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How Does Instruction Time Affect Student Achievement? The Moderating Role of Teacher Qualifications

ABSTRACT

This study focuses on the interaction between the quantity and the quality of instruction at school. On average, across all studied countries, one hour more instruction time leads to 0.03 standard deviations higher test scores. Importantly, the effect varies according to teachers' formal qualifications: It is larger for students with better qualified teachers. The moderating role of teacher quality is particularly important in understanding the effect of instruction time in developing countries: more instruction time alone has no significant effect on average in these countries, but instruction by a highly qualified teacher increases test scores by 0.02 standard deviations.

INTRODUCTION

In the course of the Covid-19 pandemic, students from all around the world have experienced severe learning and achievement losses (Chetty et al. 2020; Engzell et al. 2021; Grewenig et al. 2021; Maldonado and de Witte 2021; Woessmann et al. 2021). The pandemic-induced school closures in many countries have fueled the debate about the role of education and instruction in our society. Research shows that both instructional quantity (e.g., Lavy 2015; Rivkin and Schiman 2015) and instructional quality (e.g., Hanushek and Rivkin 2006; Rockoff 2004) prove to be important for student achievement. While there is a consensus that both quantity and quality of instruction individually are essential for students' educational achievement, the interaction between the two factors is less well understood. This article reports the findings of a recent study by Wedel (2021) on the extent to which the effect of instruction time on student performance is moderated by the quality of teachers.[1]

The effect of instruction time might go in different directions. On the one hand, a teacher might have the opportunity to cover more material, analyze and discuss it in more detail, take the time to answer students' questions, and combine concepts that arise in different classes (National Center on Time & Learning 2017) through increased instruction time. Students will probably benefit more from instruction time if teachers use the additional time efficiently, e.g., by covering new or revising old content instead of using the time for classroom management or administrative tasks. On the other hand, students might become bored or less focused such that they are not able to absorb further information, making more instruction time and more input rather harmful. At the same time, it is also important how well a teacher knows the subject and how well she can explain it to her students (Carroll 1989).

The novelty in this study is that it contributes to the literature by exploring the interaction between quantity and quality of instruction. Using the 2015 Trends in International Mathematics and Science Study (TIMSS) data also allows studying countries that were not considered in previous studies on instruction time (see Box 1 for a description of the data source). These mostly include countries from the Middle East, such as Saudi Arabia, the United Arab Emirates, and Oman, as well as Singapore and Kazakhstan. Moreover, the study focuses on fourth-graders, which is especially relevant since young children are particularly sensitive to interventions and the returns to investments in human capital are higher (Cunha et al. 2006).

MEASURING INSTRUCTION TIME, TEACHER QUALIFICATIONS, AND STUDENT OUTCOMES

The main variable of interest is *instruction time* in either math or science. Instruction time in general is defined as the ''amount of time during which students receive instruction from a classroom teacher in a school [...] context'' (UNESCO 2021). It does not include teacher training days, holidays, breaks at school, or learning time outside of school, such as

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[1] This article is a policy-focused summary of Katharina Wedel (2021), "Instruction Time and Student Achievement: The Moderating Role of Teacher Qualifications," *Economics of Education Review* 85, 102183.

DATA SOURCE AND DESCRIPTION

The TIMSS & PIRLS International Study Center at the International Association for the Evaluation of Educational Achievement (IEA) conducts standardized assessments of students' achievements in math, science and reading, which are internationally comparable. Hereby, science is a combination of life science, physical science, and earth science. The study is conducted in more than 60 countries (TIMSS 2019). In addition to information about a student's achievement, the data also include information about students' attitudes, teachers, school resources, and instructional practices (TIMSS 2019). TIMSS uses a two-stage random sample design: In the first stage, a sample of schools is determined, and in the second stage, one or more classes within a school are selected for data collection (Martin et al. 2016).

The final sample for this study contains 108,358 fourth-grade students in 1,586 classes and 4,283 schools in 39 countries[1] from the 2015 survey wave in TIMSS. The countries are categorized according to the WESP classification (United Nations 2014) into developed and developing countries as well as countries in transition. For simplicity, countries in transition and developing countries are both referred to as "developing countries." In total, 15 of the countries in the sample are developing countries. In TIMSS, every student is evaluated twice: once in math, and once in science. Therefore, the number of observations amounts to 216,716. Overall, 49 percent of the students in the sample are female and 83 percent of the teachers are female.

[1] Not all 60 countries are used in the analysis since some do not report science test scores.

time for homework and tutoring. The underlying question for teachers in the TIMSS data is the following: "In a typical week, how much time do you spend teaching mathematics to the students in this class? (minutes)" (TIMSS 2015). The same question is asked for science. To make the resulting numbers comparable to other studies, in this study they are converted into hours and aggregated on the school-by-subject level as in Lavy (2015). TIMSS also provides information on the curriculum for each participating country. Percentages of math and science lessons as a proportion of total instruction time are prescribed by a curriculum in some but not all countries: 27 (24) of the 39 countries in the sample indicate that the curriculum prescribes a certain percentage of instruction time in math (science). In some countries, these percentages vary by state or school. Other countries define a range of percentages that should be devoted to instruction time in a given subject. Hence, differences in instruction time occur both across and within countries.

Teacher quality is a major determinant of student achievement. One approach used in the literature to determine the quality of a teacher is the teacher value-added (e.g., Hanushek 1971; Koedel et al. 2015; Rivkin et al. 2005), assessing the quality of a teacher in terms of the gain in student achievement from one year to another. However, the teacher value-added cannot be measured with the TIMSS data since students and teachers are only assessed in fourth grade at one point in time. To measure the teacher value-added, one needs at least two observations per student at two points in time, ideally one at the beginning of a school year and one at the end. Instead, Wedel (2021) uses teachers' educational background as a measure for teacher quality, defined by their formal qualifications: subject specialization, years of experience, highest degree of education, and participation in professional development (Nilsen et al. 2018).

Previous evidence on the relationship between student achievement and these teacher qualifications is rather mixed: One part of the literature finds no returns to better qualified teachers (e.g., Hanushek 1986; Rivkin et al. 2005) while others find positive effects on student achievement (e.g., Clotfelter et al. 2007; Goldhaber and Brewer 2000; Goldhaber and Anthony 2007). However, in the public debate and politics as well as in educational institutions, certain teacher qualifications are required in recruitment processes and play a major role in compensation and tenure decisions (e.g., Podgursky and Springer 2007; Shuls and Trivitt 2015). In the US, for example, the No Child Left Behind Act required all core subject matter teachers to be highly qualified, which implied that they had to hold a bachelor's degree, be certified or licensed by the state, and be able to demonstrate subject matter competence (Jacob 2007).

In TIMSS 2015, teachers answered questions about their highest level of completed formal education (according to the ISCED classification), about their major in a subject, and their specialization when majoring in teacher education. The variable *major degree* indicates whether the teacher has a bachelor's degree (or higher) and whether she majored in the relevant subject. This variable thus indicates a teacher's subject knowledge. For example, studying mathematics as a major provides knowledge of the content required for teaching mathematics to students (Blömeke et al.

2016). The indicator *education specialization* measures whether a teacher has a specialization in the relevant subject if she has an educational background, i.e., a major in teacher education or pedagogy. A further aspect is participation in *professional development* (PD) in the respective subject in the last two years. Subcategories of professional development are subject content, subject pedagogy/instruction, or subject curriculum.

These three teacher qualifications are subject-specific and can vary within teachers: For example, a teacher might have a specialization in math, but not in science when her major was teacher education. Similarly, a teacher might have participated in professional development in science, but not in math. Overall, 20 percent of teachers have a bachelor's degree (or higher) with the relevant subject as their main subject and 28 percent have an educational background with a specialization in the subject. About half of all teachers participated in professional development in the last two years.

Teachers were also asked about their experience, i.e., the number of years they had been teaching. On average, teachers had been teaching for 17.4 years across all countries, with a maximum of 60 years. In her study, Wedel (2021) generates a variable that indicates whether a teacher had more than two years of experience (*high experience*). Teachers' performance with only one or two years of experience tends to be worse than that of more experienced teachers, and the latter are also better at raising student achievement than inexperienced teachers (Clotfelter et al. 2007).

A student's test score in math or science as well as her motivation and attitude towards a subject are used as outcomes. The *test score* of a student in math or science measures a student's cognitive attainment in those subjects (Woessmann 2003). To measure a student's motivation and attitude towards a subject, Wedel (2021) uses factor analysis to generate an index called *like subject* that consists of four variables for each subject. The corresponding questions include ''I enjoy learning mathematics'' and ''I learn many interesting things in mathematics,'' equivalently for science. Students could answer on a 4-point scale which ranges from ''agree a lot'' to ''disagree a lot.''

THE IMPACT OF INSTRUCTION TIME ON STUDENT OUTCOMES

From a theoretical point of view, additional instruction time can have positive or negative effects on students' outcomes. The results in the study by Wedel (2021) show that students benefit in terms of test scores from additional instruction time: An additional hour of instruction time increases students' test scores by 0.030 standard deviations. This finding is in line with the results of previous studies (Rivkin and Schiman 2015; Lavy 2015; Bingley et al. 2018).

EMPIRICAL STRATEGY

Wedel (2021) uses a student fixed-effects model and exploits within-student between-subject variation to identify the effect of instruction time on student achievement. The TIMSS data provide two observations per student and are therefore particularly suitable for using this model: Both student attainment and instruction time are reported for math and science. Using a student fixed-effects model controls for unobservable student characteristics, such as unobserved ability and school differences in both subjects (Rivkin and Schiman). The attractiveness of this model lies in the fact that the students taking two subjects have the same overall skill level and that the school environment is the same for both subjects (Rivkin and Schiman 2015). Wedel (2021) interacts the instruction time variable with a quality indicator of the teacher, measured by her formal qualifications.

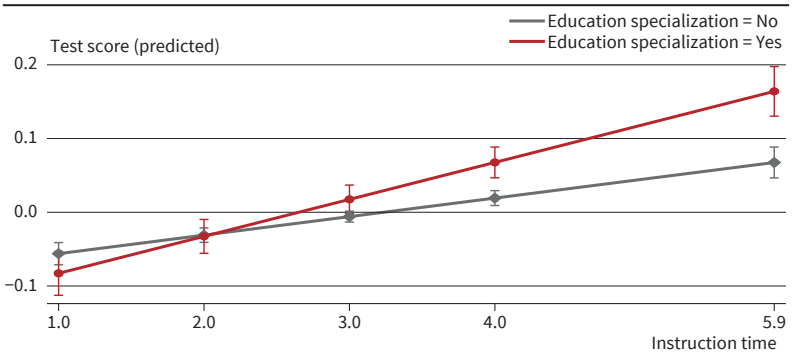
Additionally, Wedel (2021) examines whether there are differences in the effect with respect to a student's gender. The results indicate that an additional hour of instruction time leads to a higher increase in test scores for male students than for girls. Hence, boys seem to benefit more from additional instruction time, which is surprising since returns to schooling are often lower for boys than for girls, especially in low-income countries (Montenegro and Patrinos 2014). A potential reason for this might be that boys study less for school outside school hours than girls. Consequently, boys might need to spend more time studying with a teacher than girls to improve their test scores. For girls, homework time (as compared to instruction time) might play a greater role than for boys.

As explained, additional instruction time can also affect a student's attitude towards a subject. A student might become tired of a subject, leading to an aversion to the subject. Alternatively, a student might enjoy a subject even more when additional instruction time is used to deal with more specific content. The results by Wedel (2021) suggest that additional instruction time also leads to a more positive attitude towards the subject.

THE MODERATING ROLE OF TEACHER QUALIFICATIONS

As hypothesized, the effect of instruction time might differ according to the quality of the teacher: An additional hour of instruction by an unqualified teacher or a teacher who does not know the subject matter well might not result in achievement gains for students. It

Figure 1
Marginal Effects Using Specialization as the Teacher Qualification Measure



Notes: TIMSS student test scores in math and science in 4th grade in 2015. Instruction time and education specialization are aggregated on school-by-subject-level.
Source: Wedel (2021).

might be more important how time at school is spent, how good teachers are at teaching, and how motivated students are to learn, rather than the amount of instruction time (Organisation for Economic Co-operation and Development 2014). To assess this, Wedel (2021) interacts the instruction time variable with the quality indicator of the teacher, measured by her formal qualifications as described above.

The results suggest that the impact of one hour more instruction time is larger when having a teacher who participated in professional development (Table 1, column 1), who has a teacher training background and a specialization in the subject (Table 1, column 2) and who completed the relevant subject as the main subject with a bachelor's degree (or higher) (Table 1, column 3). For example, the impact of one hour more instruction time is 0.050 standard deviations for teachers with an educational background and a specialization in the relevant subject, while it is 0.025 standard deviations for teachers without such a background (Table 1, column 2). Figure 1 suggests that a teacher with an educational background and a specialization in the subject who teaches three hours has the same impact on student achievement as a teacher who teaches four hours but does not meet these criteria. When a teacher teaches the same students for many hours, i.e., more than three hours, it is especially important for the effect of instruction time on test scores whether the teacher is highly qualified.

Across all countries, it seems that the impact of instruction time is enhanced by the fact that a teacher has knowledge about the content, i.e., majored in the relevant subject, and that she has an educational background. However, in the case of having a more experienced teacher, the effect seems to be slightly reduced (Table 1, column 4). This is surprising in that more experienced teachers are expected to know how to use the time such that it benefits the students.

The results on teacher qualifications (except experience) by Wedel (2021) complement the study by Rivkin and Schiman (2015). They examine the quality and environment of the classroom instead of teacher qualifications and find that a better classroom envi-

Table 1
Results for Teachers' Formal Qualifications

	(1)	(2)	(3)	(4)
	Test score	Test score	Test score	Test score
Instruction time	0.012***	0.025***	0.024***	0.034***
	(0.004)	(0.003)	(0.003)	(0.007)
PD x instruction time	0.030***			
	(0.004)			
Education specialization x instruction time		0.025***		
		(0.005)		
Major degree x instruction time			0.034***	
			(0.005)	
Experience x instruction time				– 0.004
				(0.007)
Observations	216,716	216,716	216,716	216,716
R– squared	0.923	0.923	0.923	0.923
Student FE	Yes	Yes	Yes	Yes
Subject FE	Yes	Yes	Yes	Yes
Teacher Controls	Yes	Yes	Yes	Yes
Effect for high qualification	0.042***	0.050***	0.058***	0.030***
	(0.003)	(0.005)	(0.005)	(0.003)

Notes: Dependent variable: TIMSS student test score in math and science in 4th grade in 2015. Instruction time and teacher qualifications are aggregated on school-by-subject-level. Teacher controls are teacher being female and teacher age. Senate weights are used. PD stands for professional development. Effect for high qualification shows the coefficient on instruction time when the respective teacher qualification (PD, education specialization, major degree, experience) equals 1. Clustered standard errors at school level in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Source: Wedel (2021).

ronment increases the effect of additional instruction time. Hence, it seems that both teacher quality and student behavior in the classroom play an important role.[2]

COUNTRY ANALYSIS

In addition, the effects might vary across country groups. Various countries from different continents participate in TIMSS. Often, these countries especially differ in their educational culture and educational system. One main difference is that some participating countries are developing countries or countries in transition (such as Chile, Oman, and Saudi Arabia), while others are developed countries (such as France, the US, and Japan). The effect of instruction time on students' test scores is statistically significant and higher in developed countries (0.061 standard deviations) than in developing countries (not statistically significant). The magnitude of the coefficient on instruction time in developed countries is similar to the coefficient determined by Lavy (2015) for OECD countries.

In developed countries, the effect is smaller for girls, while it is even negative for girls in developing countries. This might be due to the fact that education for girls is still not taken as given in many developing countries. Girls might react negatively to spending more time in school, when they know that they are actually needed at home for work or that they have to earn income that their families depend on (Glewwe and Kremer 2006). Alternatively, teachers might spend the additional instruction time on boys and less on girls, leading to higher gains for boys than for girls.

More importantly, Wedel (2021) also analyzes how teacher qualifications interact with instruction time in developed and developing countries separately since the influence of teacher quality might differ between educational systems (Blömeke et al. 2016). In developing countries, the impact of instruction time is enhanced by having a teacher who completed the relevant subject as a main subject with a bachelor's degree (or higher) or having a teacher who participated in professional development. The impact of instruction time is even negative when having a low-qualified teacher, but it becomes positive when having a better qualified teacher: Instruction time by a highly qualified teacher (e.g., a teacher who has a bachelor's degree (or higher) with the relevant subject as a major subject) increases test scores by 0.027 standard deviations, while it seems to decrease test scores when having an unqualified teacher, i.e., a teacher without this qualification. A potential reason for this again might be that in developing countries students are needed at home to work. If these students stay longer at school with a teacher without good qualifications, they might become distracted and unfocused, leading to worse outcomes. The coefficient on educational background with a specialization, however, is much smaller and only statistically significant at the 10 percent level in developing countries. Hence, the results suggest that majoring in the relevant subject is more important than having an educational background. In light of the observation from previous research that teachers lack adequate knowledge and that the quality of school education in developing countries is often rather low (Glewwe and Kremer 2006), majoring in the relevant subject with at least a bachelor's degree could thus indicate more substantial content knowledge about the subject. Hence, this plays a moderating role for the impact of instruction time.

In developed countries, by comparison, having a teacher with an educational background seems to enhance the impact, as does having a teacher who majored in the relevant subject with a bachelor's degree (or higher). The coefficients are of similar magnitude and hence suggest that both subject knowledge and knowledge about pedagogical elements can enhance the impact of instruction time in developed countries.

POLICY RECOMMENDATIONS AND CONCLUDING REMARKS

In the reported study by Wedel (2021), instruction time is found to positively affect students' test scores. More importantly, teacher quality, measured by teachers' formal qualifications, plays a moderating role for the effect of instruction time on student achievement: The effect is larger for students with better qualified teachers. This is especially relevant in developing countries, where the effect of instruction time on student achievement is on average not statistically significant and close to zero. However, instruction time with a highly qualified teacher also increases test scores in developing countries.

The positive effect of instruction time on students' test scores and its interaction with teachers' qualifications is of particular importance for policy decisions, especially when considering the impact of the recent Covid-19 crisis on education. As documented by various studies, Covid-19-related school closures led to severe reductions in student achievement (Chetty et al. 2020; Engzell et al. 2021; Maldonado and de Witte 2021; UK Department for Education 2021) and losses in learning time (Grewenig et al. 2021; Woessmann et al. 2021). Lower student competencies and reduced learning time are associated with long-term losses in students' later life-time income and a substantially lower GDP for several decades to come (Hanushek and Woessmann 2020). According to estimates from mostly high-income countries, students' lifetime income losses may range from 1.5 to 5.6 percent if they miss out on one-third of a school year.

[2] In addition, Wedel (2021) examines whether the interaction between instruction time and teacher qualifications also impacts a student's motivation towards the subject. The results do not offer statistically significant results for all teacher qualifications.

In addition, there is evidence that only a small share of students attends additional tutoring lessons, and participation is especially low among socially disadvantaged students, who seem to be particularly hard-hit by Covid-19-related school closures (Chetty et al. 2020; Engzell et al. 2021; Grewenig et al. 2021; Maldonado and de Witte 2021; Woessmann et al. 2021). With more instruction time, especially when taught by highly qualified teachers, the Covid-19-induced learning losses could be mitigated, particularly for those hit hardest by the crisis. Where in-person instruction is not possible due to the pandemic situation, at least hybrid or online models could be employed.

Thus, the task of policy makers lies in finding ways to avert these learning losses to ensure future individual and societal welfare. The reported findings help to assess which measures are useful to counteract lost learning. In developed countries, more learning time could be a straightforward and effective way to increase student achievement. However, it must be scrutinized whether extending the instruction time in a certain subject increases the overall time that students spend in school and whether this is at the expense of breaks, vacation time, or other subjects (Farbman 2015; Jarrett et al. 1998). For example, more instruction time in math at the expense of instruction time in arts and music might improve test scores in math, especially if the lessons are given by a highly qualified teacher. On the other hand, this could affect students' development in terms of creativity, physical activity, and health, particularly in primary school and especially for students from lower socioeconomic backgrounds since they often do not have access to voluntary education outside of school. Hence, potential trade-offs need to be considered carefully. Developing countries, on the other hand, should first focus on the quality of instruction since a mere increase in instruction time does not seem to have a beneficial effect. Policy makers should thus aim at improving teacher training before extending instruction time.

The results described in Wedel (2021) and those of previous research (e.g., Rivkin and Schiman 2015; Lavy 2015) suggest that instruction time is indeed one of the key factors in promoting student achievement and that the quality of teachers, in particular their qualifications, can enhance the influence of instruction time on student achievement. Hence, it is the combination between instruction time and the quality of a teacher that is relevant to student achievement.

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