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Original Paper

Differential Teachers' Attention to Boys and Girls in Mathematics Whole Class Interaction Sequences

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Abstract

The relationship of gender to the quality and type of interaction in the mathematics classroom is a question that has concerned researchers for some time. Past studies have indicated that patterns of interaction can be gender-specific, despite individual teachers regarding themselves as teaching in a gender-neutral manner. Drawing on interaction theory and socialization theory, this quantitative observational study tracked the number and type of interactions in 38 high school Mathematics classes across three schools, involving 899 students and 26 teachers (12 male, 14 female). The study investigated whether there were significant gender differences in the treatment of students during their engagement in different types of questioning behavior. It found that there were significant gender differences at student level that favored boys, but that questioning behaviors amongst individual teachers were highly variable. Teachers' gender did not explain the differences. It is recommended that gender awareness be incorporated into teacher training.

Keywords

observation study, teacher-student-interaction, mathematics, gender differences

1. Introduction

Studies on differential gender-specific interactions between teachers and their male and female students have offered contradictory findings over the last 40 years. For example, in the 1980s Einarsson and Hultman identified a phenomenon they described as the 'two-thirds-principle,' whereby teachers would talk for about two-thirds of the lesson, with boys using two-thirds of the remaining time to communicate with their teachers, and girls receiving the remaining teacher attention time, calculated to be 1/9 of the lesson (Einarsson & Hultman, 1984). Indeed, many studies of co-education have indicated more frequent interruptions of girls' speech, as well as fewer opportunities for girls to respond to

teachers' questions (Hall & Sandler, 1982; Cornelius et al., 1990; Coates, 2004). German replication studies were inspired by feminist research in schools (Spender, 1982) and came to similar conclusions relating to the fact that learning environments for girls were largely male-dominated (Frasch & Wagner, 1982). From the mid-1990s research studies increasingly started to identify a gender shift, in which boys were more likely to be educationally disadvantaged, under-represented in the most academically selective schools, and over-represented in other schools. In addition, researchers have found that they are now more likely to repeat school years and to be enrolled in compensatory special schools (for Germany: Diefenbach & Klein, 2002; also see Buchmann, DiPrete, & Mc Daniel, 2008). Following the "boys-turn," (a term coined by Weaver-Hightower, 2003) researcher's interest in the differential nature of classroom interactions has increased. This was identified as a possible reason for boys' underperformance at school (Beaman, Wheldall, & Kemp, 2006; Consuegra, Engels, & Willegems, 2016). Several authors attributed this to the emergence of female school subcultures following the so-called feminization of the profession, or to the scarcity of male teachers who are not only important role-models for boys, but also potentially act as predictors of educational disadvantage (Budde, 2008; Dee, 2007; Diefenbach & Klein, 2002; for an opposing view see Neugebauer et al., 2011).

Models based on interaction theory as a means of explaining teacher-student interactions describe those interactions as some of the crucial opportunities for learning to occur, for participation and for getting teacher support (Pianta, Hamre, & Mintz, 2010). Whether or not the different sexes have their fair share of opportunities to communicate with the teacher therefore seems to be a relevant question. This paper reports on a study which examines whether there are differences between student-teacher interactions for male and female teachers with the boys and girls in their classroom. The study focusses on whole-class interaction sequences in Mathematics classes.

1.1 Observation Studies on Teacher-student Interactions Based on Interaction Theory Models

Interaction theories serve as a background to explain interaction differences in class, focusing observable behavior. Gender-specific behavior develops due to socially shared beliefs about gender, which both participants bring into an interaction. The influence of the gender category on interactions in classrooms differs because "doing gender" is situationally bound. One of the observable variables of teacher-student interactions is the frequency of students' voluntary participation by raising their hands or calling out answers. This engagement by students is interpreted as resulting from a socially negotiated opportunity, in which student characteristics (such as gender), and teacher characteristics play a major role (Hamre & Pianta, 2007; Pianta, Hamre, & Mintz, 2010). As Pianta et al remind us, 'Engagement reflects relationally mediated participation in opportunity' (Pianta et al., 2010, p. 367), meaning that being called on after raising your hand acts as a proxy for measuring the level of participation a boy or a girl can establish with his or her teacher in a given situation in class. In this traditional initiation-response-evaluation routine, participation is a relational process of establishing a fruitful interaction pattern in a learning situation (critically see Wiliam, 2014). Thus, to explain students' engagement evidenced by raising hands, frequency of answers etc. from an interaction theory

perspective, the social relations between the communicators and their behavior in interactions should be examined (ibid. p. 366). To this end, Pianta and colleagues carried out the NICHD Study of Early Child Care and Youth, in which 2,500 elementary school students were observed. The teachers used a direct instruction method for 85% of the total time. Each child interacted with their teacher fewer than four times a lesson. However, individually experienced positive interactions between teacher and student seem to have a huge potential for increasing student engagement in class (Twenge, Catanese, & Baumeister, 2002).

Participating in classroom talk seems to be significant in terms of effective learning processes, because talking about learning content fosters the development of mental concepts and meaning acquisition (Wiliam, 2014; e.g. for Science Lemke, 1990; Mortimer & Scott, 2003). High-quality classroom talk may represent a fundamental condition for learning to take place and, therefore, and such opportunities should be available to all students on a free and fair basis.

Popular students and those who are more rather than less interested in the subject tend to dominate classroom interactions, which works to their advantage. Therefore, it is important for professionals to be wary of distributing teacher attention unfairly or unevenly, particularly in STEM subjects where boys are traditionally thought to have an interaction advantage, and language and literature-based subjects where the same is thought to apply to girls.

Of course, differentiating between two genders is a relatively crude method of categorizing classroom behavior, and fails to take into account the personalities of individuals, such as ‘silent’ boys who rarely interact with their teachers, or ‘keen’ girls, who make every effort to interact with their teachers. Therefore, we must bear in mind that classifying calling out the answer – without prompting - as typically “boyish” behavior is somewhat stereotypical in itself.

1.2 Gender Specific Interaction Patterns in Classrooms: State of Research

Numerous studies from the 1980s, 1990s and even the 2000s show that boys were more frequently called on than girls. Boys call out the answer without prompting more frequently, and they actively engineer opportunities to interact with their teacher more often (see the metaanalysis of Kelly, 1988; Altermatt, Jovanovich, & Perry, 1998; Becker, 1981; Kahle & Meece, 1994; Sadker, Sadker, & Bauchner, 1984; She, 2000; Mamnoun & Nfissi, 2023). She (2000) found that if boys and girls have an identical ratio in the classroom, boys will answer 78.7% of all the teacher’s questions. In a study which was conducted in a similar manner Altermatt and colleagues reported 60.7% for boys versus 39.3% for girls (Altermatt et al., 1998, similar: Denn, Lotz, Theurer, & Lipowsky 2015; Bassi, D áz, Blumberg, & Reynoso, 2018). However, other studies were unable to confirm those findings (e.g. Brady & Eisler, 1999; Cornbleth & Korth, 1978; Galton et al., 1999) in relation to boys’ over-participation, or found it for elementary school interaction only, but not in high schools (Harrop & Swinson, 2011). None of the studies to the best of my knowledge, ever found a higher participation rate for girls than boys.

A study conducted recently in Science classes in Sweden replicates the findings of the older studies with a higher interaction rate for boys. Based on videotaped lessons of 14 Science teachers (7 of whom

were male) in ninth grade classrooms (age 15) from six Swedish schools (n = 195 students,) the research group found a higher interaction rate with boys in sequences where the teachers engage in whole class communication. The authors interpret their findings as a new confirmation of the so-called two-thirds rule for communication in Science classes (Eliasson, Sørensen, & Karlsson, 2016), which seems to be valid even 30 years after the original findings. The authors consider whether there may be other patterns of interaction at play, given the better overall performance of girls in Science in Sweden despite more frequent interactions by boys. They distinguish between "all interactions" and interactions related to subject content (Science interactions). By doing this, they count interactions in the following way: a) teacher's interactions with the whole class addressing all the students, b) interactions with single boys, c) interactions with single girls. During "whole class interactions", they found 65.4% of interactions directed to all students, 20.8% directed to boys and 13.8% to girls. However, if the researchers only examined the Science interactions, the participation patterns changed slightly in favor of the girls: the "teacher-to-all-students category" now only counted for 46% of interactions; teacher to boys: 32.1% and teacher to girls: 22.0%. Remarkable differences, however, were found if the teacher's gender had been taken into account. Of all the Science interactions of a male teacher, boys' interactions accounted for 31.9% and 17.6% for girls. In contrast, a female teacher interacted with boys in 31.7% and girls in 25.4% of cases. The number of interactions of the male Science teachers with boys was 14.3% higher than with girls (ibid. 1667).

Apparently, many teachers work from a relatively gender-blind position (Garrahy, 2001); they are unaware that they interact differently with boys and girls (Consuegra, Engels, & Willegems, 2016; Younger & Warrington, 2005; Mamnoun & Nfissi, 2023). Younger and Warrington found that teachers believe they do not treat boys and girls differently, while students reported that boys and girls are treated differently in terms of classroom management, teacher attention, teacher support, type of teachers' questions, and teachers' attitudes towards boys and girls (Younger & Warrington, 2005).

Several studies report teachers' higher interaction rates with boys as an attempt to gain or keep control of classroom events. To achieve the boys' attention for the subject at hand, teachers would call on them more often, while this may seem unnecessary with girls showing more commitment to classroom work. International studies as well as German studies found more call-outs from boys. This might explain higher interaction rates, because teachers often do not ignore, but expand on the called-out answer (Francis, 2000; Pas, Cash, O'Brennan, Debnahm, & Bradshaw 2015; Warrington, Younger, & Williams, 2000).

Research from the last decade found contradictory results regarding the question of whether boys receive more negative teacher attention than girls and whether the higher interaction rates are due to more admonitions, rebukes or other negative sanctions. Some studies actually found more negative interactions for boys (Jones & Dindia, 2004; Younger, Warrington, & Williams, 1999). Moreover, some of them report more negative and fewer positive interactions for boys than for girls (Nicaise, Cogerino, Fairclough, Bois, & Davis, 2007; Tsouroufli, 2002). However, others found no difference at all, but

report more interactions for boys on both positive and negative counts (Eliasson, Sørensen, & Karlsson, 2016; Harrop & Swinson, 2011, Merrett & Wheldall, 1992,).

Significantly more interactions with boys were reported by Swinson and Harrop (2009) in a study with 18 elementary school classes and their teachers in five different schools. Teachers praised boys significantly more often for their academic achievement and criticized them more often for social behavior than girls. The higher rates of teachers' interactions with boys are, according to this study, not to be explained by some very active boys drawing all the attention on themselves (ibid.). Compared to the boys, girls only had 65% of the boys' rates of "instruction and redirection" interactions. Swinson und Harrop explain the higher interaction rates for boys with the teachers' attempts to influence the work behavior of the boys to some extent by giving them instructions and redirections more frequently. Boys pose– as expressed by Beaman and colleagues – the higher management challenge (Beaman, Wheldall, & Kemp, 2006, p. 522).

A meta-analysis of gender-specific interactions with an analysis of 27 studies (cf. Jones & Dindia, 2004) reports that, overall, teachers have more interactions with boys. In contrast to the findings of Swinson and Harrop, Jones and Dindia found more negative interactions. The average effect size was significantly different from Zero, but small with d = .14 and heterogeneous ($\chi^2(26) = 95.86$, $p < .001$.). That is to say, there are moderating factors, which can explain the interaction behavior of teachers (Jones & Dindia, 2004, p. 454).

Many studies from 1970s to the present day show that the number of interactions not only depends on students' gender, but also on the gender of teachers. However, the findings are inconsistent: on the one hand, particularly high interaction rates for boys are reported if their teacher is male (e.g. Karp & Yoles, 1976; Eliasson, Sørensen, & Karlsson, 2016). In other studies, this is the case in female-taught lessons (Boersma, Gay, Jones, Morrison, & Remick, 1981). According to a study carried out by Jones and Wheatly (1990), male teachers pose twice as many questions as female teachers in Science classes. A college study shows that of all the direct questions, male teachers are more likely to direct them at boys, whereas female teachers direct them at boys and girls to the same extent (Karp & Yoles, 1976). Koca also found a significantly higher number of interactions of male than of female teachers with boys in a Turkish study in Physics (Koca, 2009). In an observation study with nearly 600 students and 36 teachers in 18 Mathematics and English (mother tongue) classes respectively, there was a higher number of interactions with boys found amongst female Mathematics teachers (similar Einarsson & Granström, 2010) and among English Language and Literature teachers of both sexes (vgl. Duffy et al., 2001).

The lowest rates of interactions for girls in the aforementioned study by Eliasson and colleagues (2016) were found among male Science teachers (in contrast with non-Science subjects: Malik, Javed, & Dilshad 2018). All researchers report consistently higher interaction rates for boys than for girls, but in some cases, it is the male teachers who do this, and in other cases, the female teachers. Croll (1985), Howe (1997), Jungwirth (1991a), and Thies and Röhner (2000) found no differences between male and

female teachers. In all of the studies however, there were different interaction rates in terms of students' gender. Overall, huge observation studies which include teachers' gender are, to date, rare. So whether there is a gender-specific disadvantage remains unclear. Whether or not teachers' gender plays a role explaining different interaction rates of boys and girls is the topic of the present study.

1.3 Measurement Methods of Interaction-theory Based Observational Studies

Most research on human interaction uses observational instruments. Findings support the assumption that it is crucial to consider differences between the interaction forms, in order to explain causes for differing interaction behavior of teachers (see e.g., Swinson & Harrop, 2007). A couple of observational instruments which were developed for the purpose of observation and analyzing teacher-student interaction are already available. One example is the INTERSECT-sheet (Interactions for sex equity in classroom teaching, Sadker et al., 1984) which collects forms of interaction using the categories of: "problem solving", "microteaching", and "control" for situations involving behavior regulation. The Brophy-Good Dyadic Child Interaction System (Brophy & Good, 1969; 1974) evaluates three main categories, namely academic response opportunities, non-academic teacher-initiated interactions (into which category fall all calls on students that are linked to behavior regulation), and student-initiated interactions, (e.g., with student questions). Each interaction was coded in one of three main categories, and additionally into 40 subcategories, which made the system unwieldy difficult to handle. Researchers experimented several times with combined categories (e.g. Good, Cooper, & Blakey, 1980). In the work of Brophy & Good, the academic response opportunities included process or product-related questions by the teachers, after which they (a) randomly called on a specific student, (b) a student called out an answer, or (c) open questions, after which the teacher waits for voluntary hand-raising by the students and then calls on one of them.

In Germany, Sacher (1994) developed a simple system for differentiating students' participation in classes. It listed activity, passivity, and answering with or without being called on by teachers. He suggests distinguishing the following interaction forms: A: student raises his or her hand and is called on; B: student raises his or her hand and is not called on; C: student talks without being called on; and D: student, who has not raised his or her hand is called on.

We used an observation sheet based on this groundwork in the present case because we aimed to collect information only about subject-related interaction situations, and not behavior-related interactions such as admonitions, rebukes etc.

1.4 Research Questions and Hypotheses

Based on our review of the research we can assume that teachers will interact differently with boys and girls. We evaluate the hypothesis of a quantifiable preference of boys in teacher-student interactions with a large sample of lessons and teachers. With the subject of Mathematics, we investigate one of those subjects in which gender type-casted self-staging of young people and stereotypical beliefs and expectations of teachers supposedly are at play.

The reasons for different interaction behaviors by teachers are most likely not only to be found in students' gender. Regarding teachers' gender, the findings to date are inconsistent. Consequently, in our study we investigate the effect of teachers' gender as a moderator of the difference in interaction rates with boys and girls. Because several studies report different rates for boys and girls for different forms of interaction, we include three different forms. This is based on findings which report that girls are less active in classes and raise their hands voluntarily less frequently than boys. Therefore, we presume that teachers might favor girls in choosing them even in the absence of hand-raising to compensate for their less frequent participation in voluntary forms of interactions. Hence, the study poses the following research questions:

Are there differences in the interaction frequency of boys and girls with their teacher in Mathematics classes? Does the form of interaction (being called on with or without hands up or calling out an answer) play a role? Is there a moderation effect of teachers' gender and interaction frequency? This leads to the following hypothesis:

H1a: In Mathematics whole class sequences, boys interact more frequently with the teacher than girls. This is true for the number of (a) interactions with previously raised hands, and (b) call-outs.

H1b: Without previously raised hands, girls interact more frequently with their teacher than boys.

H2: Teachers' gender affects the interaction frequency of boys and girls.

H3: The effect of students' gender is different for single teachers, even if teachers' gender is accounted for.

Presuming that with H2 the alternative hypothesis is to be accepted, we therefore claim that teachers' gender does not explain differences in interaction frequencies of boys and girls, but the teachers themselves – independently of their gender – show different gender-related interaction behavior. We will investigate interactions with boys and girls in an additional individual teacher analysis.

2. Method

We conducted the study at high schools in Germany, where school principals and teachers accepted college students as observers in their classes. We informed the school principals about the goals of the study, whereas the participating teachers were told that the participation as shown by students' hand-raising would be observed. Students who were enrolled in a masterclass as part of an educational science program at the university performed the observations. The observers were thoroughly trained on the observation sheet. Double coding was not needed, because the observation categories were clearly distinct.

2.1 Sample

In three schools, 38 classes were observed during 78 Mathematics classes. 26 teachers taught these classes, 12 of whom were male, and 14 female. The student sample consists of 899 students (49.8% male). Table 1 shows the distribution of grade levels and gender.

Table 1. Student Sample by Grade and Sex

		grade						
		5	6	7	8	9	10	sum
boys	*n*	71	97	108	51	45	76	448
	%	62.3%	47.8%	60.7%	54.3%	35.4%	41.5%	49.8%
girls	*n*	43	106	70	43	82	107	451
	%	37.7%	52.2%	39.3%	45.7%	64.6%	58.5%	50.2%
sum	*n*	114	203	178	94	127	183	899
	%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

2.2 Measurement of Interaction Behavior

Observations took place as structured, openly and sitting passively at the back of the classroom (see Atteslander, 2010). The observers only coded interactions in teacher-fronted whole class teaching sequences. If silent individual seatwork, partner or group work took place, which incidentally, rarely happened, the respective sequences were not encoded. The study therefore contains only data from sequences where the teacher worked with the entire class. Based on the distinction of Sacher (1994) and the Brophy/Good-system, we developed an observational sheet with only three distinct categories, because in our case only those children (or their interactions) should be counted who were actually successfully involved in subject-related interactions with their teacher. We define interactions as verbal statements or non-verbal interactive gestures (such as shaking one's head in direct response to a teacher question, shrugging…), which happen in public whole class interaction situations. Therefore, we encoded three possible interaction forms: (1) Call-on after raising hand, notwithstanding whether the hand-raising happens after a teacher question or voluntarily. Interactions which were related to topics outside the subject at hand (e.g. call-on because of a missing parent signature), were not encoded. The frequency with which individual students raised their hands but were not called on, were also not encoded. Instead, only successful hand-raising leading to an interaction with the teacher was coded. We replicated the procedure of Eliasson and colleagues (2016), who counted student-initiated interactions which were not interrupted by other interactions, as one contact. However, if the teacher addresses another student in between, the interaction is considered as finished. (2) Call-ons without hand raising: The student is called on by name, or nodded at by the teacher without a previously raised hand. If a student is individually called on but does not answer the question, the sequence was coded as interaction, because it is the teacher's call on behavior that matters here. A refusal to answer is, therefore, an interaction, too. (3) Call-outs: The student calls out without being asked to talk and the teacher picks up his or her contribution to the subject at hand. If several students were calling out following a question by their teacher, and were ignored, the answer or comment is not encoded as interaction. All sequences of interaction were encoded if they were related to the topic at hand. The

observation sheet contained the three interaction forms as simple symbols (see figure 1). A stretched finger for call-ons after raising hand, a crossed-out stretched finger for call-ons without previously raised hand and a loudspeaker for call-outs.

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Figure 1. Scheme of the Observation Sheet

With the help of a classroom seating plan, the observers could now count the teacher-student interactions easily. For data analysis, we calculated the means of the interaction frequencies of all three categories in all of the observed lessons in which an individual student was present. In this way, we measured his or her participation in whole class interaction sequences. As a result of the teachers' schedules, the number of lessons observed varied from one up to 10 lessons per teacher.

2.3 Statistical Analysis

Multivariate analysis of variance (MANOVA) has been used to test the hypotheses. Dependent variables were frequency of interaction after teachers call on a student with or without previously raised hands, and call-outs. To test for the influence of teachers' gender on the frequencies of interactions with boys and girls MANOVAs were calculated with students' gender and teachers' gender as fixed factors. Since the data have a hierarchical structure, the different teachers were included as random factor nested under the factor of teachers' gender. The significance level was set to 5%. Since the condition of approximately normal distribution was not met, Mann-Whitney U-Tests were used to check the results. However, they confirmed the results of the ANOVA in every single case.

3. Result

3.1 Effect of Students' Gender on Frequencies of Interaction

Overall, the observers noted 3,972 sequences of interaction. On average, teachers interacted 2.3 times a lesson with a student (SD = 1.7; Min. = 0.61; Max = 8.84). Interactions with boys account for 58.1% of all interactions, and interactions with girls for 41.9%. Considering that the sample comprises 49.8% males and 50.2% females, boys apparently have a higher, and girls a lower interaction frequency than their gender-proportion in class would suggest. Some students never interacted with their teacher: 4.3% of all boys and 6.4% of all girls. The higher number of irregular call-outs from boys, consistently reported in the research over the years, was found here, too: 61.9% of successful call-outs came from boys. Table 2 shows the mean values of the three interaction forms for boys and girls.

Table 2. Mean Interaction Frequency per Maths Lesson by Form of Interaction and Sex

		all interactions		hand-raising				Call-outs	
				with		without			
	N	*AM*	*SD*	*AM*	*SD*	*AM*	*SD*	*AM*	*SD*
boys	448	2.43	2.50	1.49	1.98	0.56	0.89	0.38	0.84
girls	451	1.73	1.87	1.06	1.42	0.46	0.67	0.21	0.60

Main effect of students' gender: H1a postulates differences in the frequencies of interactions between the gender groups. Multivariate analysis reveals that the differences are significant: Boys have higher interaction rates than girls (λ = .96; F(3, 845) = 11,04; p < .001; partial η^2 = .038). The respective ANOVAS show that this effect results from a significant main effect for the different types of interactions with small to medium effects (after raising hand F(1; 42.11) = 5.99, p = .015; partial η^2 = .007; without raising hand F(1; 30.66) = 6.27, p = .012; partial η^2 = .007, and after call-outs F(1; 34.99) = 25.06, p = .001; partial η^2 = .029). Teachers do not compensate for the more active participation of boys in voluntary whole class talk by calling on girls without hand-raising. Hypothesis H1b therefore has to be rejected.

3.2 Effect of Teachers' Gender on Interaction Frequencies

Hypothesis 2 addressed the question of whether different interaction frequencies of boys and girls are a result of teachers' gender. The descriptives show differences in interaction rates of male and female Mathematics teachers as shown in table 3. Boys have the highest interaction frequencies in classes taught by a male teacher (M = 2.50) whereas girls with male teachers have the lowest rates (M = 1.58). Note that the standard deviation value of the boys (SD = 3.02) speaks of major differences between boys, too.

Table 3. Interaction Frequency of Boys and Girls by Teachers' Gender

				boys		girls	
		AM_{all}	SD_{all}	*AM*	*SD*	*AM*	*SD*
male	all interactions	2.02	2.58	2.50	3.02	1.58	1.99
teacher	with hand-raising	1.23	2.03	1.58	2.46	0.92	1.47
	without hand-raising	0.51	0.88	0.57	1.04	0.45	0.69
	call-outs	0.28	0.71	0.35	0.83	0.21	0.56
female	all interactions	2.13	1.89	2.38	2.01	1.87	1.73
teacher	with hand-raising	1.31	1.44	1.42	1.50	1.19	1.35
	without hand-raising	0.52	0.71	0.56	0.74	0.47	0.66
	call-outs	0.31	0.76	0.40	0.85	0.31	0.76

Main effect of teachers' gender: There also is a significant main effect for the fix factor teachers' gender (λ = .98; F(3, 845) = 6.02; p < .001; partial η^2 = .021), which means that male and female teachers differ in their interaction frequencies in class. The difference is not significant for call-ons after raising hand (F(1; 25.43) = 3.31; p = .069; partial η^2 = .004). However, there is a small effect for call-ons without hand-raising F(1; 25.45) = 10.710; p = .001; partial η^2 = .012) and for call-outs F(1; 28.03) = 5.86; p = .016; partial η^2 = .007) indicating that female teachers interact a little more frequently with their students in these interaction forms than males.

No Interaction effect between students' gender and teachers' gender: multifactorial analysis of variance shows a non-significant result for the interaction between students' and teachers' gender (λ = .99; F(3, 845) = 2.33; p < .073; partial η^2 = .008). Also, none of the ANOVAS analyzing the three forms of interactions were significant (call-ons after hand-raising F(1; 42.12) = .46; p = .504; partial η^2 = .001), call-ons without hand-raising F(1; 30.66) = .338; p = .565; partial η^2 = .001), and call-outs F(1; 35.00) = 3.50; p = .070; partial η^2 = .007).

Differing frequencies of boys and girls are found with teachers of both genders, or at least we found no clear evidence against it. However, the high F- and p-values for call-outs suggest the need for further verification of the findings in the future.

3.3 Effect of Teacher on Interaction Frequencies of Boys and Girls

Main effect of teacher: The MANOVA indicates a significant effect of the teacher (λ = .43; F(72, 2526.13) = 11.36; p < .001; partial η^2 = .244), which is substantial in all interaction forms (after hand-raising F(24; 24) = 11.10; p = .001; partial η^2 = .294; without hand-raising F(24; 24) = 4.37; p = .001; partial η^2 < .291; call-outs F(24; 24) = 2.58; p = .012; partial η^2 = .132). The partial η^2 values with around 30% variance explanation point to a considerable effect of the teacher. Thus, teachers differ substantially in terms of designing opportunities for children to interact with them in whole class situations. That is to say there are teachers who, overall, shape these sequences as interactive, and there are others who arrange whole class interaction sequences, where interactions with teachers are rare, meaning that the teacher does most of the talking. Since teachers' gender shows only a minimal main effect on interaction frequencies, we now see that the variance between individual teachers is larger than between the gender groups.

Interaction effect of students' gender and individual teachers: The analysis of interaction effects between students' gender and teacher-id as random factor offers a significant result (λ = .84; F(72, 2526.13) = 2.11; p < .001; partial η^2 = .056). For call-ons after hand-raising there is no significant interaction effect (F(24; 847) = 1.32; p = .138; partial η^2 < .036). But for interactions without hand-raising F(24; 847) = 3.31; p = .001; partial η^2 =.086) and after call-outs (F(24; 847) = 2.07; p = .002; partial η^2 = .055) the results are significant.

We may conclude that there are considerable differences between teachers in terms of their gender awareness regarding interactions without previously raised hands, and interactions after call-outs. Interestingly, this refers to those interaction forms where gender-specific student behavior was found in

the past: the higher number of call-outs of boys and the lower participation of so-called “silent girls” who only interact if the teacher calls on them explicitly. The interaction effect explains approximately 6% of total variance of interaction frequency after call-outs. We found a significant interaction effect of teacher-id and students’ gender regarding call-ons without previously raised hands, indicating that there are teachers who interact more frequently with girls without hand-raising to compensate for low voluntary participation efforts. The variance explanation here is approximately 9%. The following figure illustrates the considerable effects on teacher level by showing the differences in interaction frequencies of the student gender groups with individual teachers (see Figure 2).

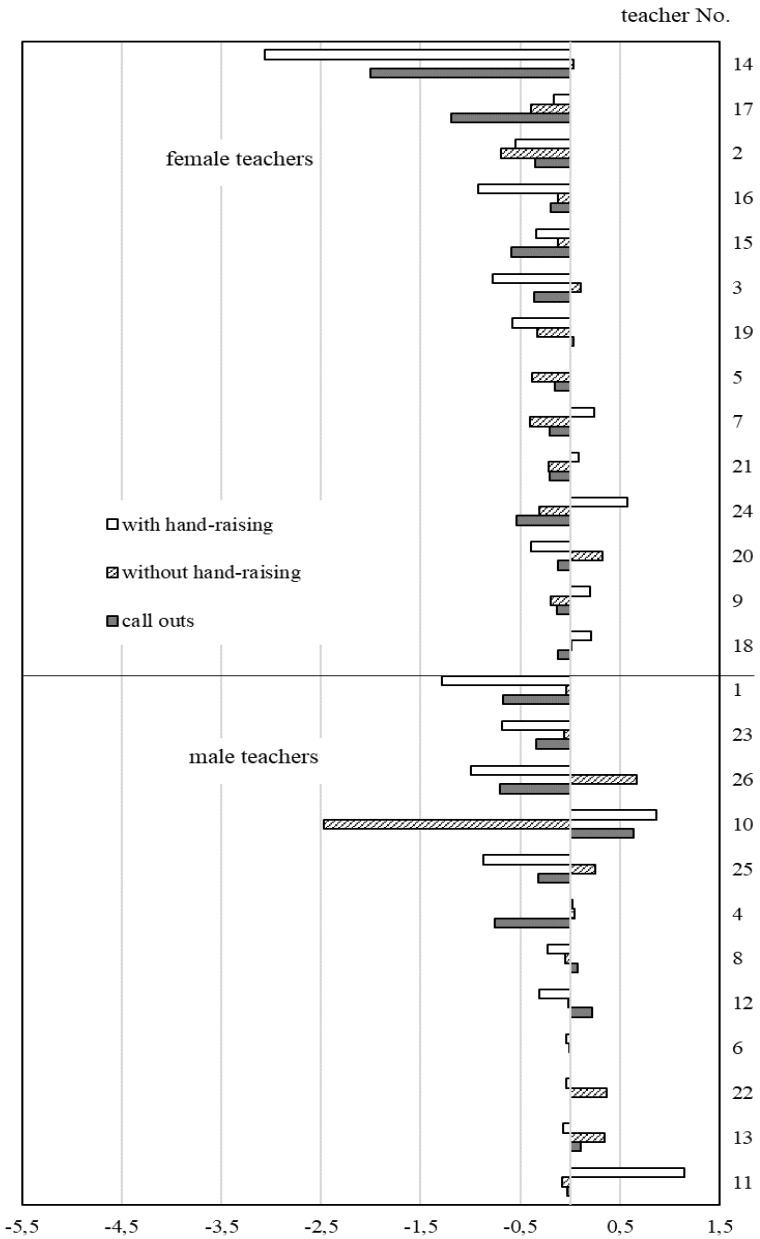

Figure 2. Difference of the Mean Interaction Frequencies for Gender and Teacher (from the Perspective of Girls)

The figure illustrates why the interaction effect of students' gender and teachers' gender is non-significant: There are male as well as female teachers who show quite a balanced distribution of interactions with the students. In addition, there are teachers of both sexes who elicit a clear disproportionate participation by boys. The biggest differences though, exist between teachers as such, not between the sexes. In other words, Mathematics teachers vary in their interaction patterns within their gender more than between the gender groups.

Considering the differences between the teachers in Figure 2 regarding the different interaction forms, there are recognizable patterns which would suggest further investigation with an even larger sample, maybe clustering patterns according to types of teachers: Most teachers interact more with boys than with girls in all forms of interaction. Hence, there is a small group of teachers who interact with girls more frequently than with boys without hand-raising. They could potentially compensate for the reserved participation of girls. An even smaller group interact more with girls than with boys; in our sample 4 out of 26 Mathematics teachers, one of whom is male.

4. Discussion

This observational study recorded three different forms of interactions in whole class teaching sequences in Mathematics lessons, namely interactions after hand-raising, without hand-raising and successful call-outs (when the teacher acknowledges the called-out answer and uses it to go on). We encoded only subject-related interactions referring to subject matter this procedure is in line with suggestions of interaction researchers, who point out that in many studies the reported disproportion between the number of interactions of boys and girls might be a result of not distinguishing between subject-related and non subject-related interactions (Eliasson et al., 2016).

Results on student level: There was a significant main effect of students' gender found in all interaction forms except for interactions without previous hand-raising, each with a higher number of interactions for boys. These results are primarily explained by the higher number of boys' call-outs. However, teachers interact more frequently with boys after and without hand-raising, too. In our interpretation the results, it should be noted that most studies working without videotapes (as is the case here, too) do not count the total number of hand-raisings after a teacher question. We therefore cannot know whether the higher number of boys' interactions is a result of a higher rate of hand-raising, or if girls raise their hands as often as the boys, but are called on more rarely. Prior research is contradictory here; some findings reported higher girls' participation in terms of subject-related questions and a higher participation in inquiry learning processes (Younger et al., 1999). Other studies note lower female activity in whole class interaction sequences (Jones & Wheatly, 1990; Kahle & Meece, 1994), which for Mathematics is explained by girls being less willing to participate in small step question-answer teacher-led procedures (Jungwirth, 1991a, 1991b). In an elementary school study with videotaped Mathematics lessons, a group of researchers from Germany found no differences in the hand-raising frequencies of boys and girls. However, the teachers interacted more frequently with the boys (Denn,

Busse, & Lipowski, 2019).

In our study we expected that teachers would call on girls more frequently without previous hand-raising. Truly, we found a smaller disproportion between boys and girls in this interaction form, but even here the difference remains significant. Some teachers try to compensate for lower female activity by calling on them without them raising hands. We found considerable interindividual differences within the gender groups. In fact, studies regarding gender are always subject to the risk of overestimation of gender effects and disregard of other causes for different behavior (Hammersley, 1990). Dynamics which are connected to the social composition of the class come into play. Current studies of school context variables such as the socio-economic status of the children and its effect on gender differences in terms of achievement suggest that the school environment shapes conceptions of masculinity and affects certain anti-school attitudes of boys, which in turn is connected with composition effects in adolescent peer-cultures (Willis, 1981; Heyder & Kessels, 2017; Legewie & DiPrete, 2012).

Additionally, there are situational influences such as current events, quality of teacher-student relationship, teachers' classroom-management competencies, etc., which can all affect the participation behavior of adolescents. Following the model of social interaction of Deaux and Major (1987) gender-specific behavior is influenced by the self-perception of the actor, expectations of interaction partners, and impacts of the situation. In this respect, apparently short-term situational influences seem to be particularly important. Whether or not gender stereotypes influence teaching, or gender-related cognitive schemata come into effect and result in gender-typical behavioral patterns, seems to depend on the specific teaching situation. Thus, the teacher can influence how intense the category of gender affects behavior in the classroom (Jones & Dindia, 2004, p. 456).

During puberty, adolescents develop their gender identity by clear demarcation from the other gender (Kessels, 2002). Differences between the gender groups are particularly noticeable in this period of development (Galambos, Petersen, Richard, & Gitelson 1985). At present, boys seem to feel a more significant adjustment pressure regarding gender stereotypes than girls (Bussey & Bandura, 1999; Hartmann & Trautner, 2009). Changes in gender-related self-presentation during adolescence are explained with global stereotypes, which are definitely helpful in quick information processing. Global stereotypes tend to become diversified in sub-stereotypes, which are used by the acting subject in specific situations (Eckes, 1997). A Mathematics lesson in such a situation, where boys and girls stage a specific form of masculinity or femininity in which stereotypes are identifiable. Following the gender-intensifications hypothesis of Hill and Lynch, gender-typical behavior increases during puberty (Hill & Lynch, 1983; see also Kessels, 2002). Frenzel, Goetz, Pekrun and Watt (2010) investigate the prevalence of the gender-intensification phenomenon in Mathematics classrooms. The authors were able to confirm its existence, albeit not in all age groups. Particularly for girls, evidence was found to confirm the hypothesis: Girls try even harder not to behave as the other gender does. These theoretical approaches can explain findings reporting a significant decrease in high-achieving boys' voluntary

participation, boys who during elementary school still had the highest levels of participation (Myhill, 2002). The author explains her findings with reference to socialization theory and forms of staging masculinity, which suggest that boys during puberty have to act "cool" so participating actively and voluntarily in classroom talk is perceived as uncool and unmanly (Heyder & Kessels, 2017; Myhill, 2002). However, our data suggest that boys make better use of the resources than girls if we take into account the opportunities to interact with their teacher.

Findings on teachers: The current study was unable to confirm any effect of teachers' gender on the participation frequency of boys and girls in whole class interaction sequences. In fact, we found -descriptively- the lowest interaction frequencies for girls with male Mathematics teachers and the highest for boys with male teachers. With female teachers, however, the girls had fewer interactions than boys, too, and by means of analysis of variance there was no corresponding statistically significant finding behind this data. A same-gender hypothesis, whereby girls might have higher chances of participation with female teachers, and boys with male teachers, was not verifiable (Powell & Downey, 1997; on the "myth of the same-sex teacher advantage" see also Neugebauer et al., 2011). The main difference resides in individual teachers, regardless of their gender. Teachers differ significantly regarding the disproportionate participation of boys. This is why the question of how often a boy or a girl gets the chance to interact with his or her teacher depends mainly on which teacher teaches in the classroom: the effect of teacher-id explains 25% of the variance of the interaction frequencies. The interaction effect of teacher-id and students' gender accounts for between 6 and 9% of the variance regarding the different forms of interaction. Thus, there is not only an unequal treatment of the gender groups by individual teachers, but there are huge differences between teachers or lessons in which children have few opportunities for participation, regardless of their gender.

Several explanations are possible here, which in part may have their origin in the teacher. Studies on teachers' patterns of coping with vocational stress and challenges confirm that teachers with risky coping strategies tend to design lessons with reduced potential for student participation to ensure undisturbed, quiet lessons (Klusmann, Kunter, Trautwein, & Baumert, 2006). On the other hand, there are classes in which students work independently and where the teacher functions as a facilitator of self-organized learning activities, or lessons with lots of group work and few teacher-centered sequences. Nonetheless, in such group work phases there are teacher-student interactions as well, but they were not measured here. A fundamental question seems to be whether lessons without student hand-raising might lead to fair participation for everybody: Wiliam suggests implementing routines where the teacher chooses students at random and students only raise their hands if they want to pose a question (Wiliam, 2014).

The phenomena of both gender blindness and gender awareness could perhaps provide an explanation for teachers' behavior. Other studies report low gender awareness among future teachers (Sikes, 1991; Scantlebury, 1995). Lots of teachers consider gender questions as settled. Nobody seriously questions women's equal rights, and girls are extremely successful at school So, where is the problem? In Belgian

high schools, Consuegra and colleagues found that at first glance, the explicit utterances of teachers about their classes were gender neutral. As soon as the authors measured perceptions of specific videotaped teaching sequences via subsequent thinking aloud, the thoughts of teachers were clearly gender-differentiated (Consuegra et al., 2016). The teachers were not aware that their comments on individual students "implicitly expressed gender-differential expectations and approaches" (ibid, p. 692). Two thirds of all thoughts referred to rule violations by boys. The authors emphasized that this does not say something about the overall amount of disruptive behavior of the gender groups, but rather illustrates the fact that male rule violations are perceived by the teacher to a greater extent. Even during subsequent reflection, the teachers were not aware that they made gender differences in their thematic attentiveness (rule violations, negative attributions about individual boys and girls). Accordingly, they did not notice that most of their comments on specific interaction sequences which referred to desirable conduct (attentiveness, helping the teacher, working cooperatively, being silent, concentrating on a task etc.) were related to boys as well (ibid., p. 691).

The teachers named a very broad range of positive aspects regarding boys whereas the range for girls was considerably smaller, and – according to the authors – more likely with regard to subject-related issues than to social behavior. Considering these findings against the background of the significant differences between individual teachers found in our study, we may assume that among all variables affecting teacher-interactions with boys and girls the extent of their gender awareness may play a crucial role. Younger and Warrington in their study base their argument on the construct of gender blindness because they were able to show that teachers were not aware of their differing behavior towards boys and girls, whereas the participating children definitely perceived the gender-specific differences in teacher behavior und could describe them precisely (Younger, Warrington & Williams, 1999; see also Raider-Roth, Albert, Bircann-Barkey, Gidseg, & Murray 2008). Expectancy effects, the impact of which on student learning have been shown repeatedly, may hereby be of particular importance (Brophy, 1982; Van Houtte, 2007).

Whether or not in a specific classroom interaction sequence gender schemes were activated seemingly plays a major role in explaining to what extent students stage gender-typical behavior. Mechanisms of reproduction of gender hierarchy, or processes of stereotyping, typically take place unconsciously und lead to differentiated teacher behavior towards boys and girls (e.g. for interactions in Maths Jungwirth, 1991b). Apparently, gender awareness/sensitization training programs for teachers can be successful (Kuruvilla, 2014; Kolovou, Ran, & Secada, 2023). However, due to the gender blindness of many teachers, Consuegra and colleagues presume that teachers do not readily enroll in relevant training programs. Because teachers are not aware of any problematic behavior on their side, they would not look for gender-sensitive teaching strategies.

Several studies show that teachers interact with boys more frequently to ensure their on-task behavior (Beaman et al., 2006; Swinson & Harrop, 2009). Externalized disruptive male behavior is said to happen more often in classes with higher deficits in rule compliance and leads to a higher number of

call-outs, for example. Future research on gender specific interactions in classes should take differences between classes and teachers into account when designing a study. On the teacher's side, more variables beyond only subject and gender should be included, to answer the question of why some teachers have a balanced participation of both genders in their whole class interaction sequences. Perhaps scales on gender awareness could support this research. Interpreting the opportunity for interaction with the teacher as a chance for participation and teacher support (Pianta, Hamre, & Mintz, 2010) and insofar as it is an important resource for learning, more studies that address mechanisms of participation and non-participation are required. It could be helpful to include classroom composition effects, hence the need for multi-level analysis.

Practical Implications: Teacher education should focus on addressing an attentiveness to gender inequities in teacher attention and highlight potential consequences. It may help to call on students in turn when there is an approximate equal distribution of genders in the class. Collegial classroom observations can help to identify unconscious patterns of interaction and thereby make these patterns changeable. Against the background of the considerable effects of good classroom management on learning outcomes, it seems essential to consistently prevent disruptive and space-consuming calling out of answers by means of interventive classroom management strategies. This alone would provide the quieter children (boys as well as girls) with the attention they deserve.

Limitations: The findings of this study should be interpreted against the background of some limitations. Even though trained observers performed the classroom observations, there were no second coders. However, since the observation instrument simply consists of three distinguishable manifest categories and we coded only subject-related whole class interaction sequences, reliability issues seem to be accounted for. The observations took place at only three Bavarian high schools, but we managed to extend the sample to 26 teachers and 38 different classes, which represent the age groups of the children quite well. However, a generalization that extends to all school types should not be made without further consideration. Considering comparable studies in high schools, our finding of a significantly higher amount of boys' participation in classroom talk is consistent.

A note of caution is called for here since the number of observed lessons per teacher and class vary between only one and up to 10 lessons. Statements on individual teacher differences should therefore be made with caution, particularly as we have no further information on the teachers and classes which could explain their specific interaction behavior.

Forecast: Further research which observes more classes with individual teachers should be undertaken in order to account for specific didactic characteristics of classes (group work phases, individual seat work phases). There is abundant room for further progress in determining connections between teacher expectancy effects und interaction frequencies. Recently applied network analyses, as a methodological option that has been rarely tested to date, seem to be a promising approach studying gendered classroom interactions when combined with video observation (Ortega, Trevino, & Gelber, 2020). To take the gender intensification theory into account, sufficient samples for different grades should be

included. Studies on the effects of gender blindness or gender awareness as a potentially powerful predictor provide a promising perspective of future observational studies on gender-specific interaction behavior.

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