**Classroom Discourse in Single-Sex Physics Classes: A Case Study**

**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 patterns of discourse – open or closed discourse segments and their initiator. A total of 549 closed-ended questions, 1151 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 are not related to the students’ 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 fall short of the boys’ discourse and in certain aspects even surpasses it, as discussed in the article.

**Key words:** 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 the United States (Pahlke, Hyde, Shibley, & Carlie, 2014), Europe (Francis, Archer, Moote, Dewitt, Macleod, & Yeomans, 2017), Israel (Zohar & Bronshtein, 2005), the Far East (Oon, Cheng, & Wong, 2020), and Australia (Abraham, & Barker, 2020) are concerned about the significant gender gap and seek ways of changing this pattern of reluctance among girls to pursue physics (Carreño, Castro-Alonso & Gallardo, 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 process (Legewie & Diprete, 2012; Jugović, 2017). Researchers attribute the low numbers of girls who pursue physics studies to low confidence in their scientific abilities (Gillibrand, Robinson, Brawn, & Osborn, 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). According to Mujtaba and Reiss (2013), girls who did opt for the sciences did so primarily because of their teachers’ influence ­– influence that apparently deserves further study, in order to assess how physics teachers can conduct their lessons in a manner that encourages girls (Murphy & Whitelegg, 2006; Jugović, 2017; Mujtaba, & Reiss, 2013).

In this study we chose to explore classroom discussion led primarily by the teacher, which is a crucially important part of the learning process (Hagenah, Kang, Stroupe, Braaten, Colley, & Windschitl, 2016). Some studies claim that girls participate more actively in classroom discourse in groups that have a majority of girls (Jurik, Gröschner, & Seidel 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, Karlsson, & Sørensen, 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, Ottander, & Benckert, 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, Kademian, Davis, & Palincsar, 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 (Windschitl & Stroupe, 2017; Ruthven, Mercer, Taber, Guardia, Hofmann, Ilie, Luthman, & Riga, 2017). Teachers who conduct an effective discourse promote their students’ conceptual understanding in a direct and impactful way (Mortimer & Scott, 2003; Chin, 2007). 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, Jones, Kennewell, & Beauchamp, 2005). Posing questions allows the teacher to cultivate new knowledge and concepts gradually while generating an active discussion with the students (Ford & Wargo, 2012; Pimentel & McNeill, 2013; Lee & Irving, 2018; Nussbaum & Edwards, 2011; 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 (Dohrn, & Dohn, 2018; Chen, Hand, & Norton-Meier, 2017; Abrami, Bernard, Borokhovski, Waddington, Wade, & Persson, 2015). 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, Hand, & Norton-Meier, 2017).

The teacher’s questions have two main functions. First, they assess the students’ knowledge and comprehension of what has been explained (Chin, 2007; Nystrand, Wu, Gamoran, Zeiser, & Long, 2003; Chin, 2006), 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 and Campbell, 2008; Mercer & Dawes, 2008). 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). Importantly, the quality of the question is affected by the context in which it is posed. An open-ended question that requires a high-order thinking is not regarded as such if it has already been discussed, or alternatively, if the teacher directs the students’ responses towards one specific answer, as this makes the question closed-ended (Erdogan and Campbell, 2008).

If the teacher sparks a fruitful class discussion, students will join the discourse not only by answering questions but also by asking questions themselves (Scott, Mortimer, & Aguiar, 2006; Nystrand et al., 2003; Furtak, & Ruiz-Primo, 2008). 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 (Windschitl & Stroupe, 2017; Ruthven et al., 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 (Gamoran & Nystrand, 1992). 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 (Tobin, 1988; De Welde, Foote, Hayford, & Rosenthal, 2013). 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, Rodriguez, Tamis-LeMonda, Spellmann, Carlson, & Snow, 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 mixed 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 and 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, Nzekwe, & Molyneaux, J., 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 & 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.

In contrast, a study by Sampson, Gresham, Leigh, & McCormick-Myers (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 one 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 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 single-sex classroom boys’ and girls’ physics lessons, with attention to the following elements:
   1. The number of words spoken by students and teacher in each class
   2. The number of closed-ended and open-ended questions posed by the teacher in each class
   3. The number of open-ended and closed-ended questions posed by the students in each class
   4. The number of closed and open discourse episodes initiated by the teacher in each class
   5. 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.

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. Both schools are intended for students with a religious background and offer only single-sex classes.

Each class covered the 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 authors over the course of three years (Authors, in press). The lesson was divided into one-minute time segments, and for each minute all the utterances 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.

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, the teacher or the 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 words and question were significantly different from each other. The number of discourse segments was too low to be statistically tested.

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 indicate 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. 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 3-5 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.

***Table 1: Elements of the Discourse in the Boys’ Class and the Girls’ Class***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Discourse parameter | Girls | | Boys | | t |
| *M* | *SD* | *M* | *SD* |
| Teacher’s words | 2104.3 | 436.8 | 2891.7 | 869.0 | 1.24 |
| Students’ words | 1701 | 814.2 | 1842.3 | 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 |  |
| Open discourse segments by teacher | 10.0 | 6.2 | 5.0 | 2.0 |  |
| Closed discourse segments by students | 6.7 | 2.3 | 5.7 | 4.0 |  |
| Open discourse segments by students | 7.6 | 2.8 | 5.3 | 1.5 |  |

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.

***Table 2: Sample Open-Ended Questions and Closed-Ended Questions***

|  |  |  |
| --- | --- | --- |
|  | Closed-ended questions | Open-ended questions |
| 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? The same thing?  Or:  Teacher, how did you calculate 7.1 seconds? | How could the 2 kg string pull 3 kg?  Or:  Wait, we said that the mass does not change, so how is it that 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? | I’m asking whether, if I were ejected into space, in a suit, would I also orbit the earth even without a spaceship?  Or:  Why, if I’m orbiting the earth, do I feel as if I’m not moving? |

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?

Female student 1: The same thing.

Teacher: Good, let’s write that down. (Lesson 3, Girls)

Male student 1: When you talk about the radius of the satellite, what do you mean?

Teacher: The radius of the track of the orbit.

Male 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:

Female 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 upwards, the thread tears. The thread is torn in the second set of circumstances, but not in the first…

Female student 2: There are forces pulling it in two directions…

Teacher: Good. How do you know?

Female student 2: There is the weight, and there is the thread upwards…

Teacher: Okay, but…

Female student 3: Because he is pulling upwards...

Teacher: At first the thread does not tear, and when I pull it upwards it does tear.

Female student 2: What variable is in the question? This is it!!

Teacher (redirecting the question to the student): What is the important variable in the question?

Female student 4: Acceleration upwards.

Teacher: In one word?

Female student 4: Upwards…

Teacher: What does it mean that there is acceleration upwards?

Female student 5: That there is force.

Teacher: And what does it mean that there is force?

Female student 5: The thread is limited; it cannot support the full force…

Teacher: What is the tension in the thread, how much tension is there here, friends?

Female 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 Sigma F of F minus T, with F in an upward direction (the teacher writes the equations on the board…). T is upwards and MG is downwards. If the force of the tension is greater than the weight of the ball, then the ball will accelerate upwards.

Female 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: Look, I have a building 100 meters high, I throw a ball from it, the initial speed is zero, and I ask you what was the velocity of the ball when it reached reach ground?

Student 1: Energy considerations need to be made

Teacher: Energy considerations, good, what's the equation?

Student 2: MGH

Student 1: Equals?

Student 2: MV square divided by R,

Teacher: Good, MV squared divided by R, we are back in energy…

Teacher: Do you know what to do here? Do you understand why we wrote this?

Student 3: Yes, for energy considerations.

Teacher: All right? What is the assumption here, what is the assumption that you did not say it orally and now you are going to say it?

Student 1: That the top of the building is zero, that the H is not that high,

Teacher: Excellent, that here H equals to 0 and here H equals to one hundred, then you said well, here there is height no speed, here there is speed no height, excellent, let us put on one side of the equation all the energies at the beginning, MGH….

Teacher: On the other side of the equation we put all the energies there are, there is simply speed here, there is no height energy here, and 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

Student 7: For example, you could determine the ... H,

Teacher: Let's say a hundred meters, set this H is equal to 0, here what H?

Student 1: 200?

Student 2: No, it's minus 100

Teacher: Minus 100, then, wait, then what will be the equation?

Student 7: It will be, MGH equals minus, it will be Delta H, ….

Student 5: It came out the same!

Teacher: True, we got exactly the same thing, in the end we will get exactly the same speeds as before.

Student 7: The minus, in short, does not matter,

Teacher: The minus does not matter, so what, what does matter?

Student 7: It should be a minus,

Teacher: No, MGH is the height energy, if the H is negative then it means that it has less height energy at this lower point compared to higher points

Student 1: Oh, so you say, okay, teacher can this equation change? Can change? Wait, G is always positive, M is positive, and what's the value of H? ….

Teacher: When is it equal to 0?

Student 8: When the R strives infinity.

Teacher: For R strives endlessly. Right? I asked when is it equal to zero?

Students: (talk together) When the R aspires to infinity,

Teacher: When the R strives infinity, I mean I brought it from Earth,

Student 1: Right, to the end of, to the end of the universe.

Student 3: Hey hey, it exists, okay, who told you it does not exist? You have not reached it yet,

Teacher: Okay, we'll do with other stars, wait, so now you guys say, so what's the minus? Why is it a minus?

Student 10: I have no idea teacher,

Teacher: No, so you still do not understand, okay.

Student 4: What was there, you wrote down zero, now you're just going down, that in infinity the energy is zero,

Teacher: Excellent!

...

Teacher: ... we chose R equals infinite, to be this 0 height, likewise here we chose this 0 to be here at the top of the building. That's how it is, it's my privilege to choose the infinite to be, where in R strives to infinity it is energy 0, …, everything is negative, right, as in the building, I am allowed to say MGH here, here it is height 0 here height is minus 5, how much energy do you have when you went down to minus 5, more or less?

Student 1: More,

Teacher: How much energy do you have?

Student 1: Less.

Teacher: Less, because you're in a lower place, right? So here too, infinitely I have 0 and everything below I have less.

Student 8: So all my energy in space is my speed less gravity, less, like

Teacher: Yes, basically what I want to say is that potential energy is a relative value, relative to the height you choose as you wish. (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 and sometimes, through targeted questions, 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?

Female student 1: But 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?

Female student 2: Why would the weight change?

Female student 3: Are you adding acceleration? (Lesson 1. Girls)

On the basis of these examples, and having listened to the recordings, we found that the students demonstrated curiosity and freely posed many 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 characteristic was evident 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 the second with some horizontal velocity into freefall. I ask them what will happen. At first they vary [in their responses], suggesting different possibilities, and then they watch the demonstration. After seeing what really happens, they begin to offer explanations. They argue, conjecture, 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 and at high speed, and asked them to calculate the landing time. They calculated that it would land in 36 hours. They immediately realized the absurdity and looked for their mistake. They discussed it among themselves, asked each other questions, offered various suggestions, replied and reasoned, 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 discussion among them 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 in the discourse. 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, did not participate in the discourse, and I also 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 and asked many questions themselves, 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**

In this case study we aimed to analyze 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 method practiced by some of the religious high schools in Israel. Single-sex classroom teaching takes place in other countries as well (Murphy & Whitelegg, 2006; Pahlke et al., 2014; Abraham & Barker, 2020) and it is important to develop a deeper understanding of the discourse in these classes.

The results of the study indicate that the girls demonstrated a similar degree of involvement and participation in classroom discussion relative to the boys. This involvement manifested in various parameters of the discourse. In all the parameters that were characterized, the girls’ class resembled that of the boys and did not show a significant difference in the number of words spoken during a lesson, the number of closed-ended questions they 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 feel freer and more self-confident, and are not afraid to express themselves and participate in scientific discourse (Simpson, et al., 2016). It was evident 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 through the questions they asked and the scientific concepts they discussed. They demonstrated that they were not content with posing closed-ended questions aimed at ensuring their understanding of ideas already taught, but that like the boys they can initiate open-ended questions and create an open discourse that enriches the discussion of the lesson’s concepts, ultimately fostering a deeper understanding of these concepts.

The finding that in single-sex classes girls’ conduct resembles that of boys confirms similar findings, such as those of Francis et al. (2017), Jurik et al. (2013), and Meece and Jones (1996), but contradict those of Sampson et al. (2014), which pointed to reduced participation by girls in single-sex classroom discourse.

The finding that there was a higher average number of teacher-initiated open discussion segments in the girls’ class may indicate that these segments were shorter. On the face of it, one might therefore argue that this discourse was more superficial, but a review of the recorded lessons and the transcripts indicates that this does not seem to be the case. The reason that the teacher initiated more discourse segments in the girls’ class was that the students asked more questions, thus taking the discussion in different directions and touching on new concepts. Consequently the discourse was interrupted more often, as the teacher redirected questions to the students or initiated a discussion of the question posed, which in turn created more open discourse segments. The findings clearly indicate that the girls did not hesitate to ask open-ended questions, which are the type of questions 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 (Dohrn, & Dohn, 2018; Chen, et al., 2017; Abrami, et al., 2015).

The teacher’s pedagogical style evidently contributed to the students’ high degree of engagement in the lesson, and he made a point of fostering as vibrant a discourse among the girls as among the boys. He used the discourse to engage students of both genders in the subject of physics. Most of these questions 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 themselves express scientific concepts, and therefore in many cases he did not answer their questions but instead incorporated them into the classroom discussion. In so doing he apparently increased their motivation to participate in the discussion and fostered their reasoning and thinking skills (Golding, 2011). His dialogic teaching style, in which students formulate the scientific concepts and mathematical equations, has the potential to promote girls’ pursuit of physics studies by improving their self-esteem and increasing their expectations of themselves (Murphy& Whitelegg, 2006; Jugović, 2017; Simpson et al., 2016; Abraham & Barker, 2020; Hughes et al., 2013).

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 such cleverness. Another narrative holds that men and women are naturally different and therefore drawn to different subjects. Our research findings refute these narratives.

In this case study the girls evidently gained an advantage by being part of the single-sex group, but to further test this hypothesis one must compare the findings with discussion participation by the same girls when they are part of a mixed group. It is important to emphasize that it is not clear to what extent the present case study may be regarded as representative. By their nature, case studies focus on a defined and circumscribed situation, usually addressing a specific question embodied in that unique situation (Reinsvold, & Cochran, 2012; Worku & Alemu, 2020; Benedict-Chambers et al., 2017; Christodoulou, & Osborne, 2014). Moreover, the very fact that a specific teacher agreed to participate in the study, along with his classes, in itself raises doubts about the extent to which the findings may be generalized. Nevertheless, it is important to bear in mind that a substantial portion of research-based pedagogical knowledge comes from case studies, and the present study, too, may offer important insights.

In conclusion, it appears from the findings of this study that under certain conditions girls-only physics classes should be encouraged so as to offer them a nurturing environment and encourage them to participate meaningfully in class. The characteristics of discourse in physics lessons does not explain why girls avoid academic studies of physics in higher education and the reasons should be further investigated in relation to sociological aspects. We believe that increasing the accessibility and involvement of girls in classroom discourse during physics lessons may encourage them to pursue physics later and reinforce the role of women in physics.

**References**

Abraham, J. & Barker, K. (2020). Motivation and engagement with physics: A comparative study of females in single-sex and co-educational classrooms. *Research in Science Education, 50(6),* 2227-2242. https://doi:10.1007/s11165-018-9770-3

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research, 85(2)*, 275-314

Authors (2021), (In press). Characteristics of classroom discourse in physics lessons. *Research in Science & Technological Education*.

Benedict-Chambers, A., Kademian, S. M., Davis, E. A., & Palincsar, A. S. (2017). Guiding students towards sensemaking: Teacher questions focused on integrating scientific practices with science content. *International Journal of Science Education, 39(15),* 1977-2001.

Carrento, M. J., Castro-Alonso, J. C., & Gallardo, M. J. (2021). Interest in physics after experimental activities with a mobile application: Gender differences. International Journal of Science and Mathematics Education, Doi: https://doi.org/10.1007/s10763-021-10228-4

Chen, Y. (2019). Developing students’ critical thinking and discourse level writing skill through teachers’ questions: A sociocultural approach. *Chinese Journal of Applied Linguistics, 42(2),* 141-162.

Chen, Y., Hand, B., & Norton-Meier, L. (2017). Teacher roles of questioning in early elementary science classrooms: A framework promoting student cognitive complexities in argumentation. *Research in Science Education, 47(2),* 373-405.

Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students’ responses. *International Journal of Science Education, 28(11),* 1315-1346.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44(6),* 815-843.

Chin, C., & Kayalvizhi, G. (2005). What do pupils think of open science investigations? A study of Singaporean primary 6 pupils. *Educational Research, 47(1),* 107-126.

Chin, C., & Osborne, J. (2008). Students’ questions: A potential resource for teaching and learning science. *Studies in Science Education 44(1),* 1–39. https://doi:10.1080/03057260701828101.

Christodoulou, A., & Osborne, J. (2014). The science classroom as a site of epistemic talk: A case study of a teacher's attempts to teach science based on argument. *Journal of Research in Science Teaching, 51(10),* 1275-1300.

De Welde, K., Foote, N., Hayford, M., & Rosenthal, M. (2013). Team teaching "Gender perspectives": A reflection on feminist pedagogy in the interdisciplinary classroom. *Feminist Teacher, 23(2),* 105-125. https://doi:10.5406/femteacher.23.2.0105

Dohrn, S. W., & Dohn, N. B. (2018). The role of teacher questions in the chemistry classroom. *Chemistry Education Research and Practice, 19(1),* 352-363.

Eliasson, N., Karlsson, K. G., & Sørensen, H. (2016). Teacher-student interaction in contemporary science classrooms: Is participation still a question of gender? *International Journal of Science Education, 38(10),* 1655–1672. https://doi:10.1080/09500693.2016.1213457

Eliasson, N., Karlsson, K. G., & Sørensen, H. (2017). The role of questions in the science classroom–how girls and boys respond to teachers’ questions. *International Journal of Science Education, 39(4),* 433-452.

Erdogan, I., & Campbell, T. (2008). Teacher questioning and interaction patterns in classrooms facilitated with differing levels of constructivist teaching practices.*International Journal of Science Education, 30*(14), 1891-1914.

Ford, M. J., & Wargo, B. M. (2012). Dialogic framing of scientific content for conceptual and epistemic understanding. *Science Education, 96(3),* 369-391.

Francis, B., Archer, L., Moote, J., Dewitt, J., Macleod, E., & Yeomans, L. (2017). The construction of physics as a quintessentially masculine subject: Young people's perceptions of gender issues in access to Physics. *Sex Roles, 76(3-4),* 156-174. https://doi:10.1007/s11199-016-0669-z

Furtak, E. M., & Ruiz-Primo, M. A. (2008). Making students’ thinking explicit in writing and discussion: An analysis of formative assessment prompts. *Science Education 92(5),* interaction 824. https://doi:10.1002/sce.20270.

Gillibrand, E., Robinson, P., Brawn, R., & Osborn, A. (1999). Girls' participation in physics in single sex classes in mixed schools in relation to confidence and achievement. *International Journal of Science Education, 21(4),* 349-62

Golding, C. (2011). Educating for critical thinking: Thought‐encouraging questions in a community of inquiry*. Higher Education Research and Development, 30(3),* 357-370.

Hogstrom, P., Ottander, C., & Benckert, S. (2010). Lab work and learning in secondary school chemistry: The importance of teacher and student interaction. *Research in Science Education, 40(4),* 505-523.

[Hughes, R. M](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Hughes,+Roxanne+M/$N?accountid=41238).,  [Nzekwe, B](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Nzekwe,+Brandon/$N?accountid=41238)., & [Molyneaux, K. J](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Molyneaux,+Kristen+J/$N?accountid=41238). (2013). The single sex debate for girls in science: A comparison between two informal science programs on middle school students' STEM identity formatio*n.* [*Research in Science Education*](https://www-proquest-com.mgs.hemdat.ac.il/pubidlinkhandler/sng/pubtitle/Research+in+Science+Education/$N?accountid=41238)[,43I(5),](https://www-proquest-com.mgs.hemdat.ac.il/indexingvolumeissuelinkhandler/23469/Research+in+Science+Education/02013Y10Y01$23Oct+2013$3b++Vol.+43+$285$29/43/5?accountid=41238)1979-2007.  https://doi:10.1007/s11165-012-9345-7

Jones, M. J., & Wheatly, J. (1990). Gender differences in teacher-student interactions in science classrooms. *Journal of Research in Science Teaching, 27(19),* 861–874.

Jurik, V., Gröschner, A., & Seidel, T. (2013). How student characteristics affect girls’ and boys’ verbal engagement in physics instruction. *Learning and Instruction, 23,* 33–42. https://doi: 10.1016/j.learninstruc.2012.09.002

Jugović, I. (2017). Students' gender-Related choices and achievement in physics. *CEPS Journal: Center for Educational Policy Studies Journal, Ljubljana, 7(2),* 71-95

Meece, J. L. & Jones, M. G. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of research in Science Teaching, 33(4),* 393-406. https://doi.org/10.1002/(SICI)1098-2736(199604)33:4<393::AID-TEA3>3.0.CO;2-N

Lee, S. C., & Irving, K. E. (2018). Development of two-dimensional classroom discourse analysis tool (CDAT): Scientific reasoning and dialog patterns in the secondary science classes. *International Journal of STEM Education, 5*, 1-17.

Legewie, J. & Diprete, T. A. (2012). School context and the gender gap in educational achievement. *American Sociological Review, 77(3)*, 463-485. https://doi:10.1177/0003122412440802

McClowry, S. G., Rodriguez, E. T., Tamis-LeMonda, C. S., Spellmann, M. E., Carlson, A., & Snow, D. L. (2013). Teacher/student interactions and classroom behavior: The role of student temperament and gender. *Journal of Research in Childhood Education, 27(3),* 283-301. https://doi: 10.1080/02568543.2013.796330

McNeill, K. L., & Pimentel, D. S. (2010). Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation. *Science Education, 94(2),* 203-229.

Mortimer, E.F. & Scott, P.H. (2003). Meaning making in secondary science classrooms. Buckingham: Open University Press.

Morris, J., & Chi, M. T. (2020). Improving teacher questioning in science using ICAP theory. *The Journal of Educational Research, 113(1),* 1-12.

Murphy, P., & Whitelegg, E. (2006). Girls and physics: Continuing barriers to "belonging" . *Curriculum Journal, 17(3),* 281-305.

Mujtaba, T., & Reiss, M. (2013). What sort of girl wants to study physics after the age of 16? Findings from a large-scale UK Survey. *International Journal of Science Education, 35(17),* 2979-2998.

Nussbaum, E. M. & Edwards, O. V. (2011) Critical questions and argument stratagems: A framework for enhancing and analyzing student. *Journal of the learning sciences, 20(3),* 443-488 https://doi.org/10.1080/10508406.2011.564567

Nystrand, M., Wu, L. L., Gamoran, A., Zeiser, S., & Long, D. A. (2003). Questions in time: Investigating the structure and dynamics of unfolding classroom discourse. *Discourse Processes, 35(2),* 135-198.

Nyström, E. (2009). Teacher talk: Producing, resisting and challenging discourses about the science classroom. *Gender and education 21(6),* 735-751. https://doi.org/10.1080/09540250903119146 |

Oon, P. T., Cheng, M. M. W., & Wong, A. S. (2020). Gender differences in attitude towards science: Methodology for prioritizing contributing factors. *International Journal of Science Education, 42(1),* 89-112. https://doi:10.1080/09500693.2019.1701217

Pahlke, E.,  [Hyde, J., Shibley](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Hyde,+Janet+Shibley/$N?accountid=41238), [A., & Carlie, M](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Allison,+Carlie+M/$N?accountid=41238). (2014). The effects of single-sex compared with coeducational schooling on students’ performance and attitudes: A meta-analysis. [*Psychological Bulletin*](file:///C:\Users\ayala\Desktop\מכללות\חמדת\אסתר%20אפללו\מגדר%20מאמר\GENDER%20ARTICLE\Psychological%20Bulletin)[*, 140(4),*](https://www-proquest-com.mgs.hemdat.ac.il/indexingvolumeissuelinkhandler/60977/Psychological+Bulletin/02014Y07Y01$23Jul+2014$3b++Vol.+140+$284$29/140/4?accountid=41238)1042-1072. https://doi:10.1037/a0035740

Pimentel, D. S., & McNeill, K. L. (2013). Conducting talk in secondary science classrooms: Investigating instructional moves and teachers' beliefs. *Science Education, 97(3),* 367.

Reinsvold, L. A., & Cochran, K. F. (2012). Power dynamics and questioning in elementary science classrooms. *Journal of Science Teacher Education, 23(7),* 745-768.

Ruthven, K., Mercer, N., Taber, K. S., Guardia, P., Hofmann, R., Ilie, S., Luthman, S. & Riga, F. (2017). A research-informed dialogic-teaching approach to early secondary school mathematics and science: The pedagogical design and field trial of the "episteme" intervention. *Research Papers in Education, 32(1),* 18-40.

[Sampson, P. M](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Sampson,+Pauline+M/$N?accountid=41238)., [Gresham, G.,](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Gresham,+Gloria/$N?accountid=41238) [Leigh, M. M](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/Leigh,+Melissa+M/$N?accountid=41238)., & [McCormick-Myers, D.](https://www-proquest-com.mgs.hemdat.ac.il/indexinglinkhandler/sng/au/McCormick-Myers,+Denice/$N?accountid=41238) (2014). Do you want single-gender science classrooms in your middle schools?[*Teacher Education and Practice*](https://www-proquest-com.mgs.hemdat.ac.il/pubidlinkhandler/sng/pubtitle/Teacher+Education+and+Practice/$N?accountid=41238)[*, 27(1),*](https://www-proquest-com.mgs.hemdat.ac.il/indexingvolumeissuelinkhandler/23469/Teacher+Education+and+Practice/02014Y01Y01$23Jan+2014+-+Mar+2014$3b++Vol.+27+$281$29/27/1?accountid=41238)190-202.

Simpson, A., Che, S. M., & Bridges, W. C., Jr. (2016). Girls' and boys' academic self-concept in science in single-sex and coeducational classes. *International Journal of Science and Mathematics Education 14(8),* 1407-1418. https://doi:10.1007/s10763-015-9676-8

Scott, P. H., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90(4),* 605-631.

Smart, J. B., & Marshall, J. C. (2013). Interactions between classroom discourse, teacher questioning, and student cognitive engagement in middle school science. *Journal of Science Teacher Education, 24(2),* 249-267. https://doi:10.1007/S10972-012-9297-9

Thompson, J., Hagenah, S., Kang, H., Stroupe, D., Braaten, M., Colley, C., & Windschitl, M. (2016). Rigor and responsiveness in classroom activity. *Teachers College Record.* https://scholarworks.boises tate.edu/cifs\_facpubs/164.

Tanner, H., Jones, S., Kennewell, S., & Beauchamp, G. (2005). Interactive whole class teaching and interactive white boards. Paper presented at the Building Connections: Research, Theory and Practice, *Proceedings of the 28th Annual Conference of the Mathematics Education Research Group of Australasia*, 720-727.

Tobin, K. (1988). Differential engagement of males and females in high school science. *International Journal of Science Education, 10(3),* 239–252.

Windschitl, M. A., & Stroupe, D. (2017). The three-story challenge: Implications of the next generation science standards for teacher preparation. *Journal of Teacher Education, 68(3),* 251-261.

Worku, H. & Alemu, M. (2020). Classroom interaction in physics teaching and learning that impede implementation of dialogic teaching: an analysis of student – student interaction. *Bulgarian Journal of Science and Education Policy, 14(1),* 101-127.

Zohar, A., & Bronshtein, B. (2005). Physics teachers' knowledge and beliefs regarding girls' low participation rates in advanced physics classes. *International Journal of Science Education, 27(1)*, 61-77.