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Research Article

Classroom discourse in single-sex physics classes: A case study

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ABSTRACT

This case study examined the characteristics of classroom discourse during physics lessons in two single-sex high school classes–a boys' vs. a girls' class. All lessons were taught by the same teacher and covered the same topics. For each class, six lessons were recorded, transcribed, and coded and the characteristics of the discussion were counted, including the number of words spoken by the teacher and students, the number of open-ended and closed-ended questions posed, and the number of open and closed discourse segments and their initiator. A total of 549 closed-ended questions, 1,151 open-ended questions, 139 closed and 168 open discourse segments were analyzed. A semi-structured interview was conducted with the teacher on his views of the discussion characteristic in his lessons and the differences he has observed between boys and girls in terms of these characteristics. The average number of all classroom discourse parameters examined was similar in both classes and no significant differences were observed. In both classes, the students participated very actively in the discourse throughout most of the lesson, both among themselves and with the teacher. From the teacher's perspective, the differences in discussions between the classes, if any, are not related to the student's gender, but rather to the character of the students and the classroom environment. The main conclusion that emerges from this study is that the girls' discourse in a single-sex class does not differ significantly from the boys' discourse, as discussed in the article.

Keywords: gender differences, physics class discourse, single-sex classes

INTRODUCTION

The persistent fact that few girls choose scientific studies generally, or physics specifically, has received attention among researchers and educators around the world. Researchers from Australia (Abraham & Barker, 2020), Europe (Francis et al., 2017), Israel (Zohar & Bronshtein, 2005), the Far East (Oon et al., 2020), and the United States (Pahlke et al., 2014) are concerned about the significant gender gap and seek ways of changing this pattern of reluctance among girls to pursue physics (Carreño et al., 2021). The situation is seemingly surprising, given that girls reportedly have higher average grades in most subjects, including the sciences, and a stronger commitment to scholastic learning processes (Jugović, 2017; Legewie & Diprete, 2012). Researchers attribute the low number of girls who pursue physics studies to low confidence in their scientific abilities (Gillibrand et al., 1999; Jugović, 2017) and to the fact that those around them–teachers, parents, and friends–usually do not encourage them to choose the sciences (Mujtaba & Reiss, 2013). Some studies claim that girls participate more actively in classroom discourse in groups that have a majority of girls (Jurik et al., 2013; Meece & Jones, 1996) and that in mixed classes, the classroom discussion during science lessons is conducted in a manner that discriminates against girls (Eliasson et al., 2016; Francis et al., 2017).

Conversely, a meta-analytical study by Pahlke et al. (2014) did not find gender discrimination in the discussion during science lessons. Because these findings are not unequivocal, and are even contradictory, we sought through the present study to gain a deeper understanding of the classroom discourse by examining the characteristics of discussion during physics lessons in single-sex classes of boys versus girls.

LITERATURE REVIEW

Discourse in Science Lessons

The main teaching tool in the classroom learning process is the discourse between teachers and students (Hogstrom et al., 2010; Mortimer & Scott, 2003; Thompson et al., 2016). In science lessons, this discourse is essential for clarifying scientific concepts, and to create a fruitful dialogue the teacher often intersperses explanations with questions (Benedict-Chambers et al., 2017) so that students can participate in the discussion (Chin, 2006). The conversation offers students an opportunity to discuss their ideas, thereby fostering active learning (Ruthven et al., 2017; Windschitl & Stroupe, 2017). By using questions teachers can shift from a monologue-style lecture about concepts, to effective dialogic teaching that engages students in the construction of these concepts (Dohrn & Dohn, 2018; Tanner et al., 2005). Posing questions allows the teacher to cultivate new knowledge and concepts gradually while generating an active discussion with the students (Ford & Wargo, 2012; Lee & Irving, 2018; Nussbaum & Edwards, 2011; Pimentel & McNeill, 2013; Ruthven et al., 2017). This teaching technique has been found to be effective in developing critical thinking and achieving a better understanding of scientific ideas (Abrami et al., 2015; Chen et al., 2017; Dohrn & Dohn, 2018). Discussion also helps correct misconceptions while enhancing interest and motivation for learning (Chin, 2006; Tanner et al., 2005). The level and complexity of classroom questions were found to have a positive effect on the cognitive level of middle school students in science classes (Smart & Marshall, 2013). In formulating their answers, students draw a connection between their previous knowledge and the new knowledge, thereby cultivating such skills as creative thinking (Chin, 2007), written and oral expression, and reasoning (Chen, 2019; Chen et al., 2017).

The teacher's questions have two main functions. First, they assess the students' knowledge and comprehension of what has been explained (Chin, 2006, 2007; Nystrand et al., 2003), and second, they inspire students to think about and discuss unfamiliar scientific concepts, synthesizing them with previously taught concepts (Nystrand et al., 2003). Erdogan and Campbell (2008) classified questions according to two types: closed-ended and open-ended. Closed-ended questions usually have one correct answer, concisely presenting specific, limited information (Erdogan & Campbell, 2008; Mercer & Dawes, 2014). Closed-ended questions inform the teacher as to the students' knowledge and understanding. On the other hand, open-ended questions, which usually do not have one definitive answer, address ideas or insights rather than necessarily factual information. Open-ended questions lead students to express a position, reason, explain, demonstrate, postulate, compare, present arguments, and solve problems. The students' answers allow the teacher to continue posing questions and to conduct a discussion that takes the scientific discussion in the desired direction (Morris & Chi, 2020).

If the teacher sparks a fruitful class discussion, students will join the discourse not only by answering questions but also by asking questions themselves (Furtak & Ruiz-Primo, 2008; Nystrand et al., 2003; Scott et al., 2006). Unlike a teacher, students usually do not know the answers to their questions. Sometimes they ask questions in order to understand an idea that they did not grasp from the explanation given; that is, they ask closed-ended questions. Sometimes, however, if the discussion and the ideas it raised spark the students' curiosity, they ask questions in order to explore scientific concepts that are new to them. In such cases they ask open-ended questions (Christodoulou & Osborne, 2014). The fact that they ask questions of their own initiative indicates that the subject taught fascinates them and motivates them to learn (Furtak & Ruiz-Primo, 2008), which is essential for effective learning (Ruthven et al., 2017; Windschitl & Stroupe, 2017). A good teacher will want to motivate students to ask as many questions as possible. Students' open-ended questions can redirect the classroom discourse to focus on new ideas raised by the students themselves, even if the teacher had not planned to discuss them (Chin & Osborne, 2008; Furtak & Ruiz-Primo, 2008). Thus, the teacher needs to be flexible and able to take advantage of the students' interest to redirect the lesson in accordance with their questions (Nystrand et al., 2003).

The questions asked in class produce different types of discourse. A triadic dialogue, in which the initiator asks a question, the other side responds, and the initiator gives feedback, is by definition a closed discourse (Mehan, 1979). If the questioner is the teacher, the feedback will usually be confirmation or correction of the student's response, thus bringing the discourse to an end. If the questioner is a student, then the teacher – or another student – will reply to the question, and the questioner's feedback will confirm the receipt of an answer to the question, after which a new discourse episode will begin (Nystrand et al., 2003). This kind of discourse is important in confirming that the learning process may proceed on the basis of previously taught ideas, but in itself it does not deal with new ideas. Teaching new ideas by way of discussion requires initiating an open discourse (McNeill & Pimentel, 2010) characterized by several additional stages of student-teacher exchange. An open-ended dialogue has many stages and is driven by open-ended questions, which play a key role in the practice and training that develop the students' argumentation skills. McNeill and Pimentel (2010) assert that open discussion encourages students to present arguments as well as their underlying reasoning, express their thoughts, and discuss their insights through a dialogue not only with the teacher but also with their classmates. According to Christodoulou and Osborne (2014), the sciences require a discourse that differs from that of other studies. Examples and demonstrations do not suffice for teaching science; rather, a dialogue supported by argumentation is a necessary central and fundamental part of the process. In their view, such an open discourse can only derive from open-ended questions.

Gender Differences in Physics Lessons

Many regard physics as a distinctly male field (Francis et al., 2017; Nyström, 2009). Teachers (Nyström, 2009) as well as students and their parents (Francis et al., 2017) have asserted that gender bias is evident in its teaching. Studies have pointed to differences in teachers' attitudes towards boys versus girls when they are present in the same classroom (Eliasson et al., 2016, 2017). Teachers usually call on boys more often than on girls during classroom discussions (Francis et al., 2017). Earlier studies also found that teachers devoted more time to classroom interaction with boys than with girls (De Welde et al., 2013; Tobin, 1988). Boys answer questions more often than girls and play a more dominant part–up to twice as much–in the classroom discourse (Eliasson et al., 2017). Science teachers gave more positive feedback to boys than to girls (McClowry et al., 2013). Male teachers were found to direct their questions more often to boys, whereas female teachers posed questions to boys and girls evenhandedly (Eliasson et al., 2017). An analysis of classroom interaction in coeducational classrooms found that boys are more likely to initiate interactions with their teachers, volunteer to answer questions, and read out answers (Jones & Wheatly, 1990). They usually tend to talk more and are not timid about participating in discussions or dominating the classroom interaction even if they are not highly capable (Eliasson et al., 2016). This might be one of the reasons they receive preferential treatment even if at times their behavior is less acceptable (Jones & Wheatly, 1990). Boys demonstrate great self-confidence and are active whatever the classroom composition, whereas girls participate in the classroom interaction only if they are very confident in their abilities (Jurik et al., 2013) and when they are part of small groups or constitute a majority (Meece & Jones, 1996).

The fact that teachers pay less attention to girls than to boys (Eliasson et al., 2017) can in itself cause girls to participate less in science classroom discussions, to the extent that they cease to participate altogether. Regarding discussion questions, Tobin (1988) found that teachers posed comparable numbers of low-level (closed-ended) questions to boys and to girls. On the other hand, teachers–both men and women–have a tendency, when initiating a discussion, to pose high-level (open-ended) cognitive questions to specific students, who are usually boys.

The gender differences in physics teachers' attitudes and in classroom discourse, as they emerged from our review, occur in mixed classes. Single-sex classes present a different picture. Education systems have single-sex classes for two main reasons, one of which relates to religion and the second to enhancing scholastic achievement (Pahlke et al., 2014). Pahlke et al. (2014) conducted a meta-analysis to examine the claims of single-sex education advocates who hold that separating boys and girls improves achievements and enhances learning interest for both sexes. They included a comparison of single-sex and mixed classes comprising 1.6 million students in grades K-12 throughout the United States. They concluded that single-sex classes had a certain advantage in terms of scholastic achievement in mathematics, but not necessarily in the sciences. Another study examining the effectiveness of single-sex classes in increasing girls' involvement in

science, technology, engineering, and mathematics (STEM) studies (Hughes et al., 2013) found that during adolescence, girls began to develop a sense of alienation from these subjects, which could be countered through pedagogical programs rather than by placing the girls in single-sex classes necessarily. Murphy and Whitelegg (2006) claim that in single-sex classes girls feel a stronger sense of belonging when studying sciences. Also, Gillibrand et al. (1999) reported that girls who studied physics in a single-sex class in western England developed confidence in the subject, as reflected in high achievements and an inclination to continue pursuing high-level physics studies.

When looking at the influence of class gender composition on academic achievements, Dustmann et al. (2018) found that both boys as well as girls gain from studying in single- sex classes: they outperform their peers in coeducational classes, and they worsen their academic achievements when move to coeducational classes. The single gender composition of the classroom was found to be advantageous by Paredes (2022) by reducing the math gender gap by more than half.

In contrast, a study by Sampson et al. (2014) presents a different picture. The authors compared a single-sex 8th-grade class with a mixed class in terms of classroom discourse, self-perception, and scientific achievements. Their findings, which contradict those of Eliasson et al. (2017), are that girls actually participate infrequently in single-sex classes. They argue that for boys there is an advantage in single-sex classes because their achievements and scientific awareness improved relative to a mixed class.

Thus, the literature on single-sex classroom discourse appears to be inconclusive and at times even contradictory. In this study we sought, therefore, to identify and characterize the parameters of single-sex classroom discourse when the students are either only boys or only girls. This case study involves one teacher who taught the same subjects to two single-gender classes. It allows us to minimize the potential bias that a different teaching style, subject matter, or teacher's gender could have on the classroom discourse. The two classes of our study belong to the religious part of the Israeli state education system. In this system, the k-12 schools consist of two main parts: Jewish (77% of the pupils) and Arabic (23% of them). The Jewish part itself consists of secular (55% of the pupils, learning in coeducational classes and schools), religious (19% of the pupils, studying in single sex classes, where elementary schools have both boys and girls classes and middle and high schools teach single sex classes only), and ultraorthodox (26% of the pupils, all of them study in single-sex schools and classes). The importance of this study is in the systematic monitoring of various elements of the discourse in single-sex physics lessons with the same teacher. Such monitoring–identifying the characteristics of the physics discourse in a boys' class versus a girls' class–is virtually unprecedented and points to the potential contribution of the present study to the pedagogical knowledge base on classroom discussion.

The Research Questions

1. What are the characteristics of discourse in boys' compared to girls' physics lessons, with attention to the following elements?
    a. The number of words spoken by students and teacher in each class.
    b. The number of closed-ended and open-ended questions posed by the teacher in each class.
    c. The number of open-ended and closed-ended questions posed by the students in each class.
    d. The number of closed and open discourse episodes initiated by the teacher in each class.
    e. The number of closed and open discourse episodes initiated by the students in each class.
2. How does the teacher characterize the discourse in the physics lessons in the boys' class and in the girls' class?

METHODOLOGY

The Study Population: The Teacher and the Students

In this case study we examined one teacher and two classes using both a quantitative and a qualitative approach. The physics teacher is a 41-year-old electronics engineer with a master's degree in science education who is currently pursuing a doctorate in science education. He has experience teaching single-sex

classes. Prior to this study he had taught six girls' classes over the course of four years, some of them for three consecutive years, and fifteen boys' classes over the course of seven years, some of them also for three consecutive years. As a teacher he participated actively in the development team that formulated the national massive open online course (MOOC) program for high school physics instruction.

Both classes belong to the Israeli religious high-school system, where all classes in the school are single-sex. In these high schools, students learn all secular subjects such as mathematics, the sciences, foreign language, computer programming etc., all courses are high level. In both classes the students excel in mathematics and physics and have chosen to study those subjects in the highest level offered by the state education system.

The boys' class was an 11th-grade class (ages 16-17) comprising 22 students studying advanced physics and planning to take the highest-level high school matriculation exams at a regional rural school in central Israel. The school's teaching staff includes men and women, and the students (boys) come from a middle-upper class socioeconomic background. The girls' class was an 11th-grade class (ages 16-17) comprising 20 girls who were also studying advanced physics and using the same curriculum. The school, located in a city in central Israel, has a teaching staff that includes men as well as women, and the students (girls) come from a middle-upper class socioeconomic background. The education level of the parents was similar in both classes. Boys: 13.6% of the parents had high school education, 45.4% had undergraduate degrees, 40.9% of the fathers and 31.8% of the mothers had graduate degrees and 9.1% of the mothers had PhDs or MDs. Girls: 10.0% of the parents had high school education, 50.0% had undergraduate degrees, 25.0% of the fathers and 40.0% of the mothers had graduate degrees and 15.0% of the fathers had PhDs or MDs. Both schools are intended for students with a religious background and offer only single-sex classes.

Both classes covered the same following subjects: Newton's three laws of motion, kinematics, and the equations of motion of bodies, the study of bodies in an accelerated frame of reference, momentum, projectile motion, energy, and work.

The Course of Research and the Data Processing

For each class, six consecutive 45-minute lessons were recorded. The lessons did not include laboratory work or exercise tutorials. The recordings were transcribed and coded using a method developed and tested by the Aflalo and Raviv (2022) over the course of three years. The lesson was divided into one-minute time segments, and for each and every minute all the utterances (words, questions of each type) and the speaker–teacher or students–were noted. When different students participated in the discourse, their remarks were differentiated using different colors. Procedural remarks were not counted. Only words related to the subject matter being taught were included. The average number of words per one lesson, as well as the average of the other discourse parameters, was their sum of six lessons divided by six.

For each lesson the questions were classified by type, whether open-ended or closed-ended, and originator–the teacher or the students. In total, we analyzed 1,700 questions, 549 of which were closed-ended and 1,151 open-ended. For each class we calculated the average number of both open-ended and closed-ended questions. Each researcher classified the question separately and then we compared them. We found a consistency rate of 85% in our classifications. We discussed those questions that we had classified differently, until we were able to reach an agreement.

The discourse segments of the lessons were counted and classified as open-ended or closed-ended, and according to their initiator, teacher, or students. A closed discourse segment was defined as one in which someone initiated an exchange, received a response, and reacted to it in a way that brought the discourse segment to a close. An open discourse segment was defined as one in which someone initiated an exchange or an open-ended question, thereby generating a response that in turn caused the initiator or others to react, following which a continuous dialogue took place with exchanges between the teacher and students or among the students themselves. The discourse segment ended when the discussion shifted to a different subject or idea. In all we analyzed 307 discourse episodes, 139 of which followed the pattern of a closed discourse and 168 of which were open discourse episodes. For each of the six lessons of both classes we calculated the average number of both closed and open discourse episodes. A t-test was conducted to determine whether the two classes' discourse parameters of number of words, questions and discourse segments significantly

Table 1. Elements of the discourse in the boys' and the girls' class

Discourse parameter	Girls		Boys		t
	M*	SD	M*	SD	
Teacher's words	2,104.3	436.8	2,891.7	869.0	1.24
Students' words	1701	814.2	1,842.3	797.7	0.01
Closed-ended questions by teacher	24.8	7.0	17.0	4.6	2.01
Open-ended questions by teacher	53.3	12.8	49.0	17.5	1.78
Closed-ended questions by students	33.8	15.8	16.0	4.6	1.07
Open-ended questions by students	39.8	27.5	49.7	11.0	0.62
Closed discourse segments by teacher	9.3	10.5	1.3	1.15	1.32
Open discourse segments by teacher	10.0	6.2	5.0	2.0	2.07
Closed discourse segments by students	6.7	2.3	5.7	4.0	1.43
Open discourse segments by students	7.6	2.8	5.3	1.5	1.42

Note. *All numbers in this column are the average value per one lesson (sum of six lessons divided by six)

Table 2. Sample open-ended questions and closed-ended questions

	Closed-ended questions examples	Open-ended questions examples
Teacher	What is the name of this equation? or What value is the negative normal?	There is no friction, so why would the body come to a stop? or What is the significance of the area below the velocity curve?
Girls	What do the scales show? Do they show the same thing? or How did you calculate 7.1 seconds?	How can the 2 kg string pull a 3 kg object? or We said that the mass does not change, so why do the scales show a different value?
Boys	How do you convert 7 km/s to meters per second? or Does a polar coordinate system consist of vectors?	If I were ejected into space in a spacesuit, would I orbit the Earth, even without a spaceship? or If I'm orbiting the Earth, why don't I feel as if I'm moving?

differed between the two classes. The t-test was conducted referring to the separate utterances per each one of the lessons.

In addition, the study included a semi-structured interview with the teacher of both classes, for the purpose of documenting his experiences and the different characteristics of discourse in the boys' versus the girls' classes that he taught. Aside from background questions relating to his age, education, years of teaching experience, and classes and subjects taught, the interview included one central question: How would you characterize the discourse during physics lessons in the boys' classes and the girls' classes that you teach, and do you think there are differences in the characteristics of each classroom discourse?

The interview, conducted by one of the article's authors, lasted 50 minutes. It was recorded and notes were taken during the interview itself. A follow-up interview was also conducted to clarify questions that had arisen when we reprocessed the recording.

RESULTS

Characteristics of the Discourse in the Boys' Class and in the Girls' Class

Table 1 summarizes the data relating to various parameters of the discourse during the physics lessons in both classes.

In all discourse parameters shown in the table, a t-test indicates that there is no significant difference between boys' and girls' classes. We found that the average number of words per lesson, on the part of the teacher as well as the students, was comparable across both classes. This was also found for the open or closed questions, initiated by either teacher or students as well as in the parameters of either closed or open discourse segment. Initiated by either the teacher or the students.

Table 2 presents a sample of open-ended questions posed by the teacher and the students in both classes. Notably, there was a good deal of variance in the number of closed discourse segments initiated by the teacher across the six recorded lessons for the girls' class. Some lessons had three-five such discourse segments while others had 20-25 such segments, which is what contributed to the large standard deviation.

An examination of the course of the discussion during the lesson found that both classes maintained a lively discourse during nearly every minute of the lesson, and that the students participated actively in the

discourse throughout the lesson. For both classes there were minutes during which only the students spoke. The girls and the boys expressed their ideas to a comparable extent, answered many questions posed by the teacher, and themselves posed many questions during the lesson. The lesson primarily took the form of a discussion rather than a monologue lecture.

The teacher's discourse was characterized by brief explanations, and during most of the lesson he would initiate dialogue by posing primarily open-ended questions, thus encouraging the students to ask questions themselves. In both the boys' and the girls' classes the teacher initiated more open discourse segments than closed segments. The closed discourse segments were usually triadic and usually involved the participation of only one student and the teacher, as the following examples illustrate:

> Teacher: What will the scale show if the elevator descends at a fixed velocity of 30 m/s?
>
> Girl student 1: The same thing.
>
> Teacher: Good. let's write that down (lesson 3, girls).
>
> Boy student 1: When you talk about the radius of the satellite, what do you mean?
>
> Teacher: The radius of the track of the orbit.
>
> Boy student 1: Okay (lesson 6, boys).

In contrast to the closed discourse segments, open discourse was characterized by a larger number of participants and longer duration, as the following portion of a discourse segment among the girls illustrates:

> Girl student 1 [reading aloud]: A student hangs a ball-shaped weight on a sewing thread. The thread does not tear, but when the student pulls the thread by lifting the ball upward, the thread tears. The thread is torn in the second set of circumstances, but not in the first.
>
> Girl student 2: There are forces pulling it in two directions.
>
> Teacher: Good. How do you know?
>
> Girl student 2: There is the weight, and there is the thread upwards.
>
> Teacher: Okay, but …
>
> Girl student 3: Because he is pulling upward.
>
> Teacher: At first the thread does not tear, but when I pull it upward, it does tear.
>
> Girl student 2: What is the variable? This is it!!
>
> Teacher [redirecting the question to the student]: What is the important variable in the question?
>
> Girl student 4: Acceleration upward.
>
> Teacher: In one word?
>
> Girl student 4: Upward.
>
> Teacher: What does it mean that there is acceleration upward?
>
> Girl student 5: There is a force.
>
> Teacher: And what does it mean that there is a force?
>
> Girl student 5: The thread is limited. It cannot support the full force.

Teacher: What is the tension on the thread? How much tension is there, friends?

Girl student 3: The tension in the thread is mg.

Teacher: Why is the tension equal to mg?

The discourse segment continued for another 40 seconds and concluded, as follows:

Teacher: Let's calculate ΣF minus T, where F in an upward direction [The teacher writes the equations on the board]. T is upward, and mg is downward. If the force of the tension is greater than the weight of the ball, then the ball will accelerate upward.

Girl student 5: And then the thread will tear.

Teacher: The thread can sustain limited force before it tears. When the tension was equal to mg, then the thread could withstand it, and when one pulls harder, there is a threshold at which the thread tears (lesson 4, girls).

We found similar open-discourse episodes in the boys' class. They included the participation of several students, as follows:

Teacher: I have a building 100 meters high. I throw a ball from it. The initial speed is zero. What is the velocity of the ball when it reaches the ground?

Boy student 1: Energy considerations need to be made.

Teacher: Energy considerations, good. What's the equation?

Boy student 2: MGH

Boy student 1: Equals?

Boy student 2: $mv^2 \div R$.

Teacher: Good. $mv^2 \div R$. We are back in energy. Do you know what to do here? Do you understand why we wrote this?

Boy student 3: Yes, for energy considerations.

Teacher: Alright? What is the assumption here?

Boy student 1: The top of the building is 0, and the H is not that high.

Teacher: Excellent. Here H=0, and here H=100. As you said, here there is height but no speed, and here there is speed but no height. Excellent. Let us put on one side of the equation all the energies at the beginning: MGH.

On the other side of the equation, we put all the energies: there is simply speed here, and there is no height energy here. Then we solved everything perfectly, but the assumption is that the height here is enormous. Now suppose I wanted to annoy you. What else could I do?

Student 6: Give us another H.

Teacher: Very good (lesson 3, Boys).

Another characteristic of the classroom discourse that was common to both classes was the teacher's practice of redirecting the students' questions back to the class. When asked a question, the teacher preferred

to have other students answer it. Sometimes, through targeted questions, he encouraged the questioner to provide the answer, as the following example illustrates:

> Teacher: Dan, who weighs 70 kg, is descending in an elevator. What will the scale show if the elevator is descending at a fixed velocity of 3 m/s?
>
> Girl student 1: If both the scale and Dan are in the elevator, why would the scale change?
>
> Teacher: Why does it matter if the scale and Dan are in the elevator?
>
> Girl student 2: Why would the weight change?
>
> Girl student 3: Are you adding acceleration? (lesson 1, girls).

On the basis of these and other examples from the recordings, we found that the students demonstrated curiosity and freely posed questions to the teacher and their classmates. The teacher guided the discourse using these questions, sometimes changing the direction of the lesson in accordance with the students' questions. This occurred similarly in both the boys' and the girls' classes.

How does the teacher view the discourse in the boys' class and the girls' class?

In response to our question as to how he characterizes the discourse in his physics lessons, the teacher said that the main tool in his teaching method is discussion, based on two principles. According to him, the first principle is that every scientific concept is learned from its basis. The teacher demonstrates a phenomenon and asks the students to guess the results. After the demonstration they conduct a discussion that covers all the stages in developing a scientific concept, from the most fundamental ideas to explication of the mathematical equation. The second principle, according to him, is that the students must express every scientific concept first orally and then in writing. The students need to ask the questions, answer them, make mistakes, debate among themselves, and ultimately be the ones who formulate the scientific concept and express it through a mathematical equation. In his view an explanatory monologue by a teacher about a physical phenomenon is devoid of value and such teaching is ineffective. Teaching achieves its aim only if the students express the scientific concept, and his aspiration as a teacher is that all the concepts taught in a lesson be formulated by the students. In his words:

> In my hands I hold two marbles. I tell them that I'm going to release one from a state of rest into freefall and release the second with some horizontal velocity into freefall. I ask them what will happen. At first their responses vary, suggesting different possibilities. After they watch the demonstration, they offer explanations. They argue, conjecture, and ask questions, because their curiosity has been sparked and this makes them think. Eventually, they explain the results and formulate the mathematical equations.

The teacher describes two types of initiative in relation to students' questions. The first occurs when they do not understand the concept being taught and ask closed-ended questions, and the second involves a new situation that they do not know how to explain, at which point they ask open-ended questions. This leads to an open discourse that includes various suggestions by students, some of them inevitably wrong. The mistakes lead to absurd results, and by trying to fix the mistake they arrive at a deeper understanding of the physical scientific concept. In the teacher's words:

> I showed them launch data for a missile fired at a certain angle at high speed. I asked them to calculate the landing time. They calculated that it would land in 36 hours. They immediately realized that was absurd and looked for their mistake. They discussed it among themselves, asked each other questions, offered suggestions, replied, reasoned, and argued until they realized on their own that they had used the wrong units for G. When they inserted the correct units, they arrived at a correct and logical answer. The class discussion will undoubtedly contribute to their not making the same mistake when facing a similar question in the future, and they will take care to use the correct units.

The teacher added: "I tell them: your goal is to make mistakes before the test. You must make mistakes, clarify the mistake, and fix it. Then when you take the test–you will not make the mistake." In this way the teacher directs students to discover the solutions to scientific questions for themselves and ascribes importance to their mistakes and interpersonal arguments. Regarding differences between boys and girls in discussions, the teacher claimed that there were no significant gender differences in the conduct of classroom discourse in his classes. When we presented him with data from his lessons pointing to certain differences in the numbers of questions and discourse segments, he attributed these differences to the different character of each class, regardless of gender. As he described it:

> There are vibrant and active classes in which the students demonstrate curiosity and are highly engaged in the discourse and formulation of ideas. In contrast, I have had classes in which the students were not inclined to ask questions or participate. I had a class of girls from an upper-class socioeconomic background in a large city. They rarely asked questions, were not curious, were passive, and did not participate in the discourse. I felt that they were not grasping the scientific concepts. In contrast, I had a class of 15 girls in a small peripheral town, and these girls were really involved: they worked enthusiastically, answered questions, asked many questions themselves, and were very engaged in the discourse. There was a positive atmosphere and sense of satisfaction during the lessons.

Regarding the nature of classroom questions, the teacher stated:

> Students are students. I ask the same questions whether there are boys or girls in the classroom. I gladly receive any question from a girl or a boy, and I usually redirect the question to them in order to cause them to think and discover the explanations for themselves.

Hence, according to the teacher, the different degrees of student participation in the discourse stemmed from the students' different characters and the overall social atmosphere, regardless of gender.

DISCUSSION AND CONCLUSION

In this case study, we analyzed the characteristics of discourse in physics lessons for two single-sex classes: a boys' class and a girls' class. These classes represent the single-sex teaching methods practiced by some religious high schools in Israel. Because single-sex classroom teaching takes place in other countries as well (Abraham & Barker, 2020; Murphy & Whitelegg, 2006; Pahlke et al., 2014), it is important to develop a deeper understanding of the discourse in these classes.

The results of this study indicate that the girls demonstrated a similar degree of involvement and participation in classroom discussion relative to the boys. Specifically, the discussion transcripts showed no significant difference in the number of words spoken during a lesson, the number of closed-ended questions the students initiated, and the number of (open or closed) discourse segments they initiated. These results reinforce other findings indicating that when girls study solely with members of their own sex, they are not afraid to express themselves and participate in scientific discourse (Simpson et al., 2016). Our transcripts show that the girls in the single-sex class not only responded well to the discourse initiated by the teacher, but also generated an active and open discourse themselves, both in the questions they asked and the scientific concepts they discussed. They demonstrated that they were not content to pose closed-ended questions solely to confirm their understanding of ideas already taught. Similar to the boys, they initiated open-ended questions and created an open discourse that enriched the discussion, ultimately fostering a deeper understanding of the lesson's concepts.

Our findings confirm earlier research suggesting that the conduct of girls in single-sex classes resembles that observed in single-sex boys' classes, such as those of Francis et al. (2017), Jurik et al. (2013), and Meece and Jones (1996). It also contradicts that of Sampson et al. (2014), which pointed to reduced participation by girls in single-sex classroom discourse. Our finding that the number of teacher-initiated open discussion segments in the girls' class was similar to that of the boys. A review of the lesson transcripts indicates that the girls did not hesitate to ask open-ended questions that are necessary for generating open discourse

(Christodoulou & Osborne, 2014). This points to their interest in physics, curiosity, and desire for an in-depth understanding of the scientific concepts (Abrami et al., 2015; Chen et al., 2017; Dohrn & Dohn, 2018).

The teacher's pedagogical style contributed to the students' high degree of engagement in the lessons, and he made a point of fostering a vibrant discourse to engage the students of both genders in the subject. Most of his questions in both classes were open-ended, and he encouraged the students to ask questions themselves (Lee & Irving, 2018). One of this teacher's pedagogical pillars is to have the students express scientific concepts and formulate mathematical equations themselves. Therefore, in many cases he did not answer their questions but instead incorporated them into the classroom discussion. In so doing, he attempted to motivate them to participate in the discussion and fostered their reasoning and thinking skills (Golding, 2011). His dialogic teaching style has the potential to promote girls' pursuit of physics studies by improving their self-esteem and increasing their expectations of themselves (Abraham & Barker, 2020; Hughes et al., 2013; Jugović, 2017; Murphy & Whitelegg, 2006; Simpson et al., 2016). A teacher with less experience teaching single sex classes might lead the discourse differently in the different classes. Yet we assume that the results presented here might not be different in physics lessons in classes in coed schools. The main reason is that these are classes of top student who excel in mathematics and the sciences, and the girls are confident enough to actively participate in the discourse and do not hesitate to ask both closed as well as open ended questions.

According to Francis et al. (2017), the different narratives employed by students and their parents regarding physics as a profession demonstrate discrimination against girls. One such narrative, for example, holds that cleverness is a masculine trait and physics is a difficult subject that requires cleverness. Another narrative holds that men and women are naturally different and therefore drawn to different subjects. Our research findings contribute to refute these narratives.

In this case study, the girls appeared to benefit from being part of the single-sex group, but to further test this hypothesis it would be necessary to compare these findings with observations of the same girls in a mixed-gender discussion. It is important to emphasize that it is unclear to what extent the present case study, which involved a single teacher who agreed to participate, may be regarded as representative of broader educational environments. By its nature, a case study focuses on a defined and circumscribed situation, usually addressing a specific question embodied in that unique situation (Benedict-Chambers et al., 2017; Christodoulou & Osborne, 2014; Reinsvold & Cochran, 2012; Worku & Alemu, 2020). This is a limitation of the study, as one teacher may unconsciously practice for the different classes different discourse parameters such as type of questions, positive or negative responses and other verbal and non-verbal expressions, and thus lead his lessons not perfectly identically. Another limitation is the small sample size, due to the nature of such case study. Therefore, it should be taken into consideration that the non-significant statistical data in this study may be related to the sample size. Further studies are therefore required, that will analyze single sex classes taught by other teachers, both males and females. The teacher whose classes were researched in this study does not teach coed classes. Therefore, another limitation of the study is that it lacks an analysis of coed classes taught by the same teacher who taught the other single sex classes, and such further study is suggested to complete the comparison of discourses in those three types of classes. Nevertheless, although research-based pedagogical knowledge derived from individual case studies may not be generalized across the entire population, it can offer important insights.

In conclusion, the findings of this study suggest that, under certain conditions, single-sex physics classes for girls could offer them a nurturing environment and encourage them to participate meaningfully in class. Although our findings do not explain why girls avoid physics studies in higher education (which is outside the scope of this study), this is an important area of further research. We believe that increasing the involvement of girls in classroom discourse during physics lessons may encourage them to pursue academic programs and careers in physics later in life.

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