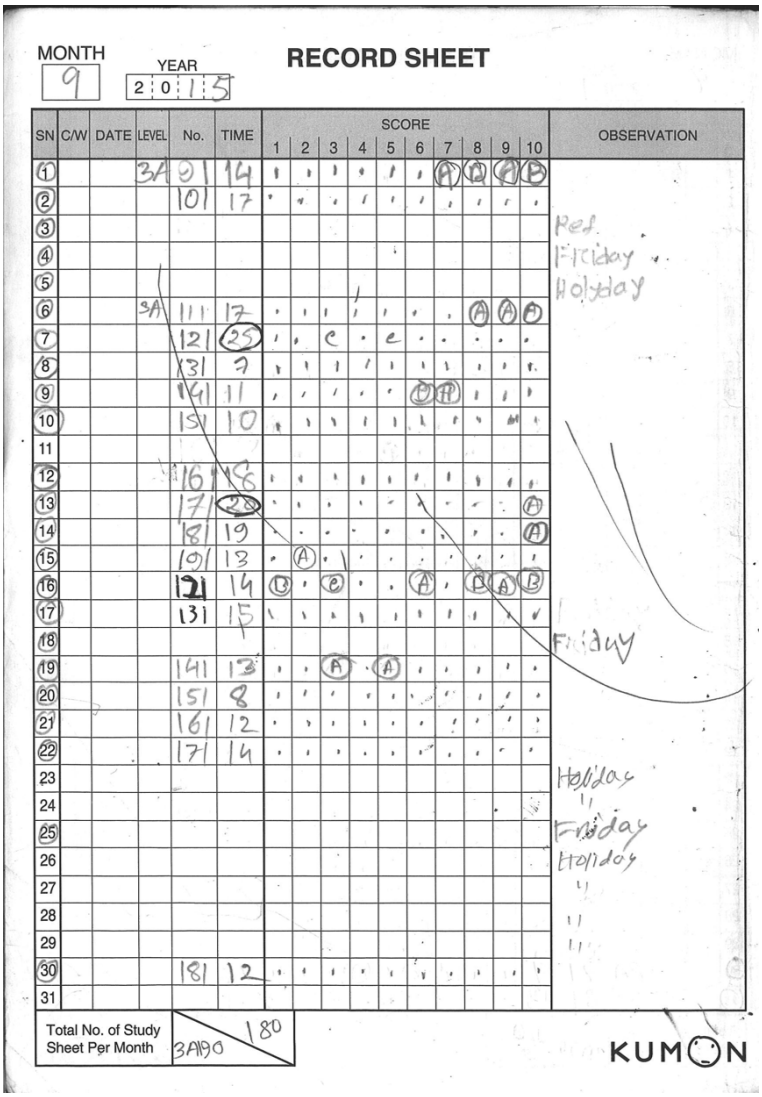

Figure 2. An Example of Score Book

discuss in detail in Figure 3. The high frequency of scoring full marks is simply because the worksheets are designed so that the students are learning the materials that are just right for them, as discussed above.

Table 1— Summary Statistics

	Mean	Standard Deviation	25%-tile	Median	75%-tile	N
Panel A: Individual-level Characteristics						
Fraction of Girls	0.3821					335
Fraction of Grade 4[a]	0.4060					335
Initial Sheet Number[b]	638.3015	161.9591	481	681	681	335
Total Days of Attendance at Kumon Session						
From August 2015 to April 2016	36.5313	7.3475	33	38	41	335
From August 2015 to October 2015	131.3642	25.5397	123	138	149	335
Panel B: Daily-level Characteristics						
Time for Solving 10 Work Sheets	11.7175	5.0014	8	11	14	12112
Total Score of 10 Sheets (Full Score = 1000)[c]	985.3160	48.8802	995	1000	1000	12234
Obtaining Full Score (Full Score = 1)						
in Sheet No. 1 to 3	0.8442	0.3627	1	1	1	12234
in Sheet No. 4 to 7	0.7866	0.4097	1	1	1	12234
in Sheet No. 8 to 10	0.7869	0.4095	1	1	1	12234

Notes. Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.
a. The sample contains grade-3 students and grade-4 students.
b. The level is converted into numbers. See the table in Appendix.
c. The score is converted into numbers. See the table in Appendix.

Figure 3 shows the number of worksheets on the X-axis and the score of each worksheet on the Y-axis. The above line is the average score among the students who solve problems faster than the median, and the line below is that of slower students. Both lines are declining toward the right, indicating that the score falls as a student solves the 8-10th worksheets. According to Kumon, the contents of the worksheets become challenging toward the end of the ten-worksheet set. This is because the latter worksheets serve as a quiz that examine students' overall understanding of the subject learned on that day.[11] In the results section, we review the speed competition's ability to maintain high motivation among students to obtain full scores even toward the end.

III. Empirical Strategy

We consider the following empirical model:

$$y_{ids} = \alpha + \beta m_{ds} + \boldsymbol{x}_{id}^T \boldsymbol{\delta} + \eta_i + \nu_d + \varepsilon_{ids}, \tag{1}$$

where y_{ids} is the outcome variable, either time or score of a student i on day d in school s. When the time is an outcome, we use the time a student i spends to

[11] If the subject learned addition and subtraction that day, the numbers to be added/subtracted become larger and complicate the calculations; the case is similar for multiplication and division. Furthermore, there are fewer hints but more questions that students have to answer and independently solve without any hints.

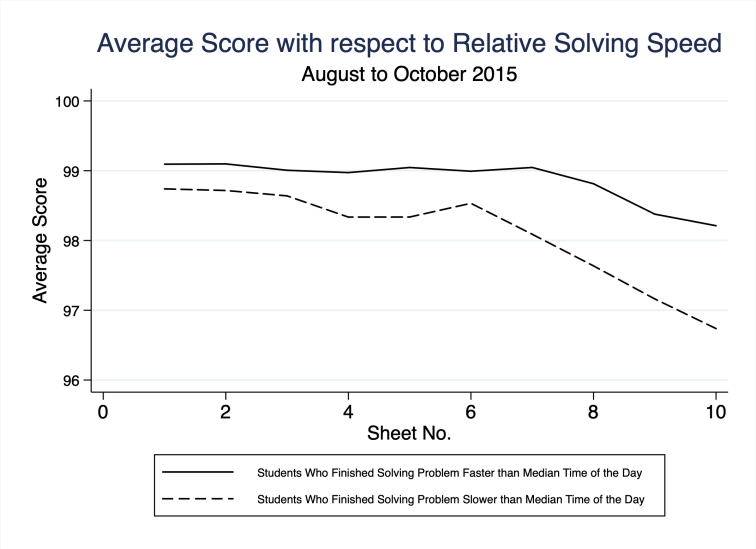

Figure 3. The Average Score of 10 Sheets Which Students Solved in a Day

solve ten worksheets and submit them to the marking assistants. For the score as an outcome, we use the dummy of obtaining a full score in the worksheets on day d. For more detailed analysis we examine the first and last three worksheets separately. The peer effect proxy variable, m_{ds}, takes either the fastest, 25%-tile, median or 75%-tile time of classmate(s) for solving ten worksheets on day d in school s. $\boldsymbol{x}_{id}$ is time-varying controls of student i on day d, η_i is the fixed effect of student i, and ε_{ids} is an error term.[12] We estimate the model using OLS, while clustering the standard errors at the student level. In this model specification, we have two major identification challenges. First is the direction of causality and second is the Manski's reflection problem.

First, in the Kumon session at BPSs, we can say that there is a clear direction of causality in terms of the time of problem-solving from students who finish earlier to those who finish later owing to the setting. The time taken by a peer to submit the worksheet is an exogenous shock to other classmates because they do not know their peers' speed until they see someone submit their worksheets. In other words, only at this point, do students learn that the peer is faster than them. During the Kumon session in the classroom, students are sitting in order from front to back in three to four lines with spaces on the side, so that each student can focus on their own assignment and not look around or chat with friends during the 30 minutes session.[13] Each student is looking down on the worksheet, and therefore,

[12]Note that these students' fixed effects also control the schools' fixed effects, because each student is enrolled in only one school.

[13]Students of BPSs sit in a circle for the regular curriculum and are able to see each other while answering questions from the teacher, who is standing in front of the blackboard. Kumon session's

the timing when a classmate finishes his or her work early can be seen as a sudden shock (Figure 4). The behavior of worksheet submission to the marking assistants in the front row of the classroom is highly noticeable to everyone. We exploit this property for the identification strategy.

Figure 4. Classroom during Kumon Session

Another identification challenge for investigating the peer effect of time on a student's performance (time and score) is the reflection problem discussed by Manski (1993). This is a common problem in peer effect or social interaction estimations. If we use the non-mean value of a variable, such as the median, we can mechanically avoid such identification issues.[14] Using the fastest time or a median classmate's time also fits better in our research context. Some solve the ten sheets much slower than others and the class size is not large (i.e., about 30 students per class). Therefore, the mean is easily affected by these outliers. Furthermore, it is less likely for students to know the average time, but rather likely that they recognize how many students have finished before them. From these viewpoints, using the fastest or faster student's time appear justifiable not only because of a mechanical reason for avoiding the reflection problem, but also to better fit the context.

seating is unique to this intervention.

[14]Appendix C discusses this problem rigorously.

IV. Results

Table 2— Peer Effect on Time for Solving 10 Sheets

	Dependent Variable: Time for Solving 10 Sheets											
	All Students				Faster Students than Median				Slower Students than Median			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Effect of the Fastest Student's Time												
Fastest Student's Time of the Day	0.8377***	0.7985***	0.5247***	0.4757***	0.7848***	0.7688***	0.5337***	0.5221***	0.7923***	0.7600***	0.4273***	0.3480***
	(0.0381)	(0.0398)	(0.0361)	(0.0394)	(0.0219)	(0.0235)	(0.0201)	(0.0201)	(0.0518)	(0.0526)	(0.0584)	(0.0670)
Level of Work Sheets		0.0029***	0.0061***	0.0129***		0.0011***	0.0035***	0.0029***		0.0027***	0.0069***	0.0148***
		(0.0005)	(0.0007)	(0.0017)		(0.0003)	(0.0003)	(0.0008)		(0.0006)	(0.0010)	(0.0027)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10944	10944	10944	10944	5777	5777	5777	5777	5167	5167	5167	5167
Panel B: Effect of the Median Time of the Day												
Median Time of the Day									1.1075***	1.0944***	1.0574***	1.0529***
									(0.0292)	(0.0296)	(0.0330)	(0.0369)
Level of Work Sheets										0.0009	0.0012	0.0098***
										(0.0006)	(0.0008)	(0.0022)
Individual Fixed Effect											x	x
Day Fixed Effect												x
N									5167	5167	5167	5167

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 3— Peer Effect of Time on Probability of Obtaining Full Score in Sheet No. 1 to No. 3

	Dependent Variable: Dummy of Full Score in All of Sheet No. 1 to No. 3 (Full Score = 1)											
	All Students				Faster Students than Median				Slower Students than Median			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Effect of the Fastest Student's Time												
Fastest Student's Time of the Day	-0.0007	0.0017	-0.0047**	-0.0042*	-0.0034	-0.0015	-0.0044	-0.0036	0.0033	0.0056	-0.0038	-0.0032
	(0.0027)	(0.0026)	(0.0023)	(0.0024)	(0.0029)	(0.0029)	(0.0030)	(0.0031)	(0.0038)	(0.0037)	(0.0036)	(0.0040)
Level of Work Sheets		-0.0002***	-0.0001**	-0.0004***		-0.0001***	-0.0000	-0.0005***		-0.0002***	-0.0001*	-0.0002
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	11065	11065	11065	11065	5776	5776	5776	5776	5289	5289	5289	5289
Panel B: Effect of the Median Time of the Day												
Median Time of the Day									0.0010	0.0038	-0.0058**	-0.0060**
									(0.0028)	(0.0026)	(0.0028)	(0.0030)
Level of Work Sheets										-0.0002***	-0.0001	-0.0002
										(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect											x	x
Day Fixed Effect												x
N									5289	5289	5289	5289

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 2 shows the peer effect of classmates' speed on the time of solving ten worksheets. In panel A, the measurement of the peer effect uses the fastest student's time of the day within the classroom. In panel B, the median time of the classroom of the day is used for the peer effect proxy.[15] The first four columns show the results using all student samples with some variations in the control variables such as the level of worksheets, individual fixed effect, and day fixed effect. The middle four columns show the results for students who solved

[15]The results using the 25th percentile and 75th percentile time for the peer effect measurements are reported in the Appendix Tables A3, A4, and A5 respectively.

Table 4— Peer Effect of Time on Probability of Obtaining Full Score in Sheet No. 8 to No. 10

	Dependent Variable: Dummy of Full Score in All of Sheet No. 8 to No. 10 (Full Score = 1)											
	All Students				Faster Students than Median				Slower Students than Median			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Effect of the Fastest Student's Time												
Fastest Student's Time of the Day	-0.0046	-0.0013	-0.0067***	-0.0049*	-0.0087**	-0.0061*	-0.0072**	-0.0066*	0.0013	0.0046	-0.0057	-0.0029
	(0.0029)	(0.0027)	(0.0025)	(0.0026)	(0.0035)	(0.0033)	(0.0035)	(0.0037)	(0.0040)	(0.0038)	(0.0038)	(0.0040)
Level of Work Sheets		-0.0002***	-0.0001***	-0.0005***		-0.0002***	-0.0001	-0.0005***		-0.0003***	-0.0002**	-0.0005**
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0001)		(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	11065	11065	11065	11065	5776	5776	5776	5776	5289	5289	5289	5289
Panel B: Effect of the Median Time of the Day												
Median Time of the Day									-0.0019	0.0019	-0.0099***	-0.0079**
									(0.0033)	(0.0031)	(0.0034)	(0.0036)
Level of Work Sheets										-0.0003***	-0.0001*	-0.0004*
										(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect											x	x
Day Fixed Effect												x
N									5289	5289	5289	5289

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

the problems faster than the median time of the class. The last four columns show the results for students who solved the problems slower than the median time of the class. We find a positive and significant effect of classmates' time on individual students' time across different measurements of peers' time and students' type (i.e., faster or slower in problem-solving than the median time of the class). Each coefficient of peers' time can be interpreted as follows: the shorter the problem-solving time of a peer by one minute, the shorter the individual student's problem-solving time by the magnitude of the coefficient. For example, for all samples, when the fastest student's time is shorter by one minute, an individual student's time will reduce by 0.8377 minutes on average. The magnitude of this coefficient varies slightly, but the peer effects of time on time seems robust across measurements and the student type. We further examine whether this suggestive evidence of speed competition results in a negative (i.e., the trade-off between speed and quality) or positive (i.e., the speed competition leads to better quality) impact on the score. In short, the next two tables show the answer to our main hypothesis: does haste make waste?

Table 3 shows the peer effect of classmates' speed on the score of the first three worksheets (worksheets no. 1 to 3).[16] The score is measured by a dummy indicating whether a full score is obtained. Panels A and B use different measurements of a peer's time: the fastest student's time, and the median time in the class, respectively. Similarly, the structure of columns is the same as Table 1. We do not find any significant peer effects of time on the score in the first three worksheets among the faster students. For the slower students, on the other hand, we can see some negative and significant coefficients on the peers' median time, depending on the specifications. This indicates that as the median time gets faster $(-)$, the likelihood of having a full score is higher $(+)$. This makes sense if the classmates

[16]In the main analysis, we use the linear probability model. We also use the Logit and the Probit models, but the result is robust in the specification.

start to submit worksheets when the slower students are solving the earlier sets of worksheets.

Table 4 shows the peer effect of classmates' speed on the score of the last three worksheets (worksheets no. 8 to 10). The structure of rows and columns are the same as tables 1 and 2. We find negative and significant coefficients of the fastest peer's time on the individual students' scores among the faster students. Again, this indicates that as the peer's time gets shorter (−), the likelihood of having a full score becomes faster (+). On the other hand, those figures are not significant among the slower students. Instead, for the slower students, we see negative and significant coefficients of the median time, depending on the specifications. For the final three worksheets where the problems are more challenging and require more attention and effort, the speed competition seems to work positively for both faster and slower problem-solving students. Furthermore, this speed competition effect is visible among the students who are closer in speed and abilities (i.e., the fastest student speed improves the faster students' scores, while the median speed improves slower students' scores).

These findings jointly suggest that there is an overall positive impact of the speed competition among the peers within a classroom both on the individual student's speed, but also for the score. To answer our hypothesis, we conclude that haste does not make waste in this setting. Instead, students seem motivated to get better scores when the peer finishes earlier and faster.

V. Conclusion

In this study, we examine the peer effect of problem-solving speed on primary school students' learning outcomes on two dimensions: the speed of problem-solving (time) itself and the math score (score). The contribution of this paper to the literature is to examine the peer effect of a speed competition in an educational context. Furthermore, we investigate the potential trade-off or complementarity in quality of learning and speed. To test our hypothesis, we use the daily progress records of the students who received individualized self-study program sessions in Bangladesh. The records provide the time taken to submit ten worksheets and the daily score of those worksheets for each student, as long as he or she attends the session. We find that there are positive peer effects on the speed of problem-solving. Furthermore, we find positive effects on the outcome of learning through this speed competition among closer-ability students. Based on these results, we conclude that haste does not make waste in this setting. These findings will contribute to shaping a productive learning environment incorporating effective peer pressure, especially the effects of the speed competition on quality in an educational setting.

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Appendix A: Tables and Figures

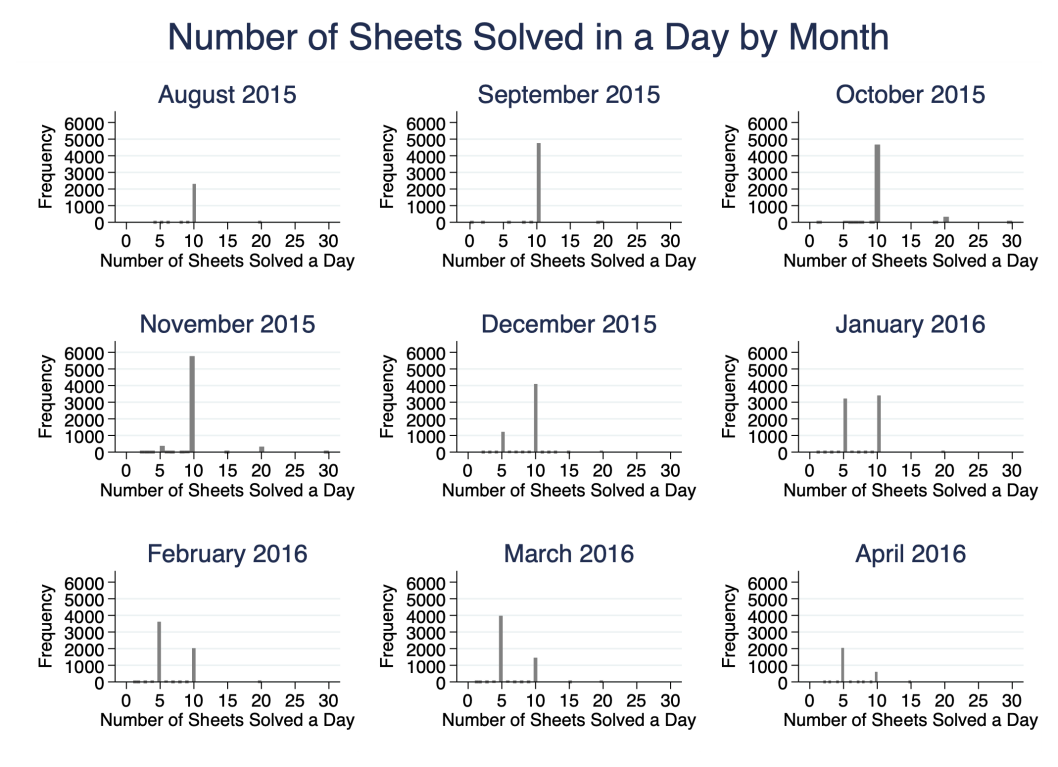

Figure A1. The Average Number of Sheets Which Students Solved in a Day by Month

Table A1— Level of Work Sheets

	Level	Converted Sheet Number	Contents
Higher	F	2001–2200	Calculations and story problems
	E	1801–2000	Fractions
	D	1601–1800	Multiplication, division by more than one digit numbers, and fractions
	C	1401–1600	Multiplication and division by one digit numbers
	B	1201–1400	Column addition and subtraction
	A	1001–1200	Addition, subtraction, and mental arithmetic
	2A	801–1000	Addition and mental arithmetic
	3A	601–800	Addition based on tables
	4A	401–600	Writing numbers and reading tables
	5A	201–400	Counting numbers up to 50
Lower	6A	1–200	Counting numbers from one to ten

Notes. Each level has 200 sheets and we convert the variable "Converted Sheet Number" to control the level and sheet number, which effectively controls the difficulty of the sheets as a continuous variable. In this intervention, we did not use 6A and 5A levels. The original lecture materials extend the level down to Level ZI, II, III, which contains tracing lines and pictures that leads to a basic ability to write numbers and alphabets, and up to Level V, which contains surface geometry.

Table A2— Level of Work Sheets

Symbol	Score Range	Class Value
$\cdot$	100	100
A	$90 \leq \text{score} < 100$	95
B	$70 \leq \text{score} < 90$	80
C	$50 \leq \text{score} < 70$	60
D	$0 \leq \text{score} < 50$	25

Notes. The symbol is written in the Record Books. Circles and triangles around alphabets on the score sheets indicates that the students obtained the full score by correcting their answer after the first grading.

Table A3— Peer Effect on Time for Solving 10 Sheets

	Dependent Variable: Time for Solving 10 Sheets											
	All Students				Faster Students than Median				Slower Students than Median			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Effect of the Median Time of the Day												
Median Time of the Day	0.8881***	0.8531***	0.7911***	0.7772***	0.7048***	0.6952***	0.6184***	0.6076***	1.1075***	1.0944***	1.0574***	1.0529***
	(0.0374)	(0.0378)	(0.0329)	(0.0344)	(0.0193)	(0.0200)	(0.0216)	(0.0222)	(0.0292)	(0.0296)	(0.0330)	(0.0369)
Level of Work Sheets		0.0024***	0.0026***	0.0112***		0.0006**	0.0012***	0.0008		0.0009	0.0012	0.0098***
		(0.0007)	(0.0007)	(0.0017)		(0.0003)	(0.0003)	(0.0008)		(0.0006)	(0.0008)	(0.0022)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10155	10155	10155	10155	4988	4988	4988	4988	5167	5167	5167	5167
Panel B: Effect of the Fastest Student's Time												
Fastest Student's Time of the Day	0.8377***	0.7985***	0.5247***	0.4757***	0.7848***	0.7688***	0.5337***	0.5221***	0.7923***	0.7600***	0.4273***	0.3480***
	(0.0381)	(0.0398)	(0.0361)	(0.0394)	(0.0219)	(0.0235)	(0.0201)	(0.0201)	(0.0518)	(0.0526)	(0.0584)	(0.0670)
Level of Work Sheets		0.0029***	0.0061***	0.0129***		0.0011***	0.0035***	0.0029***		0.0027***	0.0069***	0.0148***
		(0.0005)	(0.0007)	(0.0017)		(0.0003)	(0.0003)	(0.0008)		(0.0006)	(0.0010)	(0.0027)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10944	10944	10944	10944	5777	5777	5777	5777	5167	5167	5167	5167
Panel C: Effect of the 25%-tile Student's Time												
25%-tile Student's Time of the Day	0.6753***	0.6473***	0.5673***	0.5519***	0.4916***	0.4802***	0.3809***	0.3717***	0.8255***	0.8138***	0.7788***	0.7611***
	(0.0277)	(0.0276)	(0.0262)	(0.0282)	(0.0147)	(0.0154)	(0.0148)	(0.0152)	(0.0342)	(0.0340)	(0.0407)	(0.0483)
Level of Work Sheets		0.0027***	0.0034***	0.0104***		0.0011***	0.0026***	0.0019**		0.0012*	0.0021*	0.0115***
		(0.0006)	(0.0006)	(0.0016)		(0.0003)	(0.0003)	(0.0008)		(0.0007)	(0.0012)	(0.0029)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10270	10270	10270	10270	6700	6700	6700	6700	3570	3570	3570	3570
Panel D: Effect of the 75%-tile Student's Time												
75%-tile Student's Time of the Day	0.6753***	0.6473***	0.5673***	0.5519***	0.4916***	0.4802***	0.3809***	0.3717***	0.8255***	0.8138***	0.7788***	0.7611***
	(0.0277)	(0.0276)	(0.0262)	(0.0282)	(0.0147)	(0.0154)	(0.0148)	(0.0152)	(0.0342)	(0.0340)	(0.0407)	(0.0483)
Level of Work Sheets		0.0027***	0.0034***	0.0104***		0.0011***	0.0026***	0.0019**		0.0012*	0.0021*	0.0115***
		(0.0006)	(0.0006)	(0.0016)		(0.0003)	(0.0003)	(0.0008)		(0.0007)	(0.0012)	(0.0029)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10270	10270	10270	10270	6700	6700	6700	6700	3570	3570	3570	3570

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table A4— Peer Effect of Time on Probability of Obtaining Full Score in Sheet No. 1 to No. 3

	Dependent Variable: Dummy of Full Score in All of Sheet No. 1 to No. 3 (Full Score = 1)											
	All Students				Faster Students than Median				Slower Students than Median			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Effect of the Median Time of the Day												
Median Time of the Day	0.0006	0.0034*	-0.0017	-0.0017	-0.0003	0.0019	0.0015	0.0022	0.0010	0.0038	-0.0058**	-0.0060**
	(0.0021)	(0.0019)	(0.0019)	(0.0019)	(0.0024)	(0.0023)	(0.0028)	(0.0029)	(0.0028)	(0.0026)	(0.0028)	(0.0030)
Level of Work Sheets		-0.0002***	-0.0001***	-0.0003**		-0.0001***	-0.0001	-0.0003*		-0.0002***	-0.0001	-0.0002
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0001)		(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10275	10275	10275	10275	4986	4986	4986	4986	5289	5289	5289	5289
Panel B: Effect of the Fastest Student's Time												
Fastest Student's Time of the Day	-0.0007	0.0017	-0.0047**	-0.0042*	-0.0034	-0.0015	-0.0044	-0.0036	0.0033	0.0056	-0.0038	-0.0032
	(0.0027)	(0.0026)	(0.0023)	(0.0024)	(0.0029)	(0.0029)	(0.0030)	(0.0031)	(0.0038)	(0.0037)	(0.0036)	(0.0040)
Level of Work Sheets		-0.0002***	-0.0001**	-0.0004***		-0.0001***	-0.0000	-0.0005***		-0.0002***	-0.0001*	-0.0002
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	11065	11065	11065	11065	5776	5776	5776	5776	5289	5289	5289	5289
Panel C: Effect of the 25%-tile Student's Time												
25%-tile Student's Time of the Day	-0.0020	-0.0004	-0.0034**	-0.0028*	-0.0009	0.0004	-0.0004	0.0008	-0.0020	-0.0004	-0.0082***	-0.0080***
	(0.0016)	(0.0015)	(0.0014)	(0.0015)	(0.0017)	(0.0016)	(0.0018)	(0.0018)	(0.0025)	(0.0024)	(0.0027)	(0.0031)
Level of Work Sheets		-0.0002***	-0.0001**	-0.0004***		-0.0001***	-0.0001	-0.0004***		-0.0002***	-0.0001	-0.0002
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0003)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10390	10390	10390	10390	6698	6698	6698	6698	3692	3692	3692	3692
Panel D: Effect of the 75%-tile Student's Time												
75%-tile Student's Time of the Day	-0.0020	-0.0004	-0.0034**	-0.0028*	-0.0009	0.0004	-0.0004	0.0008	-0.0020	-0.0004	-0.0082***	-0.0080***
	(0.0016)	(0.0015)	(0.0014)	(0.0015)	(0.0017)	(0.0016)	(0.0018)	(0.0018)	(0.0025)	(0.0024)	(0.0027)	(0.0031)
Level of Work Sheets		-0.0002***	-0.0001**	-0.0004***		-0.0001***	-0.0001	-0.0004***		-0.0002***	-0.0001	-0.0002
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0003)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10390	10390	10390	10390	6698	6698	6698	6698	3692	3692	3692	3692

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table A5— Peer Effect of Time on Probability of Obtaining Full Score in Sheet No. 8 to No. 10

	Dependent Variable: Dummy of Full Score in All of Sheet No. 8 to No. 10 (Full Score = 1)											
	All Students				Faster Students than Median				Slower Students than Median			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Effect of the Median Time of the Day												
Median Time of the Day	-0.0042	-0.0006	-0.0091***	-0.0078***	-0.0073**	-0.0047*	-0.0106***	-0.0101***	-0.0019	0.0019	-0.0099***	-0.0079**
	(0.0025)	(0.0024)	(0.0023)	(0.0024)	(0.0029)	(0.0028)	(0.0032)	(0.0034)	(0.0033)	(0.0031)	(0.0034)	(0.0036)
Level of Work Sheets		-0.0002***	-0.0001*	-0.0004***		-0.0002***	-0.0000	-0.0002		-0.0003***	-0.0001*	-0.0004*
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0001)		(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10275	10275	10275	10275	4986	4986	4986	4986	5289	5289	5289	5289
Panel B: Effect of the Fastest Student's Time												
Fastest Student's Time of the Day	-0.0046	-0.0013	-0.0067***	-0.0049*	-0.0087**	-0.0061*	-0.0072**	-0.0066*	0.0013	0.0046	-0.0057	-0.0029
	(0.0029)	(0.0027)	(0.0025)	(0.0026)	(0.0035)	(0.0033)	(0.0035)	(0.0037)	(0.0040)	(0.0038)	(0.0038)	(0.0040)
Level of Work Sheets		-0.0002***	-0.0001***	-0.0005***		-0.0002***	-0.0001	-0.0005***		-0.0003***	-0.0002**	-0.0005**
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0001)		(0.0000)	(0.0001)	(0.0002)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	11065	11065	11065	11065	5776	5776	5776	5776	5289	5289	5289	5289
Panel C: Effect of the 25%-tile Student's Time												
25%-tile Student's Time of the Day	-0.0050***	-0.0026	-0.0065***	-0.0060***	-0.0050**	-0.0032*	-0.0055***	-0.0049**	-0.0021	0.0005	-0.0067**	-0.0058*
	(0.0018)	(0.0017)	(0.0017)	(0.0018)	(0.0020)	(0.0019)	(0.0021)	(0.0021)	(0.0029)	(0.0027)	(0.0031)	(0.0034)
Level of Work Sheets		-0.0002***	-0.0001**	-0.0005***		-0.0002***	-0.0000	-0.0004***		-0.0003***	-0.0002***	-0.0005*
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0001)		(0.0000)	(0.0001)	(0.0003)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10390	10390	10390	10390	6698	6698	6698	6698	3692	3692	3692	3692
Panel D: Effect of the 75%-tile Student's Time												
75%-tile Student's Time of the Day	-0.0050***	-0.0026	-0.0065***	-0.0060***	-0.0050**	-0.0032*	-0.0055***	-0.0049**	-0.0021	0.0005	-0.0067**	-0.0058*
	(0.0018)	(0.0017)	(0.0017)	(0.0018)	(0.0020)	(0.0019)	(0.0021)	(0.0021)	(0.0029)	(0.0027)	(0.0031)	(0.0034)
Level of Work Sheets		-0.0002***	-0.0001**	-0.0005***		-0.0002***	-0.0000	-0.0004***		-0.0003***	-0.0002***	-0.0005*
		(0.0000)	(0.0000)	(0.0001)		(0.0000)	(0.0001)	(0.0001)		(0.0000)	(0.0001)	(0.0003)
Individual Fixed Effect			x	x			x	x			x	x
Day Fixed Effect				x				x				x
N	10390	10390	10390	10390	6698	6698	6698	6698	3692	3692	3692	3692

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix B: Proof on Identification

In this section, we review the reflection problem. Remember Equation (1):

$$y_{ids} = \alpha + \beta m_{ds} + \boldsymbol{x}_{id}^T \boldsymbol{\delta} + \eta_i + \nu_d + \varepsilon_{ids}, \tag{B1}$$

where y_{ids} is the outcome variable, either time or score of a student i on day d in school s. When the time is an outcome, we use the time a student i spends to solve ten worksheets and submit them to the marking assistants. The peer effect proxy variable, m_{ds}, takes either the fastest, median, 25%-tile, or 75%-tile time of classmate(s) for solving ten worksheets on day d in school s. $\boldsymbol{x}_{id}$ is time-varying controls of student i on day d, η_i is fixed effect of student i, and ε_{id} is an error term. Denote the dimension of the vector $\boldsymbol{\delta}$ as k.

If we use the mean instead of the median, the regression equation is as follows:

$$y_{ids} = \tilde{\beta}_0 + \tilde{\beta}_1 \mu_{ds} + \boldsymbol{x}_{id}^T \tilde{\boldsymbol{\delta}} + \tilde{\eta}_i + \tilde{\nu}_d + \tilde{\varepsilon}_{ids}, \tag{B2}$$

where μ_{ds} is the mean time of classmate(s) solving ten worksheets on day d in school s, which is defined as $\mu_{ds} := E_i^d[y_{ids}|\boldsymbol{x}_{id}]$. Note that E_i means the expectation over i and E^d means that the expectation depends on d.

Take the expectation of Equation B2 conditioning on $\boldsymbol{x}_{id}$, η_i, and ν_d; we then have the following:

$$E[y_{ids}|\boldsymbol{x}_{id}, \eta_i, \nu_d] = \mu_{ds} = \tilde{\beta}_0 + \tilde{\beta}_1 \mu_{ds} + \boldsymbol{x}_{id}^T \tilde{\boldsymbol{\delta}} + \tilde{\eta}_i + \tilde{\nu}_d. \tag{B3}$$

After arranging Equation (B3), we obtain the following:

$$\mu_{ds} = \frac{\tilde{\beta}_0}{1-\tilde{\beta}_1} + \boldsymbol{x}_{id}^T \frac{\tilde{\boldsymbol{\delta}}}{1-\tilde{\beta}_1} + \frac{\tilde{\eta}_i}{1-\tilde{\beta}_1} + \frac{\tilde{\nu}_d}{1-\tilde{\beta}_1}. \tag{B4}$$

When we substitute Equation (B4) into Equation (B2), we obtain the following equation:

$$y_{ids} = \frac{\tilde{\beta}_0}{1-\tilde{\beta}_1} + \boldsymbol{x}_{id}^T \frac{\tilde{\boldsymbol{\delta}}}{1-\tilde{\beta}_1} + \frac{\tilde{\eta}_i}{1-\tilde{\beta}_1} + \frac{\tilde{\nu}_d}{1-\tilde{\beta}_1} + \tilde{\varepsilon}_{ids}. \tag{B5}$$

Here, we have $k+2$ unknown parameters in addition to fixed effects, while we have $k+1$ parameters excluding fixed effects. Therefore, we cannot identify the peer effects. This is the reflection problem.

On the other hand, if we use Equation (1) (accordingly, (B1)), we can avoid this problem. Define the difference between the median and the mean as $d_{ds} := \mu_{ds} - m_{ds}$, then arrange Equation (B1) as we did with Equation (B2). We then obtain the following equation:

$$y_{ids} = \frac{\alpha}{1-\beta} + \boldsymbol{x}_{id}^T \frac{\boldsymbol{\delta}}{1-\beta} + \frac{\eta_i}{1-\beta} + \frac{\nu_d}{1-\beta} - \frac{\beta}{1-\beta} d_{ds} + \varepsilon_{ids}. \tag{B6}$$

Here, we have $k+2$ unknown parameters in addition to fixed effects, and we have $k+2$ parameters excluding fixed effects. Therefore, this regression equation is identified.

Appendix C: Empirical Support on Identification

Table C1— Summary Statistics on the Difference between the Median, 25%-tile, and 75%-tile, and the Mean of Time for Solving 10 Sheets

	Mean	Standard Deviation	25%-tile	Median	75%-tile	N
Difference between the Median and the Mean[a]	0.5011	1.0681	-0.0909	0.4118	1.0000	631
Difference between the Median and the Mean[b]	0.4996	0.9937	-0.0625	0.4167	1.0000	10278
Difference between the 25%-tile and the Mean[a]	-2.2708	1.4283	-3.0476	-2.0952	-1.3077	639
Difference between the 25%-tile and the Mean[b]	-2.3022	1.4046	-3.0588	-2.1364	-1.3889	10393
Difference between the 75%-tile and the Mean[a]	-2.2708	1.4283	-3.0476	-2.0952	-1.3077	639
Difference between the 75%-tile and the Mean[b]	-2.3022	1.4046	-3.0588	-2.1364	-1.3889	10393

a. The observations in this statistics is at the session-level.
b. The observations in this statistics is at the student-level.

Here, we show the empirical support for the discussion in . More specifically, we describe the summary statistics of d_{it}, which is the difference between the median and the mean. The identification strategy works when the random variable d_{it} is not zero, that is, the median and the mean are different. The summary statistics on d_{it} is shown in Table C1. This supports the fact that the median and the mean are different and therefore the empirical strategy seems valid.