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Learning and Peer Effects

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ABSTRACT

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The paper documents the results from an experiment on peer effects in learning processes. The experimental approach eliminates endogeneity and selection problems which typically restrict the measurement of peer effects. The results provide evidence for the optimal composition of learning groups. Learning with a partner is more successful than learning without one, though differences between gender and age groups are observable. High ability students provide benefits to other high ability students. Subjects who are member in a club provide a benefit to partners who are not. The paper discusses how further experiments can overcome the limitations of the chosen approach.

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1 Introduction

Education is a customer-input-technology (Rothschild and White, 1995). The educational performance of a student depends on the characteristics and behaviour of his fellow students. Hence it is not irrelevant for a single student with whom he or she is studying. Furthermore, the selection of students into different types of school is a policy topic in many countries. One of the biggest obstacles for a reasonable debate about selection policies is the measurement of peer effects which puzzles statisticians and econometricians for quite a while. This paper approaches the measurement problem from a different point of view. It documents an experimental learning environment which identifies "clean" peer effects and offers insight into the optimal composition of learning groups.

Economists and educational researchers put great effort into the identification of this optimal composition. The selection of students according to perceived ability into different tracks is a controversial topic in many countries. Its efficiency is disputed and it has distributional consequences (Hanushek and Wößmann, 2006). The identification refers to two empirical problems: Who provides the most external effects in learning groups and who can reap the greatest benefits from them? This approach to peer effects differs from the one provided by Falk and Ichino (2006). These authors find experimental evidence for positive peer effects in a "real task" production environment. In their case the peer effect stems from the mere presence of another person in the room. They relate their approach to the "social facilitation paradigm", a research topic in the psychological literature (e.g., Zajonc, 1965, Cottrell et al., 1968, or more recently Feinberg and Aiello, 2006). The experiment in this paper goes one step beyond this. The subjects can interact and discuss the problems, thus helping each other in the preparation for a final performance measurement.

In the economic literature, high ability students are typically assumed to provide more beneficial external effects than low ability students. A popular measure for such an assumption is average ability in a class (e.g. in Epple & Romano, 2003). The measure implies that high ability students can also benefit more strongly from better peer effects because their marginal productivity is greater. Such a pattern suggests that homogeneous learning groups are efficient. Students should be sorted according to ability. However, if low ability students benefit more strongly from high ability students then heterogeneous groups are the dominant solution. A similar argument can be made if low ability students provide the positive externality. Table 1 summarizes the optimal group composition.

Table 1: Providers and beneficiaries of peer effects with implications for tracking policies.

Direction of peer effects and optimal policies		(Higher) benefits from peer effects	
		High Ability	Low ability
Provider of positive peer effects	High ability	Selection	Mixed groups
	Low ability	Mixed groups	Selection

As stated above, the properties of peer effects in many theoretical contributions imply that selection is efficient, but international studies do not show that selective systems perform better. These results question the way peer effects are modelled, although they do not contradict them necessarily (see Maier, 2004, de Fraja and Landeras, 2006, Eisenkopf, 2007). The objective of this paper is to provide and discuss evidence on three research questions:

1. Do peer effects exist?
2. Who provides peer effects, who benefits from the effects?

The results of question 2 lead to implications to the more fundamental question which was addressed above:

3. What is the optimal composition of learning groups? Should policy makers track students according to ability and/or some other measure?

Econometricians face several problems when estimating peer effects, the most important methodological discussion of them is provided by Manski (1993). Nevertheless a large literature has been devoted to getting around them (e.g. Hoxby, 2000, McEwan, 2003, Hanushek et al., 2003, Cullen, Jacob and Levitt, 2003, these and others are summarized in Ammermüller and Pischke, 2006). I will sketch three of them at this moment. Firstly, most measures are endogenous. Take average performance of fellow class members as an example. If positive peer effects exist, the performance of any student should improve with the performance of his class members. However, the left hand variable has an impact on the peer effect measure, as any observed student also has an impact on his fellow students. This problem could be ignored if an independent ability measure for any student was available which lacks in many datasets.

Secondly, students are not randomly assigned to their peer groups. Parents, schools or any other party decide where students enrol. Such a selection process precludes the identification

of a counterfactual. How would a student have performed in a different peer group or as a single learner?
Thirdly, teacher behaviour and other environmental characteristics can change with the peer group composition. The same teacher may teach the same topic in a different way, if the average ability or the ability distribution changes in a class. Arguably, such an effect is part of a peer effect. One could distinguish between a direct peer effect, where students directly influence each other, and an indirect one, where students influence each other via the teacher. The focus in this paper is on the direct peer effect. Most of the theoretical literature also focuses on the direct peer effect and ignores the indirect one. The exception by Meier (2004) proves the rule.
Obviously, a single experiment cannot represent an entire educational process or make econometric analysis meaningless. However, the experiment documented in this paper measures peer effects without any of the discussed econometric problems. It has an independent ability measure, assigns peers randomly and includes no teachers at all. The drawbacks of the chosen experimental approach become obvious and will be discussed at the end of the paper. Most critical objections can be met with the help of further experiments and the design of this experiment provides a methodological battle horse for future replications, specifications, and refinements. To my best knowledge, this paper provides the first truly experimental approach in the economic literature which measures peer effects in a learning environment.
In the experiment described in this paper the participants learned solution strategies for a logical puzzle either alone or with a partner. The results show the existence of a positive peer effect. Two results stand out with respect to optimal group composition. Firstly, only high ability students benefit from increasing ability of the partner. Secondly, subjects who are member in a club (e.g. sports team or orchestra) provide a positive effect for non associated subjects (i.e. those who are not in a club). The performance of club members is independent of the membership status of their partners.
This is not the first paper which identifies peer effects in an educational context with randomized assignments of the observed individuals to different groups. Sacerdote (2001) estimates peer effects with data from Dartmouth College where students where randomly assigned to different dorms. The data do not allow an identification of the actual mechanisms how peer effects work and the effects may be caused by changes in local arrangements during the observation period.

I will describe the experiment in the following section. The results with respect to the research questions are presented in section 3. Section 4 concludes with a summary and discussion of the results

2 The Experiment

The objective of the experiment was to provide evidence on the existence and properties of peer effects in learning processes. To identify a learning process a task was chosen in which the subject could improve themselves within reasonable time. A logical puzzle called Kakurasu was chosen. A detailed description of the puzzle can be found in the appendix and at www.janko.at (in German). The correct boxes in the following matrix have to be marked:

Figure 1: Exemplary Kakurasu puzzle

	5	**6**	**1**	**2**	
3					**1**
7					**2**
1					**3**
2					**4**
	1	**2**	**3**	**4**	

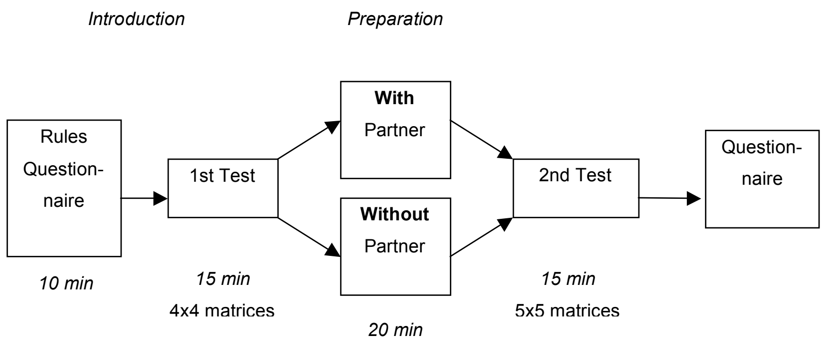
Each box in the matrix has two values depending on its column and row (see numbers below and on the right hand side). The sum of the marked boxes has to add up to the values on the top (row values) and the left hand side (column values). Figure 2 provides the correct solution.

Figure 2: Solution for the example

	5	**6**	**1**	**2**	
3			X		**1**
7	X	X		X	**2**
1	X				**3**
2		X			**4**
	1	**2**	**3**	**4**	

The students got the rule in written form but no hints how to solve the puzzles. A first test with a set of these puzzles measured how much the students did understand. 4x4 matrices as used in Figures 1 and 2 were used for this test. The test score of this test serves as an ability measure in the analysis. After this test the students could prepare for a final test. In this preparation period the experimental treatment took place. In the single treatment group the subjects prepared alone. In the pair treatment group they could cooperate with a partner. A final test concluded the learning process. This final test contained 5x5 matrices. All subjects had to solve it alone. The number of correctly solved puzzles provides the test score in both cases. Questionnaires collecting data on control variables were handed out at the beginning and the end of the experiment. All tests and questionnaires are documented in the appendix.

Figure 3: The design of the experiment



The first experiment was conducted on December the 5th in 2006 with 85 Swiss students which we recruited at a high school (Kantonsschule) in Kreuzlingen in the canton of Thurgau in Switzerland. The students applied with their name and their class level and got 20 Swiss Franks (about 12.40 € or 16.25 US$) for their participation. A replication is scheduled for February at a similar school in the same canton.

The experiment was conducted with students from the Kantonsschule Kreuzlingen (Switzerland) in the classrooms of that school. 29 participants were assigned to the single treatment and 56 to the pair treatment group. The subjects were assigned randomly to the different groups. Each subject in the pair treatment group got a randomly assigned partner, though only from the same class level and sex. Due to missing partners, two pairs were formed with subjects from different class level. Table 2 shows the composition of single treatment and pair treatment groups. All subjects did the experiment at the same time to ensure that students could not communicate solution hints to following students. Due to capacity constraints the subjects did the experiment in five different rooms. Two rooms were filled with single learners, three rooms (including a large one) with the pair treatment group. Since the differences across rooms within a specific treatment group are insignificant, it is assumed that differences in rooms do not matter between the treatment groups, too.

The student received their instructions in oral and written form from the author of this paper. In each room an overseer was in charge of the technical details. These overseers received instructions about the procedure of the experiment but not the puzzle. The participants were explicitly told that the overseer could not answer questions with respect to the puzzle.

Table 2: The distribution of the subjects into single treatment and pair treatment groups

	Single treatment group			Pair treatment group		
Classlevel	Male	Female	Sum	Male	Female	Sum
Level 2	6	5	11	11	17	28
Level 3	4	6	10	5	11	16
Level 4	6	2	8	4	8	12
Sum	16	13	29	20	36	56

3 Results

3.1 The Existence of Peer Effects

The descriptive statistics show (significant) differences between single treatment group and pair treatment group in the second test score (label: *secondtest*). The results in the first test (*firsttest*) also differ, but not significantly. Further research may reveal if this difference is caused by the fact that the participants knew at the beginning of the first test about the enrolment in the pair treatment and about their prospective partner.

Table 3: Descriptive Statistics

	Single treatment		Pair treatment	
	Mean	St.dev	Mean	St.dev
secondtest (5x5 matrices)	2.069	1.981	3.125	2.001
firsttest (4x4 matrices)	3.207	3.109	4.018	2.526

Negative binomial regressions show the treatment effect, i.e. the existence of peer effects (Table 4). Learning with a partner provides a benefit even if one controls for differences in the first test and heterogeneity in class levels and sex. Count data like in our case the number of correctly solved puzzles require either negative binomial or Poisson regressions, depending on the dispersion of the counted measures. Throughout the paper, only the results from negative binomial regressions are reported. The results from the different approaches do not differ very much anyway.

The first test score is a good ability measure since it is a highly significant predictor of the final test score. A great number of control variables have been collected, e.g. performance in school, marks in math, membership in clubs, etc. The subjects could also evaluate how they liked the partner, the assigned task, the cooperation and much more. Only one of them was significant, club membership (*Club*), i.e. if the subject was member in any type of club like a sports team or an orchestra. Controlling for club membership of the subjects implies that the treatment effect is significant only on a 10% level. The share of club members was much greater in the pair treatment group and club membership somehow boosts performance. The club membership issue will be addressed in greater detail later in the paper.

Table 4: Estimation of the Peer or Treatment Effect

Negative binomial regression; N =85, *Indep.Var: Secondtest;* coefficients (St.err)					
Treatment	.412** (.179)	.322* (.150)	.343* (.152)	.463** (.176)	.257^ (.155)
Firsttest		.195*** (.026)	.191*** (.026)		.174*** (.027)
Classlevel			.093 (.081)	.175 (.158)	.084 (.082)
Sex			.039 (.134)	.157 (.095)	-.025 (.136)
Club					.420*** (.159)
Constant	.727*** (.152)	-.084 (.185)	-.360 (.300)	.171 (.331)	-.451 (.303)
Pseudo R^2	.0149	.1678	.1717	.0254	.1923
*Significance levels: ***=.001,**=.01,*=.05, ^=0.1*					

The treatment effect differs with the subsamples. Only male subjects (Table 5) and students from higher class levels (3rd and 4th level, Table 6) benefit from a partner. The peer effect among men may be explained by results from Gneezy, and Rustichini (2004) who find that men, but not women perform much better in competitions than if acting alone. In this case, working together in the preparation induces competition.

Table 5: Estimation of the Treatment Effect, separate for men and women

NBReg; Male subjects; N = 36		*NBReg; Female subjects;* N = 49	
Treatment	.487* (.215)	*Treatment*	.177 (.211)
Firsttest	.173*** (.040)	*Firsttest*	.208*** (.035)
Constant	-.060 (.266)	*Constant*	-.043 (.258)
Pseudo R^2	.1803	*Pseudo R^2*	.1637

Table 6 : Estimation of the Treatment Effect, separate for younger and older subjects

NBReg; Class level 2; N = 39		*NBReg; Class level 3 & 4; N = 46*	
Treatment	.131 (.241)	*Treatment*	.504** (.192)
Firsttest	.118** (.0385)	*Firsttest*	.262*** (.038)
Constant	.334 (.256)	*Constant*	-.516 (.279)
Pseudo R^2	.0712	*Pseudo R^2*	.2623

3.2 Providers of and Beneficiaries of Peer Effects

The literature about peer effects typically focuses on the ability of learning partners. The score in the first test provides the ability measure in this experiment. Of course, the analysis is restricted to those 56 subjects who studied with a partner. Again club membership is the only significant control variable and remains in the analysis. Table 5 documents the results. Regarding the whole sample the ability of the partner does not have a significant impact on the performance of a subject. However, the impact of a good partner depends on the subject itself. Only good subjects (who solved four or more puzzles in the first test) benefit from an increasing ability of the partner. The negative coefficient for low ability students becomes even significant if club membership as a control variable is dropped.

Table 7: The impact of the partner's ability on performance in the second test

Negative binomial regression, Independent Variable: *Secondtest;* coefficients (robust St.err)			
	N = 56	Firsttest<4; N=23	Firsttest≥4; N=33
Partnerscore (firsttest of partner)	.022 (.022)	-.110 (.068)	.057* (.022)
Firsttest	.171*** (.027)	.152 (.120)	.173*** (.031)
Club	.378* (.146)	.343 (.282)	.340* (.145)
Constant	-.009 (.201)	.536 (.356)	-.131 (.249)
Pseudo R^2	.1644	.0890	.1041
*Significance levels: ***=.001,**=.01,*=.05, ^=0.1*			

However, promoters of "soft skills" trainings claim that the benefits of cooperation do not depend only on the ability of the partners but on some sort of social competence. The membership in a club suggests that a subject has more experience in interaction with others than a non-associated subject. Hence, the next analysis focuses on the impact of club membership of a subject and his partner on performance in the second test. I repeat the analysis from above and control also for club membership of the learning partner. Table 6 documents the results. In general, the club membership of a partner does not provide a benefit for a subject. But an asymmetric effect exists again. For club members (*Club* = 1) the membership of the partner does not matter. However, non-associated subjects (*Club* = 0) benefit from learning together with a club member. The sample size for this analysis is quite small but the effect is still highly significant.

Table 8: The impact of club membership on performance in the second test

Nbreg, Independent Variable: Secondtest; coefficients (robust St.err)			
	N = 56	Club = 0, N = 19	Club = 1, N = 37
firsttest	.168*** (.027)	.155*** (.054)	.168*** (.029)
Clubpeer (membership of partner)	.089 (.109)	.850*** (.202)	-.065 (.118)
Club	.385** (.142)		
Constant	.029 (.188)	-.512* (.255)	.513** (.189)
Pseudo R^2	.1634	.1569	.1351

4 Summary and Discussion of the Results

This first experiment has shown that peer effects in learning exist. Furthermore it revealed that, for the given task and difficulty, good students benefit from increasing ability of their partners. Club members provide a positive effect for subjects who are not in a club.

The third and most fundamental research question was about the optimal composition of learning groups. The existence of peer effects suggests that single learners, e.g. in cases of home-schooling, face some deficits which have to be compensated elsewhere. There is evidence that selecting learning groups according to ability increases the efficiency level (see also Table 1 and the related discussion in the introduction). Yet this argument is qualified by the club membership issue. Club members perform on average better but they produce a positive effect for their non-associated partners. This evidence supports rather comprehensive education.

One should be reluctant to read too much into a single experiment. I will discuss some caveats and how further research can meet them.

- The sample size is fairly small. A replication of the study at another Swiss school is in preparation at the moment.
- The experiment captures only one specific learning process. The results may change with the type, workload and difficulty of the problem.
- Following Lazear (2001), the peer effect and the optimal composition of peer groups changes with the number of persons in a group.
- Almost all subjects knew their learning partner. Though personal appreciations of the partner (liking the partner, being close friends, enjoying the cooperation) did

not influence the final performance a replication with unknown learning partners may bring different results. I conducted a pre-test for this experiment with first-year students during the introductory week at the University of Konstanz. Most of these students did not know each other. The results indicated a peer effect even in this setting.

- The payout does not depend on the performance and students have no incentive to perform well. The experiment can be replicated easily with variable payouts though the observation of subjects during the experiment suggests that students were motivated anyway. By the way, the same critique applies to educational achievement studies like PISA or TIMSS.

In general, the external validity of any single experiment seems questionable. What does the experiment actually reveal about education and policy tools? Peer groups are larger and more complex in schools, as it is the case with the problems the students have to solve. However, most of the critical issues can be addressed in further experiments and most available data on actual peer groups in education precisely imply the econometric problems discussed in the introduction: endogeneity, the lack of reliable counterfactual, and the unobserved change in behaviour by a third party.

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