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Teacher–student interaction in contemporary science classrooms: is participation still a question of gender?†

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ABSTRACT

We show that boys still have a greater access to the space for interaction in science classrooms, which is unexpected since in Sweden today girls perform better in these subjects than boys. Results from video-recorded verbal communication, referred to here as *interaction*, show that the distribution of teacher–student interaction in the final year of lower secondary school follows the same patterns as in the 1980s. The interaction space for all kinds of talk continues to be distributed according to the two-thirds rule for communication in science classrooms as described by previous research. We also show that the overall interaction space in science classrooms has increased for both boys and girls when talk about science alone is considered. Another finding which follows old patterns is that male teachers still address boys more often than girls. This holds true both for general talk and for talk about science. If a more even distribution of teacher–student interaction is desirable, these results once again need to be considered. More research needs to be undertaken before the association between girls' attitudes and interest in science in terms of future career choice and the opportunity to participate in teacher–student interaction is more clearly understood.

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Teacher–student interaction; science education; gender; two-thirds rule

Introduction

Serious concerns about the low recruitment of women to higher education in science, technology, or engineering (SET) have been expressed as far back as in the 1960s. Despite little, if any, gender differences in terms of students' attainment in science, women remain under-represented (Smith, 2010). Extensive research, mainly in the 1980s, focussed on identifying the barriers to female participation in SET and on finding successful strategies for attracting girls (Kelly, 1981, 1988; Sørensen, 1986, 1990; Whyte, 1986a, 1986b).

In the past, research has shown that boys in Sweden and in many other countries performed better than girls in science (Beaton et al., 1996; Johnson & Murphy, 1986; Utbildningsdepartementet, 2004) and that one possible barrier for girls' involvement in SET could be explained by boys' domination in science classrooms with respect to teacher–student interaction. Research also showed that a distribution according to a two-thirds

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rule[1] could be used to illustrate teacher–student interaction. With this distribution, teachers used two-thirds of the total available space for communication, while boys used two-thirds of the remaining space. This left girls with one-ninth of the total space for communication (Einarsson & Hultman, 1984).

One question is whether it is possible to explain a change in science performance in favour of girls if they are given more opportunities to participate in the general space for interaction in conjunction with school science education. Therefore, the main focus for this study is to examine whether teacher–student interaction today is different compared to teacher–student interaction presented by research about 30 years ago. This is interesting since contemporary Swedish girls at the end of compulsory school perform better in science on national tests, have higher final grades, and also perform better according to international student assessments compared to boys (Skolverket, 2009, 2013). For example, the results for Swedish boys and girls, according to the Programme for International Student Assessment (PISA), have declined since the first assessment in 2000 from a position high above the OECD average to below the mean compared to other members in OECD in 2012. Although the PISA results have been declining over this period, Swedish girls have more or less performed at an equal level as boys in science. However, from 2006 onwards, the deterioration in boys' results has been larger than that for girls, and in PISA 2012, girls performed better than boys in science for the first time (Skolverket, 2013). Other findings show that girls choose not to pursue science, even though they are both competent and believe in their capability to succeed, and some, but not all, studies suggest that one of the most important factors behind students' attitudes towards science is gender (Osborne, Simon, & Collins, 2003).

The study of this subject is also interesting since recent quantitative research on teacher–student interaction is rare. We will use the term *interaction* for the verbal public communication that takes place between teachers and their students in science classrooms.

Einarsson and Hultman (1984) described the distribution of teacher–student interaction in the middle of the 1980s, and one question is whether this distribution still applies. This article shows how teacher–student interaction is distributed between science teachers and their Grade 9 students from six different Swedish schools. Video-recorded classroom observations were the basis of the analyses of sequences where teacher–student interaction takes place.

Background

Do gender differences in teacher–student interactions matter?

In a study like this, biological sex is the only way to categorise boys and girls when a different number of events are to be quantified. This is one reason why it is sometimes hard to avoid a neutral approach to gender when writing and reading a quantitative report like this or other similar reports. Boys and girls in text and data are often treated as belonging to two distinct groups. Therefore, it may seem like assumptions about any gender differences are attributed to every boy or girl in each group (Murphy & Whitelegg, 2006). We believe that all differences referred to in this study are to be considered as trends at a group level and not to all members belonging to each single group. We also share the broad view of

gender as constructed in social interaction rather than as a fixed attribute of an individual. With this in mind, we return to the question about gendered differences in teacher–student interaction and why this may matter at all.

There is survey evidence that uncovers gender differences in reported interest in science (Murphy & Whitelegg, 2006) and for different subareas in science (Oscarsson, 2011; Schreiner, 2006; Sørensen, 2008). Boys are reported to have 'a consistently more positive attitude to school science than girls, although this effect is stronger in physics than in biology' (Osborne et al., 2003, p. 1062). Research has also shown that students with prominent positions in a group tend to influence communication in a way that affects lesson content in a direction towards their own interests (Öhrn, 2002).

This difference in interest, together with a possibility to influence content, is one reason why a skewed distribution of teacher–student interaction may contribute to increased benefits for a particular group. To be engaged in talking during science lessons also matters since talk in itself is seen as central to the meaning-making process and is central to learning (Mortimer & Scott, 2003). In other words, to learn science involves learning to talk science, and students learn to talk science through the classroom discourse (Lemke, 1990). This includes not only understanding different science concepts, but also learning how to use structures and features of the scientific language (Ødegaard & Klette, 2012). This is why patterns of teacher–student interaction in science class are both important and interesting to study.

Another aspect to consider is the picture of teachers as an important resource for learning. In their work *Promoting Effectiveness in Classroom, Instruction*, Sadker, Sadker, Bauchner and Hergert argued that 'The teacher represents the crucial classroom learning resource, and … all students should have their fair share of access to that resource' (cited in Kelly, 1988, p. 1). Swedish students who have failed to obtain fully passing grades after nine years in compulsory school claim that one underlying reason for this failure is the lack of a trusting relationship with teachers or other adults in school. More individual contact with the teacher might have led to more support and confirmation, which is needed in order to reach the school's objectives (Skolverket, 2002).

Belonging to a group of students that gets more attention from teachers compared to other groups is not necessarily a benefit to this group or to one single individual. Kelly (1988) argued that it is important to know where the inequalities are manifest, and she mentioned that a group of students may, for example, receive more criticism but an equal amount of instruction or subject content, and this is not necessarily an advantage. Inequalities may also have different origins: for example, among individual students, groups of students, or the teacher (Einarsson & Hultman, 1984). However, this is beyond the focus of this study.

Previous research

According to research regarding communication in classrooms, typically, teachers tend to control both what is said and the major share of the talk (Einarsson & Hultman, 1984). In the early 1960s, Flanders (1970) wrote that both previous research and research conducted by him and his research staff showed that the teacher did two-thirds of all talking in the classroom. This two-thirds rule was also used later by Einarsson and Hultman (1984) as an illustration of how teachers use the major part of the available space for talk in classrooms.

The interaction they referred to took place in the parts of lessons where general whole-class communication was going on, and therefore did not involve entire lessons. They have also shown that this rule applies to the remaining space for interaction and that boys use the greater part of this space. Speech activity may also be unevenly distributed among different individuals. For example, every class may include a smaller number of students who speak a lot (Einarsson & Hultman, 1984). Sadker and Sadker (1985) reported that a few star male students receive the bulk of the teacher's attention and that one or two students often account for as much as 20% of this attention.

In a meta-analysis on gender differences in teacher–student interaction with studies mainly from the USA but also some from Australia, Great Britain, Canada, and Sweden, Kelly (1988) found that none of the included studies reported more teacher–student interaction with girls than with boys. She also found that girls were particularly under-involved in lessons within science or social studies, and girls only received 44% of the total number of response opportunities. Kelly argued that even seemingly small differences in participation rate may result in large differences in the end. For example, an average girl involved in 44% of the total teacher–student interaction would end up with 30 fewer hours of individual attention compared to an average boy after the end of a child's school career. Kelly built this figure on the assumption that only half of the lesson time is used for teacher–student interaction and that a teacher's total attention is divided among a class of 30 students.

These gendered differences are in line with studies that have focussed on science and have shown that teachers spend more time interacting with boys (Wernersson, 2006; Wilson Morse & Handely, 1985). Findings have revealed that male teachers ask twice as many direct questions as female teachers (Jones & Wheatly, 1990). In college classes, more of these directed questions from male teachers were directed to male students, while female teachers were equally likely to ask these direct questions to both male and female students (Karp & Yoles, 1976). Several studies have shown that teachers value boys' experiences more and generally treat boys more favourably than they treat girls (Murphy & Whitelegg, 2006; Staberg, 1994; Wernersson, 2006). Brophy (1985) argued that teachers probably sustain or reinforce gender differences that already exist, at least to some degree, even though they do not seem to be the major factors causing or broadening these student gender differences. Another summary of different research findings says that boys are more likely to initiate teacher interactions, to volunteer in answering questions, and to call out answers compared to girls (Jones & Wheatly, 1990; Kahle & Meece, 1994). This, together with a larger proportion of positive or negative criticism directed to boys, resulted in more opportunities for this group of students to interact with teachers in science classes.

Research questions

Contemporary Swedish girls at the end of compulsory school perform better in science on national tests, have higher final grades, and are performing significantly better than boys for the first time according to PISA 2012. Previous research has shown that boys interact with teachers in the classroom to a greater extent than girls; this has been particularly evident in the context of science education. The research questions are as follows:

1. Based on this new gap in science performance between girls and boys, is it possible to identify new patterns in teacher–student interaction in science classrooms today as compared to previous research?
2. If so, what are the characteristics of these new patterns?

Methods

The empirical material used in this study is part of a larger body of data. The material is in the form of video recordings and originates from the SONAT[2] project. The larger body of data in SONAT consists of more than 200 hours of video recordings from different science classroom practices in Sweden in the final years of the lower secondary school. This expansive amount of video material can be considered as raw data with several analytical possibilities based on different theoretical approaches and with different research questions in focus (Fisher & Neuman, 2012; Tiberghien & Sensevy, 2012). The video documentation was conducted by members of SONAT during the end of autumn of 2013 and the spring of 2014. Different researchers involved in the SONAT project videotaped groups of students at various schools during science lessons.

The SONAT project addressed the ethical considerations and permissions required to film students in class. The SONAT project also collected consent forms for under-aged students (younger than 15 years), which were signed by their parents. Schools and participants were given fictitious names in order to protect the contributors' identities. Any member of this research group undertakes to comply with these established conditions.

Participants

The study constitutes a small sample of science teachers and students in Sweden. A total of 85 boys and 110 girls, all in Grade 9, participated together with 7 male and 7 female science teachers from 1 private school and 5 public schools.

The selected schools were located in the southern and middle parts of Sweden, and they differed in terms of locations due to the size of municipality, size of the school, and school performance. The variation in school performance was measured as average increment credit and ranged between about 160 and 240 points.[3] Parents' average educational level ranged between 1.65 and 2.52, compared to the Swedish average of 2.25.[4] In two schools, the vast majority of students used a language other than Swedish as their first language; three schools had a majority of students with Swedish as their first language, while one school only had students with Swedish as their first language. The variation in location of schools, composition of students at schools, and average performance constituted a reasonable sample of different types of Swedish schools together with participant teachers and students.

The research questions in this study were addressed to an existing empirical material. Important decisions on how the data collection should be carried out had already been made collectively by the research group SONAT. This includes, for example, the selection of schools; contacts with teachers, students, and School Principals; decisions on which science activities were suitable for recordings; the use of technical equipment; and the position of video cameras and other devices such as audio recorders and

photo cameras used for documentation. How to locate video cameras in a classroom setting is normally a consideration connected to differing research questions. If, for example, the aim is to capture students' communication in small workgroups, different camera locations are required, as compared to an investigation of teacher–student interaction in a whole-class discussion.

Data analysis

The video-recorded sequences from the science lessons studied consisted of several videos from each lesson, where up to three different cameras were arranged in different positions. Therefore, we could choose among several videos to capture sequences that best showed each critical event. Often, but not always, the camera placed next to the teacher – in order to film the class – was the best for capturing the ongoing interactions.

The first step in the selection of video sequences

We selected approximately 40 hours of video-recorded science lessons from a total of over 200 hours in the first step in this study. We selected these 40 hours because they all include at least one event (but more often several) where the whole student group was supposed to pay attention to the ongoing interaction.

One way to conceptualise different video sequences[5] is to apply a perspective where these sequences represent different events that all occur in a certain time and space and have distinct beginnings and endings (Zacks & Tversky, 2001). Extensive video material will contain many different events. According to Lemke (2000), these different events will have underlying structures that reflect several parts and timescales. Every event can also be divided into different sub-events as well as being a part of a larger course of events (Derry et al., 2013). Consider, for example, an event in a classroom where a teacher is giving a group of students instruction on how to perform a laboratory experiment. This event can be divided into different sub-events such as a student asking a question, a comment made by another student, or elements of confusion or acceptance. Zacks and Tversky (2001) argued that action and event cannot be considered as synonymous. Even though many observed events are also actions, one difference is that actions are performed intentionally by actors, and actions are therefore less general than events (Zacks & Tversky, 2001, p. 4). This more general meaning of events is suitable to describe the primary sequences selected for a more detailed analysis.

The analytic software tool used in this study was ATLAS.ti, and the selected 40 hours of video-filmed events were imported into this software. ATLAS.ti is mainly a workbench for qualitative analysis of large textual, graphical, and audio–video data (Friese, 2013). However, in order to sort, identify, display, repeat, select, transcribe, and assign codes to selected events, this software was sufficient. The possibility to view and review video-recorded situations was an advantage that influenced the validation of coding in a positive manner (Tiberghien & Sensevy, 2012). One restriction in the software was that each individual code was only allowed to be used once within each event.[6] We solved this problem by adding numbering to each applicable code that occurred more than once within each single event. After importing data to the statistical software SPSS®, all sub-codes were merged into one, overall code for each category.

The second step in the selection of video sequences

The second step consisted of 14 hours out of the 40 marked as events which all included some kind of teacher-led, whole-class instruction. The start of each selected event began when the teacher made a first attempt to create a common focus of attention for the entire student group. Each event ended naturally when the shared communication was transformed into other classroom activities. The concepts *Bids to Start* and *Closing* were initially used by Lemke (1990) as a description of a teacher's first initiative to start a lesson as a generally shared social activity and to mark the ending of a lesson. The length of these events ranged from 2.5 seconds[7] up to 50 minutes, and one lesson may include more than one event of various length and content. After transcribing an event, we gave the different kinds of interaction within this event a code.

How we coded teacher–student interaction

The codes we used in this study drew upon codes used in the action research project Girls into Science and Technology (GIST) led by Whyte (1986a). The twin aim for that project was to investigate the causes of female underachievement in science and technology and simultaneously try to change that situation. Initially, project members used classroom observation in order to increase teachers' awareness of the variable participation in science and craft lessons (Whyte, 1986b). The schedule for observations GISTOS I (a) was an adaptation of Brown's Interaction Analysis System (BIAS) from 1975 and applied to those parts of the lesson in which public class discussion took place (Whyte, 1984). The schedule, accepted by teachers as an external measure of how well they were managing to engage girls' participation, was used in order to notify the quantity of teacher- or student-initiated public, verbal contributions. The average number of interactions was divided into the categories *interaction initiated by the teacher with boy or girl* and *interaction directed to teacher, by boy or by girl* (Whyte, 1984). These categories are included in this study together with additional categories that distinguish between teacher interaction with the whole group and that with individual boys or girls.

Einarsson (2003) has shown that there is a high correlation ($r = 0.85$, $p < .0001$) between the number of contacts between the teacher and students and the number of utterances that are exchanged in each of these contacts. For example, a student who takes the initiative to make many contacts with a teacher also exchanges many utterances with this teacher. This implies that a measure of the number of contacts or the number of utterances is comparable and that this phenomenon can be considered as a measure of the extent of the teacher–student interaction. Henceforth, the word contact[8] will be used to denote an utterance. This means that everything from a single word up to several coherent sentences that a teacher or a student utters without interruption or if the speaker turns to a new recipient is considered as one contact. Each single contact has been treated as independent and has been assigned a code based on the content of what was said. The following excerpt shows how the teacher, *T*, in the first contact, gives a first *Bid to Start* the lesson by asking the whole group about a previously distributed task. The excerpt ends with a *Closing* as the last contact. Here, all single lines represent one contact, but a contact may also consist of several lines. In lines 3 and 4, the teacher changes focus from the whole group to one individual girl. Therefore, this part of the event has been divided and coded as two contacts with different codes. A contact is divided and allocated different

codes if a teacher or student changes the focus on the topic of conversation. Each contact ends with the assigned code, and Table 1 presents the used abbreviations in the different codes; these will be described in detail shortly.

1. T: What task did you get before we finished [the last session]? Have you done this? (TtAIP)
2. G: Write about solar cells. (GtTIP)
3. T: How does it work … (TtA)
4. T: Have you done this? (TtGIP)
5. G: Now? (GtTIP)
6. T: Yes … Write, no. No, but you do have time! (Points at the clock; TtGIP)

T, *B*, and *G* are used as abbreviations for *Teacher*, *Boy*, and *Girl*. An *A* is used for communication with the entire group (i.e. *All*).

For example, the code *TtA* is used when the teacher (*T*) says something to the entire student group, and *to* (*t*) indicates the direction of this conversation. We used different insertions in order to distinguish between different types of interaction. *Sc* is used for talk about science; *IP* is used for talk about *Instructions or Procedure*; and a single *I* is used for *Distracting or Irrelevant* talk.

The following excerpt is from a lesson about optics and shows how interaction concerning science has been coded. It also shows how teachers' and students' individual interaction is a part of the general whole-class teaching. When the girl answers 'Antennas' in line 2 and the teacher confirms her answer as correct in line 3, this is meant to be heard by all present in the classroom.

1. T: Have you seen when these kinds of things are placed on houses? As plates. What is that? (TtASc)
2. G: Antennas. (GtTSc)
3. T: Yes, exactly. (TtGSc)
4. T: And they are called? (TtASc)
5. G: Satellite dishes. (GtTSc)
6. B: Satellite dishes. (BtTSc)
7. T: Exactly, satellite dishes. (TtBSc)

The event started when the teacher directed a question to all students in the group. The question was about satellite dishes and the class was discussing the shapes of some mirrors and lenses, which are concave like satellite dishes. The contacts involved in this event were all about science. The code given for the first contact (*TtASc*) is to be read as 'Teacher to All, Science'. Since the boy in this case gives the same answer 'Satellite dishes' after the girl, the confirmation given by teacher is coded as directed to the boy (*TtBSc*). Examples of

Table 1. Key for all codes used in this study.

Category	Teacher	Boy	Girl	All	Science	Distracting or irrelevant	Instructions or procedures	to
Abbreviation	*T*	*B*	*G*	*A*	*Sc*	*I*	*IP*	*t*

codes used for distracting or irrelevant talk, together with talk about instructions or procedures, are shown in the following excerpt:

1. T: Listen, while we are waiting for wh … , that the others will arrive, I would like to see … (TtAIP)
2. B: Anja, shou … (BtTI)
3. T: … how your work proceeded yesterday. (TtAIP)
4. B: Anja, Anja … (BtTI)
5. T: … you shall show to me … (TtAIP)
6. B: Anja! (BtTI)
7. B: Can we read, read about (inaudible) advantages and disadvantages? (BtTIP)
8. T: No, because you will continue to work now. (TtBIP)
9. G: Aha. (GtTI)
10. B: Anja! (BtTI)
11. T: … but I want to see if you have all … (TtAIP)

In this event, the teacher is interrupted several times by two different boys who are both demanding her attention (*BtTI*). She, on the other hand, is trying to get some information about how the group has proceeded with their work (*TtAIP*, *TtBIP*). When the two boys are shouting out her name, she obviously loses the thread and the boys' behaviour is therefore coded as *Distracting or Irrelevant* (*BtTI*). A girl loudly makes a comment on the given instruction from teacher to one boy ('Aha'), which is considered as irrelevant and is therefore given the code (*GtTI*).

Distinctions between different codes

For the most part, judging which code to assign to the contacts has not been problematic. On a few occasions, the difference between what should be coded as *Instruction or Procedure* and coded as *Science* has been less clear. The following excerpt shows a contact which has been divided into two parts due to a change in subject. First, the teacher calls for everyone's attention, which is coded as *Instruction or Procedure* (*TtAIP*). The second contact is coded as *Science* (*TtASc*) even though this is also a kind of instruction. The major difference is that this contact includes instructions on how to perform a lab; since knowledge on how to perform a lab is a part of the Swedish science curriculum, this contact is coded as *Science*.

1. T: Will you all listen now so we can manage to finish this. (TtAIP)
2. T: I have made some cross outs here in order to save some chemicals. We do not need to make such large quantities. So you will have two beakers. I have written 50 ml. They must not be, but not the enormous ones now. Take the smaller ones. (TtASc)

On a few occasions, it was less obvious whether a contact should be coded as *Distracting or Irrelevant* or should receive another code. In the following excerpt, the teacher urges students to use protective equipment such as coats and goggles. She is interrupted by a boy who makes a comment on how important this is (*BtTSc*). Even though this comment interrupts the teacher, his comment is right since using the right equipment

is a part of performing a lab. Therefore, this contact is coded as science, as is the following feedback that the teacher gives to this boy. In the next contact, the same boy once again makes a comment, now on the accuracy of the eye showers in the classroom. However, this comment is considered too far out of task and has therefore received a code for *Distracting or Irrelevant* talk together with the two following contacts (*BtTI*) and (*TtBI*).

1. T: But, it is nevertheless so that when you dissolve this, and if it eventually splash up; it is a bit caustic to. So we put on the goggles and you will especially put on the coats … (TtASc)
2. B: That is very important now! (BtTSc)
3. T: Yes, that is important. My Lord, anything might happen! (TtBSc)
4. B: How do the eye showers work with an expiration date in 2003? Do they work anyway? (BtTI)
5. T: Everything here is totally ok. (TtBI)
6. B: They will be shifted in the month of May, right? (BtTI)

In most cases, any ambiguity about which code to assign to a contact was resolved by choosing to examine the same sequence filmed by another camera or by examining what was said before and after the problematic contact. In fewer than five cases, it was impossible to determine whether it was a boy or a girl who spoke. These cases have been excluded from this study.

Calculations

The number of different codes was summed up, and we present the results first as raw data and then as different shares in percentages. These calculations are normalised to reflect the assumption of an equal number of boys and girls. Since the code *T-tot* includes both teachers talking to all and teachers talking to individual boys or girls, a second assumption is that an increased number of boys and a decreased number of girls in this study would have raised the number of contacts directed from teachers to boys and accordingly lowered the number of contacts with girls. Therefore, as a part of *T-tot*, codes *TtB* and *TtG* have been recalculated according to the same assumption of uniform distribution. *TtA* is not assumed to be affected by the uneven number of boys and girls.

Recalculations on teacher–student interaction made with respect to lessons held by male or female teachers are also normalised according to the same assumption with one exception. The total number of boys and girls in groups led by male teachers (59 boys and 67 girls) and female teachers (66 boys and 91 girls) is somewhat higher than the number of participating boys and girls. This is because some students participated in lessons held by both a male teacher and a female teacher but on different occasions.

Results

Raw data based on number of contacts for All Interaction and Science Interaction

The quantity of teacher–student interactions in terms of number of contacts is presented in Table 2. This table includes the numbers of contacts for *All Interaction* and for *Science*

Table 2. Number of contacts for *All Interaction* and *Science Interaction*, from teacher to students and students to teachers, raw data.

All Interaction	(*N*)	Science interaction	(*N*)
T-tot	5527	T-tot	2698
BtT	1333	BtT	943
GtT	1210	GtT	878
Total	8070	Total	4519

Interaction. The category *All Interaction* includes talk about instructions or procedures, distracting or irrelevant talk, and talk about science. The category *Science Interaction* only includes talk about science. *T-tot* includes when teachers talk to the whole group and talk to individual boys and girls. The table also includes the same categories of talk directed *from boys to teachers* (*BtT*) and *from girls to teachers* (*GtT*). During 14 hours of gerally shared interaction in science classrooms, we observed a total number of 8070 contacts.

If the total number of contacts for *Science Interaction* (4519) is subtracted from the number of contacts for *All Interaction*, a total of 3551 contacts remain. This number of contacts is about things other than science, and this amount corresponds to 44% of all interactions.

The teachers' part of *All Interaction* and *Science Interaction* (*T-tot*) is presented in Table 3 and is divided into *teachers' talk to all*, *teachers' talk to boys*, and *teachers' talk to girls*.

As mentioned earlier, the numbers of participating boys and girls in this study are not equal. In order to make comparisons of how the space for interaction is distributed between boys and girls, it is necessary to take into account this difference in group size. From now on, we will present all results as recalculated in order to reflect an equal number of participating boys and girls.

Distribution of teachers', boys', and girls' interactions in science class

Table 4 includes the percentage of *All Interaction* and *Science Interaction* with recalculations based on the assumption of a uniform distribution of boys and girls. For all interactions, teachers initiate 68.2% of all contacts. Boys' proportion of the remaining communication space for the same category of interaction is 5.6% higher than that for girls. All highlighted or discussed differences in this study are significant at the 95% level in simple chi-squared tests, if not otherwise stated. All highlighted differences discussed in this study are tested with simple chi-squared tests. χ^2 values ≤ 0.05 are considered to be significant.

Teachers' proportion of public science interaction is 59.5% of the available space. The boys' proportion of the remaining space for science interaction equals 23.5%. This is 6.6%

Table 3. Number of contacts for *All Interaction* and *Science Interaction*, from teachers to all, teachers to boys, and teachers to girls, raw data.

All interaction	(*N*)	Science interaction	(*N*)
TtA	3648	TtA	1257
TtB	1013	TtB	764
TtG	866	TtG	677
Total	5527*	Total	2698*

*Note that the total number for *All Interaction and Science Interaction* here equals *T-tot* in Table 2 for respective categories.

Table 4. *All Interaction* and *Science Interaction*, from teachers to students and students to teachers.

All interaction	(%)	Science interaction	(%)
T-tot	68.2	T-tot	59.5
BtT	18.7	BtT	23.5
GtT	13.1	GtT	16.9
Total	100.0	Total	100.0

higher than that for the group of girls. Of boys' and girls' shared general space for science interaction, the girls' proportion equals 41.8%.

Distribution of teachers', boys', and girls' interactions in science class in lessons held by male or female teachers

In Table 5, *All Interaction* and *Science Interaction* are once again presented, but are now divided into *lessons held by male teachers* and *lessons held by female teachers*. The distribution of interaction space between teachers, boys, or girls does not differ much between male and female teachers. Male teachers' interaction space with respect to all interaction corresponds to a two-thirds distribution, while female teachers' proportion is slightly above this value. Boys' proportion of contacts is lower than a two-thirds distribution, and girls' proportion is higher compared to a two-thirds distribution. This holds true regardless of whether the lesson is held by a male or a female teacher. We also recalculated results divided by male and female teachers to reflect an equal number of participating boys and girls.

Similar to *All Interaction*, the distribution of interaction space between teachers, boys, and girls for *Science Interaction* does not differ much between lessons held by male and female teachers. Male teachers' proportion of the science interaction space is 7.7% lower than that for all interactions. For female teachers, this proportion is 9.5% lower. This lower proportion of teachers' science interaction space means that both boys and girls have increased their proportion of contacts. The boys' proportion does not differ significantly from the two-thirds rule on lessons held by both male and female teachers. The girls' proportion is above the expected values with respect to this rule. If only the group of students is considered, girls' proportion of this part of the science interaction space is 40.7% for lessons held by male teachers. For lessons held by female teachers, girls' proportion is 43.6%.

For the sake of clarity, *All Interaction* and *Science Interaction*, together with a two-thirds part distribution, are summarised in Table 6.

Notable in Table 6 is the teachers' decreased proportion of science interaction space compared with a two-thirds distribution (–7%) and girls' increased share of the same space (+6%).

Table 5. *All Interaction* and *Science Interaction*, from teacher to students and students to teachers on lessons held by male or female teachers.

All interaction	Lessons held by male teachers (%)	Lessons held by female teachers (%)	Science interaction	Lessons held by male teachers (%)	Lessons held by female teachers (%)
T-tot	66.8	69.3	T-tot	59.1	59.8
BtT	19.6	17.7	BtT	24.2	22.6
GtT	13.6	13.0	GtT	16.6	17.5
Total	100.0	100.0	Total	100.0	100.0

Table 6. Summary of distribution of interaction in percentages.

	Distribution according to two-thirds (Einarsson & Hultman, 1984)	All interaction 2014	Science interaction 2014
T-tot	67	68	60
BtT	22	19	24
GtT	11	13	17

How teachers' interaction is divided among the whole student group and between boys and girls

The results for *All Interaction* and *Science Interaction* are given in Table 4 and are summarised in Table 6. In connection to Table 2, the results also described how teachers' total space for interaction, *T-tot*, is built up by the components *TtA*, *TtB*, and *TtG*. Those components of *T-tot* are used in order to get a picture of the extent to which teachers interact with the entire student group and with individual boys or girls. We present the proportion of *All Interaction* and *Science Interaction* distributed among these groups in Table 7.

For *All Interaction*, teachers share contacts with the entire group to an extent of 65.4%. This proportion is reduced to 46% when the focus of interaction is science, and teachers address both individual boys and girls more often when science is discussed as compared to all kinds of interaction.

Table 8 presents *T-tot* with respect to male and female teachers in order to capture any gendered differences in teachers' interactions with the two different groups of students. The greatest differences in how male and female teachers address these groups are found for the category *Science Interaction*. Male teachers address the entire student group to the same extent as individual students. Male teachers' contacts with boys are 14.3% higher than their contacts with girls. Female teachers more often address individual boys or girls than the entire group, and their contacts with girls are 7.8% higher than male teachers.

Conclusions and discussion

The aim of this study was to examine whether there are any differences in the patterns of teacher–student interaction in science classes over time. Previous research has shown that

Table 7. T-tot for *All Interaction* and *Science Interaction* divided into teacher to all, teacher to boy, and teacher to girl.

All interaction	(%)	Science interaction	(%)
TtA	65.4	TtA	46.0
TtB	20.8	TtB	32.1
TtG	13.8	TtG	22.0
Total	100.0	Total	100.0

Table 8. T-tot for *All Interaction* and *Science Interaction* divided into teacher to all, teacher to boy, and teacher to girl for lessons held by male and female teachers.

All interaction	Lessons held by male teachers (%)	Lessons held by female teachers (%)	Science interaction	Lessons held by male teachers (%)	Lessons held by female teachers (%)
TtA	67.1	64.4	TtA	50.5	42.9
TtB	20.7	20.6	TtB	31.9	31.7
TtG	12.2	15.0	TtG	17.6	25.4
Total	100.0	100.0	Total	100.0	100.0

boys tend to use more resources than girls with respect to the available interaction space in class (e.g. Einarsson & Hultman, 1984; Kelly, 1988; Murphy & Whitelegg, 2006).

Teacher–student interaction is presented as all kinds of talk that occur in science class when teachers and students share the general space for interaction; talk that deals exclusively with science is presented in this study as well. We found that the proportion of interaction that does not include talk about science in this study equals 44%. This means that a fairly large portion of science class time is used for talk about instructions or procedures and also to distracting or irrelevant talk, which is a part of the category *All Interaction*.

Older studies stated that a two-thirds distribution generally reflected how the available space for interaction was divided among teachers, boys, and girls (Einarsson & Hultman, 1984; Flanders, 1970). This distribution still seems to apply since teachers' proportion of all interaction today is on the same level as 30 years ago. Communication on how to solve different tasks, homework, and other school-related issues is a necessary part of the daily practice, and this may be one reason why teachers, as leaders of the group, use a greater part of this kind of interaction compared to their students.

Results also reveal that boys as a group today use less of the available space for all interaction (18.7%), and girls as a group use more space (13.1%) compared to a two-thirds distribution. However, it is not clear whether this difference from previous findings is enough of an explanation to why boys' performance in science has deteriorated more than girls' performance, or why Swedish girls now perform better than boys. As stated by Kelly (1988), it is important to know where the inequalities are manifest and whether talking science is an important part of learning science; it might be a good idea to separate out talk about science from talk about other things and once again review data with a focus on equalities between boys and girls.

Findings show that when the interaction space is exclusively filled with talk about science, teachers tend to use less of this interaction space. Teachers' interaction space here equals 59.5%, boys' space equals 23.5%, and girls' space equals 16.9%. This could indicate that more active student participation in talk about science may be prevalent in classroom communication as compared to the overall communication and that a teacher-directed classroom environment no longer dominates. It is notable that only the boys' proportion is still in line with a two-thirds distribution and that the girls' share has increased in comparison to the older distribution of one-ninth.

There are no major differences in the distribution of interaction space between teachers and students that depend on whether the lesson is held by a male or a female teacher, and this holds true for both *All Interaction* and *Science Interaction*. When the topic is science, both male and female teachers' interaction space is decreased in favour of both boys and girls. Boys' interaction space is larger than girls' space, and these findings are supported by previous research that states that boys are more likely to initiate contact with teachers, to call out answers, and to volunteer in answering questions (Jones & Wheatly, 1990; Kahle & Meece, 1994).

The main differences between male and female teachers seem to exist in the proportion of contacts that teachers direct to the whole group or to individual boys or girls. Results presented in this study show that teachers do have a larger proportion of contacts with both individual boys and individual girls compared to contacts directed to the entire group when they talk about science. Among these individual contacts, teachers will have contact with a boy instead of a girl 60% of the time, and this holds true for both

All Interaction and *Science Interaction*. This study also shows that male and female teachers more often contact boys, which is in line with the findings by Karp and Yoles (1976). Karp and Yoels showed that male teachers address more direct questions to male students and that female teachers more evenly direct questions between boys and girls.

The main findings are that boys still have access to a greater part of the available interaction space in the science classroom compared to girls and that this holds true for both *All Interaction* and *Science Interaction*. Although the old pattern of boys' dominance still persists, girls have extended their proportion of the science interaction space, and this may explain to some extent why Swedish girls today perform better in science than boys.

But there is reason to be cautious about using the results in this study to explain girls' improved performance in science, since it only covers a part of all ongoing communication in today's science classrooms.

To talk science and being engaged in science lessons are crucial parts of the meaning-making process as described by previous research (for example, Lemke, 1990; Mortimer & Scott, 2003). This proven, important communication occurs not only as generally shared interaction, but also in other forms and in other combinations during science lessons: for example, by listening or by interacting with written texts or in smaller groups. However, this other form of interaction lies outside the research conducted in this study.

Swedish girls have passed boys in terms of knowledge in science in the final year of lower secondary school. They perform better in science in national tests, have higher final grades, and also perform better according to international student assessments (Skolverket, 2009, 2013). This is despite only small changes in interaction space compared to the 1980s. One possible explanation is that girls' lower access to the interaction space only affects their science results to a limited extent. Boys have more obvious access to the generally shared interaction space and some research has shown that boys have a consistently more positive attitude to school science than girls (Osborne et al., 2003). If space for interaction is related to attitude, one implication might be that when both male and female teachers more often address their talk to boys, this might lead to a negative effect on girls' attitudes to school science and ultimately if they may choose a future science career. There is reason to be cautious in drawings any far-reaching conclusions, but as proposed by Brophy back in 1985, it could to some extent be that teachers still sustain or reinforce gender differences. One reason to be cautious is some limitations of the study.

As mentioned earlier, one limitation is that the study only covers the interaction that occurs generally in science classes. Other limitations are that it does not take into account the length or quality of what is being said or the extent to which individual students are involved in this interaction. This study has described the differences in teacher–student interactions in relation to gender. Later analysis of our data will look more at the content of the communication.

Notes

1. Einarsson and Hultman (1984) use the term *rule*, but make no claim that this is a scientific rule. Instead, this distribution should be regarded as a mnemonic rule, and that is how it is used in this study.

2. SONAT is a Swedish–Danish research project with members from Malmö University, Linnæus University, Aarhus University, Mälardalen University, and Mid Sweden University, with focus on relations between trends in large-scale studies and how teaching and learning are constituted in the science classroom.
3. Average increment credit for Swedish schools is 215, and maximum credit is 320 (2014). http://siris.skolverket.se/siris/f?p=101:54:0::NO
4. Three levels of parents' education are used: *passed primary or lower secondary education*, *passed upper secondary school*, and *tertiary education*. http://siris.skolverket.se/siris/f?p=SIRIS:164:0::NO:::
5. Instead of the wording sequence(s), Zacks and Tversky (2001) used the wording segment(s) when they discussed how particular elements from complex environments are captured by video, removed from larger contexts, and eventually become *clips* for further examination.
6. These events are called *quotations* in ATLAS.ti.
7. In this short event, the teacher addresses all students and says, 'Then we are back up and running' (TtAIP). Directly after saying this, the short, general teacher–student interaction ends since the teacher gets involved in discussions with single students.
8. This differs somewhat from Einarsson's study in which the term *contact* is used to denote a coherent sequence of communication between a teacher and a student.

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