DO OPEN-ENDED TEACHERS' QUESTIONS PROMOTE OPEN CLASS DISCOURSE?

Ester Aflalo
Ayala Raviv
Hemdat College of Education, Israel

ABSTRACT

The present study aimed to examine the relationships between the types of questions asked by teachers and the patterns of class discussion that develop from them. The study analysed seven high schools' classroom discourse involving 124 students. Recordings and classroom observations were used from a total of 25 lessons for the analyses. Each of the teachers' questions was categorized as either closed or open-ended and each discourse episode was also classified as either a closed episode or an open discourse episode. A total of 1748 questions and 533 discourse episodes were analysed. The findings show that the teachers asked many open-ended questions however, no significant statistical correlation was found between the open-ended questions and open discourse. That is, most of the open-ended questions did not lead to open dialogical discourse, and the class discussion did not facilitate deep conversation. The pedagogical significance and implications of these findings are discussed.

Keywords: Class discourse, Closed questions, Open discourse, Open-ended questions, Teachers' questions

INTRODUCTION

The verbal interaction between teachers and students has a considerable role in shaping the learning atmosphere in the classroom, and various studies have emphasized the importance of classroom discussion for learning (Hogstrom et al., 2010; Mortimer & Scott, 2003; Thompson et al., 2016).

In science learning, for example, scientific ideas and ways of reasoning are learned through social interactions in parallel with individual activity, and these interactions are advantageous in the development of science comprehension (Mercer et al., 2004). Giving students the opportunity to discover their ideas through conversation with the teacher and with each other is one of the foundations of active learning (Ruthven et al., 2017; Windschitl & Stroupe, 2017). When teachers conduct effective class discussions, they directly support the conceptual understanding of their students (Chin, 2007; Mortimer & Scott, 2003).

The questions teachers ask and the feedback they give when students answer constitute the most common practice for generating classroom discussion; this practice has a critical impact on creating effective discourse that promotes students' thinking (Chin, 2006; Morge, 2005). Effective discourse is an open, dialogical discourse that encourages a variety of perspectives and is based on the exchange of ideas between the teacher and the students, and among students themselves (Ford & Wargo, 2012; Pimentel & McNeill, 2013).

It has been argued that open-ended questions that do not have a single correct answer—questions of higher-order thinking that require students to present a position, support arguments, conjecture, and compare, and the like—are questions that encourage open discourse (Chin 2006; Nystrand et al., 2003; Smart & Marshall, 2013).

In a previous study, we analyzed the characteristics of classroom discourse in physics classes (Aflalo & Raviv, 2020). The main objective of the present study was to learn about the relationships between the quality of a teacher's questions (open-ended or closed) and the quality of the classroom discourse that emerges from them (open or closed). Understanding these contexts can contribute to increasing teachers' awareness of these aspects of their teaching and their professional advancement, with respect to using open-ended questions as lead-ins to effective discourse.

LITERATURE REVIEW

The Teachers' Questions

Questions are so widespread in classroom practice that it sometimes seems as though they constitute the core essence of teaching. Both research and practice over the past century have shown that asking questions in class is one of the most influential teaching activities (Dillon, 2006), and that most of the questions in the classroom are asked by the teacher (Erdogan & Campbell, 2008; Kaya, 2014; Reinsvold & Cochran, 2012). Unlike the role of questions in the real world, where those posing the question expect to receive an answer that is unknown to them, the opposite process takes place in the classroom: teachers mostly ask questions to which they know the answers (Nystrand et al., 2003).

Teachers' questions have many purposes. A teacher's questions help build the student's knowledge and gradually lead to the clarification of information. They help the student to focus their thinking, develop the ability to present well-founded arguments, and develop critical thinking (Abrami et al., 2014; Chen, 2019; Golding, 2011; Morris & Chi, 2020). Questions also encourage students to use language as a thinking tool (Benedict-Chambers et al. 2017; Mercer & Howe, 2012), and increase the motivation to learn (Chin & Kayalvizhi, 2005). Through questions, teachers can attempt to identify students' misconceptions, to resolve conflicts, to develop students' ideas, and to bridge the gap between new information and existing information (Yip, 2004). The most basic goal of teachers' questions is to encourage students' oral communication and to increase verbal interaction in the classroom (Walsh, 2013).

Researchers use different methods and concepts to classify teachers' questions, and it is often possible to find connections and commonalities among the classifications. For example, Nystrand and Gamoran (1991) classified the questions according to their level of authenticity in relation to the students' inner world, while Nassaji and Wells (2000) classified them in accordance with whether they asked about "known information" or if the questions were "open to negotiation"—that is, questions about basic knowledge as opposed to questions meant to provoke discussion. A variety of classifications are essentially based on the level of thinking required to answer the question. Bloom's taxonomy (Bloom et al., 1956) offers a hierarchy that sorts questions into a spectrum, from knowledge questions, which express the lowest level of thinking, through comprehension questions, and questions of application, analysis, synthesis, and evaluation. Anderson et al (2001) subsequently changed this taxonomy, emphasizing the differences between cognitive processes, and classifying the questions as ones that invite the student to remember, understand, apply, analyse, evaluate, and create.

Yip (2004) analyzed and classified teachers' questions that led to a change in the students' perceptions. He divided these questions into four groups: eliciting, challenging, extending, and applying—i.e., questions that checked students' perceptions, challenged them to deal with different views; directed them towards extending their knowledge and integrating it with their previous knowledge, and questions that helped students to apply new information.

Other researchers have proposed a broad distinction between questions of lower-order and higher-order thinking. Lower-order questions examine factual knowledge, usually of a sort that is extracted from memory, and relates to what has already been learned. Higher-order questions engage the student's abilities to understand, analyse, generalize, and synthesize (Karmon, 2007; Resnick et al., 2010; Zohar, 2004). Thus, in classrooms where the teacher asked more questions of higher-order thinking, students showed a deeper understanding of scientific concepts (Smart & Marshall, 2013). Similarly, another classification that had been previously proposed also posits two categories of questions: confirmation versus transformation questions. Confirmation questions aim to clarify information, to define and to explain concepts; transformation questions involve the student's rebuilding and reorganizing of knowledge (De Jesus et al., 2003).

The present study uses Erdogan and Campbell's (2008) classification into open-ended and closed-ended questions. Closed-ended questions are questions that usually have one correct answer, or a very narrow spectrum of possible answers. These questions usually require short factual answers that provide only units of information; they are designed to test what the student knows, and the answers are known to the teacher (Mercer & Dawes, 2008). In contrast, open-ended questions are questions that do not have one decisive answer, and which lead the student to express a position, offer examples or proofs, hypothesize, compare, argue or justify arguments, and solve problems. They are intended to promote discussion and to examine the student's reasoning and thinking, and at the same time to develop the skills of this thinking (Chin, 2006). Open-ended questions do not relate to knowledge in its plain state alone, but rather ask students to execute a particular action on the basis of the knowledge and by means of it. It is important to emphasize that the quality of the question is influenced by the context in which it is asked. An open-ended question, at the level of higher-order thinking, is not considered as such if it has already been the subject of a prior discussion or, alternatively, if the teacher directs the students' responses towards a specific answer alone.

Studies show that despite their importance, the frequency of open-ended questions is low in frontal and teacher-centred lessons (Alexander, 2008). It is commonly supposed that good teaching means asking questions that promote engagement and thinking among students, especially with respect to the frontal teaching model (Chen, Hand, & Norton-Meier, 2017). According to Osborn et al. (2003), the importance of the questions lies in the fact that it makes learning meaningful. It is not enough for learners to be exposed to scientific ideas; they must practice the ideas personally through discussion and analysis. However, systematic analyses of lessons reveal that teachers tend to ask few thought-provoking questions; in most cases, the answers to the questions involve a simple act of reproducing existing knowledge and are limited to a single answer or a small number of correct possibilities (Barnes, 2010; Biggers, 2017; Eliasson et al., 2017; Dohrn & Dohn, 2018; Harpaz & Lefstein, 2000).

Classroom Discourse

Questions are the most common technique for increasing student engagement and interaction in the classroom. In practice, most whole-class discussions develop from the questions that teachers pose (Nassaji & Wells, 2000). Thus, these questions, and the resulting discourse have a direct impact on the cognitive processes that the students undergo (Backer, 2018; Chin 2006; Morge, 2005; Smart & Marshall, 2013). For example, Morris and Chi (2020) addressed teachers' questions according to their influence on discourse. They distinguished between passive questions, which require very short answers such as "yes" or "no"; active questions, in which the student is required to reproduce information that was presented previously; and constructive questions that require the student to present answers beyond information that was learned in class, thereby promoting effective discourse. The more the questions challenge existing opinions, the more likely they are to stimulate debate and encourage student involvement in the class discourse (Scott, 2008).

Engaging in effective whole-class discourse is a significant challenge. Class discourse may be placed on a spectrum ranging from a "lecture" approach, where it is mainly the teacher who speaks and controls the content of the lesson, through closed questions that create very short discursive episodes, to open and dialogical discourse, that is prompted by open-ended questions (Alexander, 2008; Tanner et al., 2005). In open discourse there is an exchange of ideas between the teacher and the students, and among the students themselves, which encourages a variety of views and ideas (Scott et al., 2006). Open and dialogical discourse places students at the centre and promotes meaningful learning (Ford & Wargo, 2012; Lee & Irving, 2018; Pimentel & McNeill, 2013).

The importance of dialogical discourse has been emphasized, for example, in the teaching of science and mathematics. The widespread recognition of the importance of constructive learning, and the understanding that students develop alternative perceptions of scientific concepts, explain the need for open and dialogical discourse. Through open discourse, the teacher can influence the shaping of students' conceptual perceptions (Erath et al., 2018; Ruthven et al., 2017).

However, open classroom discourse is not common. The more prevalent structure in classrooms is a closed discourse that usually consists of a three-stage sequence as first described by Mehan (1979). This sequence is made up of a teacher's prompt or question, a student's response, and the teacher's feedback on the student's answer, and is called IRE: I = teacher initiates; R = student responds; E = teacher evaluates. The teacher's feedback can determine whether the conversation will actually develop into an open discourse or whether the discourse will remain closed. For example, when the teacher only confirms the student's answer, the discourse will be closed. Conversely, when the teacher incorporates the student's response into their later remarks, and expands upon it, following it up with another question, an open discourse may ensue (Gamoran & Nystrand, 1992). When the teacher responds to the student's words with a question, and the student, or several students, respond to the teacher's remarks, and the teacher engages in an open discussion, a multi-stage discourse sequence is created (Scott, et al., 2006). An open discourse is characterized by a chain of sequences and has fewer IRE sequences that are cut off after teachers receive the answer they expected. Closed IRE sequences generally block the development of discussion, as well as students' opportunities to participate in discourse and to challenge their ideas (Christodoulou & Osborne, 2014; McNeill & Pimentel, 2010). In many classrooms, the discourse is mostly a monologue by the teacher, making extensive use of IRE sequences, and focusing on the transmission of facts with very limited student involvement (Badr, 2019, Pemental, & Mcneill, 2013). Nystrand et al. (2003) found that open classroom discourse is rare, lasting an average of 50 seconds in eighth grade, and 15 seconds in ninth grade. It emerges primarily as a result of open and authentic teachers' questions.

In the present study, we examined the extent to which teachers' open-ended questions developed into open discourse. The aim of the study was to examine the connections between the types of questions asked by the teacher and the types of discourse that developed from them. Understanding these relationships can contribute to the professional advancement of the teacher and can improve classroom discourse and promote meaningful learning. Thus, the present research sought to answer the following questions:

1. What are the types of questions asked by teachers and what are the discourse patterns in the class that develop following these questions?
2. What is the correlation between the questions asked by the teacher and the type of class discourse that follows?

RESEARCH DESIGN AND METHODOLOGY

The study encompassed seven case studies and was based on systematic and naturalistic collection of data, without external intervention in the classroom. The research was conducted within a quantitative paradigm and supported by qualitative data. The quantitative analysis included monitoring the number of questions and discourse episodes in each lesson. The qualitative analysis included determining the type of each question and characterizing each discourse episode by examining the context in which the questions were asked and the discourse that developed from them. The questions were classified as open questions, at a high-order of thinking, and closed questions, at a low-order of thinking. Discourse episodes were classified according to the discourse patterns of open or closed discussions.

A pilot study that included 10 recordings of physics classes, in which discourse patterns and question types were analyzed and tested for reliability, was conducted about a year before the start of the present study. For various reasons, the data collected in the pilot study were not included in the present study, but they helped sharpen the methods of data collection and analysis as well as helped validate the research tools.

Participant Characteristics and Research Process

The study was carried out with seven classes, involving seven physics teachers and 124 students whom they taught. The classes belonged to seven different high schools located in the central and southern regions of Israel. Five of them are single-gender religious schools and two coeducational secular schools as shown in Table 2. The instruction was conducted partly in the classroom and partly in the laboratory. Experiments were conducted in the laboratory and short videos, demonstrations and exercises from the set textbook were used in the lessons. The present study only followed the classroom lessons and did not include the laboratory lessons. All teachers had access to physics teaching sites, and Nur and Assaf also had a unique site for each class they taught. These sites gathered ideas and activities for physics lessons from different teachers. Permissions were gained to audio-record the lessons in the classrooms, but only two teachers agreed to classroom observations. Teachers and students were aware that the purpose of recording the lessons was to conduct research to improve teaching and learning. All the teachers were informed in advance that their school principals had consented to the recording of their lessons. Permission from the students' parents was not required as no change was made to the normal course of the lessons. All teacher names are pseudonyms. In addition, the ethics committee of the researchers' academic institution gave approval to conduct the research.

Table 1 summarizes the background characteristics of the teachers. Three female teachers and four male teachers participated in the study, ranging in age from 30-56. All seven teachers had academic degrees in the discipline. Their experience in teaching physics ranged from at least 4 years to 26 years. Table 2 shows background characteristics of the students, the class, and the school where the lessons took place. As can be seen from the table, the students, who were between the ages of 13-14 and 17-18, studied in schools with a variety of characteristics. Two classes were co-educational, belonging to secular schools in which boys and girls studied together. Four of the classes were in all-girls classes in religious schools, and one class was an all-boys class in a religious school. The two co-educational classes (of the teachers Nur and Assaf) were classes for students who excelled in physics, who had undergone a preliminary screening and were chosen to study in an advanced class. There was also a difference in the topics of study; the topic covered in each class was chosen according to the age of the students, the curriculum, and the teacher's decision. The common element for all the students was that they had all chosen to study physics at an advanced level. All of the lessons were frontal. As mentioned above, lab lessons or special exercise lessons in which most of the class was devoted to student work were not included in the study. The students sat in class in rows.

Table 1: Teacher characteristics

Teacher (recorded n lessons)	*Age*	*Experience in teaching physics*	Education	% of full-time post
Shem (3)	49	26	Master's degree in physics education	100
Yosef (4)	56	22	Master's degree in science education	100
Dan (4)	36	12	Bachelor's degree and teacher certification in science education	75
Adi (4)	32	8	Master's degree in physics	100
Nur (3)	35	7	Engineer with master's degree in science education	100
Asaf (3)	30	6	Masters in neuroscience, Ph.D. in teaching physics	40
Ger (4)	38	4	Electronics engineer, master's in science education	80

Table 2: Student, school, and subject characteristics

Class	Age	Student n and gender	Student class characteristics	Topics of study in lessons	Location and school characteristics
Shem	17–18, 12th grade	8 girls	Medium socioeconomic status, preparing for matriculation in physics at 5-point level	Receptor discharge/load, in-line and parallel connecting of resistors	Religious girls' high school in southern Israel
Yosef	16–17, 11th grade	13 girls	Medium socioeconomic status, preparing for matriculation in physics at 5-point level	Gravity, free fall, satellites, centrifugal force	Religious girls' high school in southern Israel
Dan	17–18, 12th grade	11 boys	Middle-high socioeconomic status, preparing for matriculation in physics at 5-point level	Newton's laws, conservation of energy	Religious boys' high school in southern Israel
Adi	17–18, 12th grade	22 girls	High socioeconomic status, preparing for matriculation in physics at 5-point level	Kinematics, Newton's laws, electrical circuits	Religious girls' high school in central Israel
Nur	14–15, 9th grade	30 boys and girls	Middle-high socioeconomic status, scientific reserve class, outstanding students	Mechanical motion, Newton's laws, kinetic energy, coils	Non-religious high school in southern Israel
Asaf	15–16, 11th grade	30 boys and girls	High socioeconomic status, class for outstanding physics students	Optics, refraction in various media, lenses	Non-religious scientific high school in central Israel
Ger	16–17, 11th grade	20 girls	High socioeconomic status, preparing for matriculation in physics at 5-point level	Newton's laws, voltage, normal kinematics, friction	Religious girls' high school in central Israel

Data Analyses

A total of 25 lessons were recorded, three or four consecutive lessons of the same class per teacher (see Table 1). Each lesson lasted about 45 minutes and was fully transcribed as follows: The lesson was divided into one-minute units of time. Everything said within each minute was written and tagged according to the speaker—the teacher or the student. When different students participated in the discourse, their words were marked in different colours. In addition to the recordings, we also conducted observations of Dan's and Yosef's classes, and the researchers took written notes during these lessons; this information was analyzed together with the recordings.

All of the teacher's questions pertaining to the topic of study, in each lesson, were counted and coded. Questions related to class administration or organization were not included. The coding included checking the frequency of all of the teachers' questions, and also determining the type of each question. To determine the types of the questions, we used Erdogan and Campbell's (2008) classification, which divides the questions into two main groups. The first group was closed-ended questions, which usually had one short correct answer. These are questions of low-order thinking, and their aim is to clarify information, to define, and to check students' existing knowledge of what has already been explained. The second group entailed open-ended questions, or high-order thinking. These are questions that usually have more than one correct answer, and involve understanding and rebuilding existing knowledge, synthesizing data, expressing a position, explaining observations, and so on. The classification process for each question included evaluation of the content and also of the context in which the question was presented, in relation to the sequence of the lesson, and in relation to what was taught previously and what was said before the question. That is, the type of each question was determined according to the context in which it was embedded, without being isolated from other aspects of the lesson. As we were able to follow three or four consecutive lessons, and the study began with a new topic that was introduced in the first lesson, it was possible to establish the context of the questions with considerable accuracy.

The screening method for open-ended and closed questions was selected after evaluating two other classification methods. In a preliminary investigation, each researcher analyzed about 100 questions selected from three lessons of three of the teachers, according to the classifications of Anderson (2001) and of Chin (2007). The classification method that was eventually selected gave the most similar results when compared between the two researchers of the current study. In addition to the greater internal reliability of the classification according to open-ended and closed questions, this method was also more suitable because of the tremendous mass of questions that were collected in this study. In total, we analyzed 1748 questions, of which 717 were closed-ended questions and 961 were open-ended question. Each of the two researchers in the current study classified the questions separately, and the evaluations were subsequently compared. An 84% match was found between the two classifications. Through discussion, consensus was reached where the classification results were not identical.

In addition, we counted and analyzed the discourse episodes that developed following the teachers' questions in each lesson. A discourse episode was defined as an event that contained a verbal exchange between the teacher and one or more students, or a verbal exchange between two or more students that developed from a teacher's question. These discourse episodes are well-known and appear in most classrooms (Leinhardt & Steele, 2005). An episode was identified and counted when the discourse ended, and the teacher went on teaching the subject at hand. A subsequent episode was counted only if it dealt with a different sub-topic or appeared after an extended time in which only the teacher was speaking. An episode could be very short if, for example, a student answered the question and the teacher immediately continued teaching. Alternatively, it could be longer, when different students were involved in the conversation and the teacher was not satisfied with one answer or did not immediately supply an answer to the question.

The discourse pattern of each episode was determined and sorted into one of two groups: closed discourse—in which the discourse was three-staged (I-R-E pattern): the teacher asked a question, a student responded, and the teacher confirmed or gave the answer and continued teaching; and open discourse—in which the discourse was longer and multi-staged, with a chain of interactions, or involved several students (Scott et al., 2006). In each lesson there were dozens of discourse episodes prompted by questions, and a total of 533 discourse episodes were analysed, of which 305 were of the closed discourse pattern and 228 were open discourse episodes. A one-way analysis of variance (ANOVA) was used to examine the differences in variables between the teachers. A Pearson Product Moment Correlation Coefficient test was also conducted to test the correlation between the types of questions and the discourse patterns.

RESULTS

The average number of questions each teacher asked, the type of questions, and the average number of the discourse episodes that resulted, as well as their discourse patterns, are presented in Table 3. All seven teachers asked a great many questions, about 70 questions per lesson on average, and it is evident that the questions actually led the classroom discourse.

Despite the variety in the teachers' personal characteristics, and the differences between the classes, including the students' different characteristics, the different nature of the schools, and the subject matter (refer Tables 1 and 2), no statistically significant difference was found in the overall number of questions that the teachers asked. Similarly, no significant difference was found in the total number of discourse episodes in the classes, which ranged on average from 18 to 26 discourse episodes per lesson.

Table 3: Mean and Standard Deviation for types and number of teachers' questions and classroom discourse

	Total questions	Closed questions	Open questions	Total discourse episodes	Closed discourse episodes	Open discourse episodes
Shem (3)	68.33	26.67	41.67	24.00	8.33	15.67
	(17.79)	(2.08)	(19.55)	(2.65)	(1.53)	(3.05)
Yosef (4)	72.00	10.33	63.77	26.33	10.00	16.33
	(34.87)	(10.97)	(22.50)	(4.51)	(4.31)	(1.53)
Dan (4)	69.50	23.00	46.50	18.00	14.25	3.75
	(19.70)	(5.88)	(17.90)	(5.47)	(4.99)	(2.22)
Adi (4)	63.00	15.75	47.25	22.00	13.50	8.50
	(17.51)	(2.22)	(15.43)	(9.49)	(13.48)	(8.74)
Nur (3)	61.00	16.67	21.00	18.00	12.00	6.00
	(26.21)	(4.51)	(12.53)	(5.57)	(4.00)	(1.73)
Asaf (3)	72.00	10.33	63.77	26.33	10.00	16.33
	(34.87)	(10.97)	(22.50)	(4.51)	(4.31)	(1.53)
Ger (4)	91.50	38.75	52.75	20.00	9.50	10.50
	(27.23)	(21.36)	(23.12)	(4.55)	(2.65)	(3.00)
Total Mean	69.92	28.68	48.44	21.32	12.20	9.12
	(22.94)	(18.27)	(23.43)	(5.82)	(6.23)	(5.79)
F	.74	3.72*	3.66*	.71	.31	2.34*

*$P < 0.05$

Analyses of Question Types

Analysis by question type shows that there were statistically significant differences between teachers but, surprisingly, all seven teachers asked more open-ended questions than closed questions. As mentioned, closed questions are questions of low-order thinking, such as questions of clarification, questions that check factual knowledge, or review questions.

An example of a closed-ended question might be:

> *In the previous lesson, we asked: What is the gravity between two people whose masses are, say, 50 kg, and who are two metres apart. We calculated this and put it into a formula. Who is ready to repeat the formula and the method of calculation?* (Yosef, Lesson 2).

Open-ended questions are, as described above, questions of high-order thinking, such as those aimed at formulating arguments, presenting a position, or drawing conclusions about a phenomenon, creating a synthesis or a comparison.

An example of an open-ended question might be:

> *We spoke about the acceleration of free fall being constant. Despite this, it is known that the acceleration of free fall depends upon the location on the face of the Earth. Why do you think this is? How can we explain it?* (Yosef, Lesson 2).

Given the high number of open-ended questions, it was expected that most of these would lead accordingly to open discourses. However, as can be seen from Table 3, the number of open discourse episodes was significantly lower than the number of closed discourse episodes for four teachers (Yosef, Dan, Adi, Nur). Only in Shemesh and Assaf's classes did more open discourse episodes develop. Even in Assaf's class, who asked the highest number of open-ended questions, only a small portion of those questions led to open discourse.

The closed discourse episodes were mostly characterized by the three-staged discourse in which the teacher asks a question, the student responds with a short answer, and the teacher confirms or corrects the answer without developing the student's response. Closed discourse is thus very short, such that the student's response usually includes just a few isolated words.

For example:

Teacher: In this case here, is there conservation of energy or conservation of charge?
Student: Both
Teacher: Correct (Shem, Lesson 3).

Frequently, closed discourse developed even when the teacher asked an open-ended question that could have led to an open discourse. In these cases, the teacher closed the discourse by providing a quick answer, by not addressing all of the students' questions, or not developing them.

For example:

> *Teacher: Let's understand what acceleration is. Who is ready to try to explain, from your general knowledge? How do you think that it is related to gravity?*
> *Student A: It is a rate.*
> *Student B: No, it is distance relative to time.*
> *Teacher: No, acceleration refers to an increase in speed. That in the first second, the [moving] body goes a certain distance, and in the second second, the [moving] body*

> *goes a longer distance. Now, gravity accelerates towards the centre . . .* (Dan, Lesson 2).

As can be seen in this example, the teacher provides the answer almost immediately, without waiting for additional responses, and without directly addressing the answers of the two students. In contrast, episodes of open discourse were characterized by a longer conversation in which the teacher is less dominant and navigates the discourse on the basis of the students' responses.

For example:

> *Teacher: Gravity acts equally on all bodies. It does not matter if you are a large or small body. But in different places on the face of the Earth, one can feel a different gravitational force. Why do you think this happens?*
> *Student A: The force increases as we move further away from the centre of the Earth.*
> *Student B: No, the force decreases as we move further away.*
> *Student A (turns to the teacher): the further away we are, the stronger the force acts, no?*
> *Teacher: Let's check. (Specifies the name of student B), why did you determine that gravity decreases as we move further away?*
> *Student B: because . . .. I'm not sure . . .*
> *Student C: I think it may be related to the radius of the Earth.*
> *Teacher: How is it related?*
> *Student C: The Earth is a bit elliptical, and so its radius is different at the poles, so . . . (the student became silent)*
> *Teacher: Very good. Who will complete the answer?*
> *Student D: So, I think that at the poles, which are further away, gravity will be weaker*
> *Teacher: Right. Let's try to understand this phenomenon a little more*. (The teacher extends the explanation for four minutes without the intervention of the students. (Dan, Lesson 3).

Another example of an open discourse episode is from Nur's lesson. Similar to the previous discourse example, here too, the students' answers are very short.

> *Teacher: Look here. I have a pendulum* (The teacher is about to present a video demonstration to the students).
> *Student A: What is a pendulum?*
> *Student B: A pendulum is a wire tied to a weight*
> *Teacher: I want to explain. We have a pendulum here, look at the picture here, at first, we hold it, now I continue, I release the pendulum from rest. What will happen?*
> *Student C: The pendulum will start to move.*
> *Teacher: It's moving to these points. Suppose the pendulum swings from side to side . . . let's focus on one movement. What happens in the beginning? What is its potential energy at this point?*
> *Student C: The greatest amount of energy.*
> *Teacher: The greatest energy, right? Now look, what happens in this process?*
> *Student B: The potential energy decreases.*
> *Teacher: Very good, excellent! Potential energy is converted into kinetic energy. The potential energy decreases, and the kinetic energy increases.*
> *Student A: But I did not understand . . . it's not clear . . .*

> *Teacher: Wait a minute . . . now who can tell me, raise your hands, when the kinetic energy is greatest? Someone I did not hear yet.*
> *Student D: It seems to me that after the first point . . .*
> *Teacher: Why?*
> *Student D: Because it has gained speed and then the speed goes down.*
> *Student E: No . . . At the first point.*
> *Teacher: Why?*
> *Student E: Because most of it is height.*
> *Teacher: I asked when the kinetic energy is highest. The overall energy in the process does not change, right? The sum of the energy in the process does not change; at the lowest height, the potential energy is lowest, so the kinetic energy is greatest. So basically, here I have the greatest, maximum kinetic energy, okay?* (The teacher continued to explain for three minutes without the intervention of the students. (Nur, Lesson 3).

It is also interesting to compare the class discourses when the study topics were similar. For example, Dan, Adi, Nur and Ger taught Newton's laws. All four teachers first demonstrated a certain phenomenon (the action of a spring, the free fall of an object), and asked students to guess what was going to happen, running a discussion about it. Then they asked them to explain what had actually happened. At these stages of the lesson, most of the questions were open-ended. When discussion took place, Dan and Nur, unlike Adi and Gur, did not insist that the students articulate the scientific principles, but rather did it themselves. All four teachers involved the students in the solution process when solving questions from the textbook, but Dan, Adi and Nur were more inclined to explain the solution and Ger insisted that the students be more involved in the explanation.

From an examination of the overall average of the seven teachers, it can be seen that the number of open discourse episodes was lower than the number of closed discourse episodes (Table 3). The vast majority of open discourse episodes for all of the teachers were relatively short. They lasted less than 30 seconds, with only one to three students participating in the conversation. Despite the brief duration, such a discourse was classified as an open discourse and not as a closed discourse because it included questions of higher order thinking that were not answered immediately, and an attempt was made to encourage thinking and understanding. A multi-participant open discourse of four or more students was very rare and was found only in Adi's class.

Correlations Between the Types of Questions and the Types of Discourse

The correlation between the types of questions and the types of discourse is presented in Table 4. A statistically significant relationship is evident between the number of teachers' closed questions, and the number of closed discourse episodes that developed in the classrooms ($r = .59$, $p<0.05$). In other words, closed questions led to closed discourse. In contrast, no significant correlation was found between the number of open-ended questions and the number of open discourse episodes. In other words, open-ended questions did not necessarily develop into open discourse. Additional findings, presented in Table 4. They show that there was a statistically significant negative correlation between the number of open discourse episodes and the number of closed discourse episodes ($r = -.53$, $p<0.01$). In other words, the higher the number of closed discourse episodes in the classroom, the lower the number of open discourse episodes.

Table 4: Correlation between types of questions and types of discourse

	Total questions	Closed questions	Open questions	Total Discourse episodes	Closed discourse episodes	Open discourse episodes
Total questions	1					
Closed questions	.35	1				
Open questions	.59**	-.32	1			
Total discourse episodes	.17	-.26	.31	1		
Closed discourse episodes	.13	.59**	-.02	-.54**	1	
Open discourse episodes	.02	-.37	.33	.42*	-.53**	1

**p< 0.0; *p< 0.05

In addition, there was a significant positive correlation between the overall number of discourse episodes that developed in the classroom and the number of closed or open discourse episodes. That is to say, as would be expected, as the classroom discourse is generally livelier, there is an increase in the number of both closed discourse episodes and open discourse episodes.

DISCUSSION AND CONCLUSION

In this study we examined the relationships between the types of questions physics teachers asked and the patterns of class discourse that developed from them. We found that despite the range of characteristics among teachers who participated in this study, all seven of them asked more open-ended questions than closed questions during their lessons. This finding is surprising since other studies show that teachers actually tend to ask few open-ended questions of high-order thinking (Barnes, 2010; Biggers, 2017; Eliasson et al., 2017; Harpaz & Lefstein, 2000). Closed questions undoubtedly play an important role in classroom teaching. These questions allow the teacher to test students' knowledge and enable students to focus, and link prior knowledge to new information. However, the excessive use of closed questions is liable to give class discourse a fragmented quality and block broader and more open discussion. It appears that the teachers who participated in this study, who actually asked many open-ended questions, were aware of the necessity of those questions for beneficial learning. But do teachers really use these questions to promote open and dialogical discourse? This is the central question of the present study.

Classroom discourse is largely based on the teacher's questions; a discourse that stimulates and promotes student understanding develops out of questions that encourage open discourse (Mortimer & Scott, 2003). Open-ended questions challenge student thinking (Morris & Chi, 2020), and require more linguistically complex answers, and should therefore raise the level and diversity of students' speech. In contrast, the most important finding from our study is that most of the teachers' open-ended questions did not lead to open discourse in the classroom. Examination of the relationship between the number of open-ended questions and the number of open discourse episodes shows that there is no statistically significant correlation between them. This is in contrast to the significant high correlative relationship found between the closed-ended questions and closed discourse.

Our systematic analysis examined every word that was said in class, both by teachers and students. From this analysis it emerged that in many cases, after teachers asked an open question, they were satisfied with an answer from just one or two students, or they supplied the answer themselves, after which they closed the discussion and proceeded without developing it further. Therefore, even though the teachers in this study asked more open questions, they actually expected one correct answer, and did not invite thinking or encourage additional students to contribute to the conversation. An open-ended question is liable to become a closed question, as Cazden (2008) argued. It is not enough to present the question as open-ended (e.g., "What do you think about . . .? How do you interpret . . .?"). Research shows that a teacher's feedback on students' answers will determine the type of discourse (Gamoran & Nystrand, 1992). If a teacher does not encourage a discussion about the answers, then it is in fact a closed question in the guise of an open one.

In essence, in most of the lessons we studied, the teachers "bombarded" the students with multiple questions. They did not give the students a reasonable amount of time to think about these questions, to formulate the answers for themselves, and finally to present them within the class discourse. Rowe (2003) emphasizes the importance of the waiting time, which is the amount of time that passes between the teacher's question and receiving a response. Allowing a reasonable waiting time after asking a question encourages students to engage in logical thinking, increases the student's self-confidence, and invites more students to participate in the discourse. According to Rowe, teachers who learn to lengthen the waiting time after asking questions will accordingly reduce the number of questions they ask.

It is important to note that all seven teachers who participated in this study led a lively and continuous discourse throughout the lessons, consistently engaging students by means of many questions, and avoiding lengthy monologues. The high number of total discourse episodes (both closed and open-ended), averaging about 20 per class, attests to the students' lively participation in the class discussions. It is evident that the atmosphere in those classes was good, there was mutual respect between students and teachers, and the students were confident and felt comfortable to talk freely. Such active and continuous student involvement is not at all trivial, as attested by many studies that show how often teaching is a monologue in which the teachers speak and students listen (Badr, 2019; Pimentel & McNeill, 2013). Yet despite the active and substantial involvement and participation of the students, as revealed in this study, their answers were typically very short and superficial. Although the teachers asked open-ended questions and questions of high-order thinking, the potential inherent in these questions was not properly utilized to invite thinking, varied responses, and in-depth discussion.

The classroom discourse of the teachers in this study can be pedagogically characterized as interactive-authoritative, following the terminology of Mortimer and Scott (2003). Although students were involved in the discourse, the teachers did not really allow them to develop their ideas. The students' substantial involvement created an important dynamic in class, but in order to achieve a dialogical-interactive discourse, teachers must elaborate on students' answers, even if they are not the answers that they expected. A teacher who gives students opportunities to formulate and express their ideas is privy to vital information pertaining to the depth of their understanding and misconceptions—this is information that can enable the teacher to support the students' cognitive growth (Chin, 2007).

Despite teachers' awareness of the importance of open-ended questions, it appears that there are factors that actually make it difficult to develop these questions into open discourse. Turning open-ended questions into closed questions allows teachers to have greater control over the class and the discourse conducted. Authentic open-ended questions demand from the teacher a high degree of confidence in the disciplinary material and flexibility in the teaching process. Similarly, asking a large number of open-ended questions of high-order stands in constant tension with completing the curriculum that the teacher has to teach, and the teacher finds it difficult to manage this tension in practice. The considerable amount of information that needs to be taught according to the curriculum dictates a fast pace. The teachers thus often cut discussions short, providing the answer themselves, so there is not enough time left for the students to engage in deep thinking and meaningful discourse.

Another possible issue is the influence of the approach by which teachers assess students. It is likely that if the assessment is primarily based on multiple-choice tests or other closed questions that the teacher will conduct a more closed discourse. An open-book exam where, for example, students have access to the material and are asked to respond with short or long written answers or to interpret the results of experiments can encourage open classroom discourse.

Implications and Limitations

Teachers play a crucial role in the process of the development of their students' thinking. In order for teachers to be able to play this important role, they must first become more aware of the types of questions they ask, of the patterns of classroom discourse, and of their impact on students' understanding and thinking. Teachers rely to a great extent on questions in their teaching, and such a reflective process is likely to directly influence their teaching praxis (Smart & Marshall, 2013). Since the questions largely shape the conceptual framework of the answers, it is important that teachers formulate in advance some of the questions that they will ask in the course of the lesson. Obviously, the questions need to be related to the lesson learning objectives, such that it is especially important to incorporate open-ended questions and to develop the discussion from the students' answers in order to strengthen their involvement.

As ascertained in the current study, the teachers actually asked many open-ended questions, but many of them turned into closed questions and did not lead to in-depth discourse. Such superficial and lively discussion in classrooms can lead even the teacher to the mistaken belief that the discourse is open and productive when in fact for the most part it is not. Teachers should not be apprehensive about silences during the lesson in order to both allow more time for thinking after the presentation of open-ended question and encourage a dialogical and more student-centred discourse. This would reduce the number of questions asked by the teachers, as well as the number of discourse episodes and, correspondingly, would lengthen their duration and deepen them.

In order for teachers to succeed in creating an open dialogue that requires more class time, they must deal with the requirement to complete a large amount of learning material. This requires the teachers to adopt a less dominant pedagogical approach, in which it is not mandatory to learn everything in the course of the lessons themselves. The students can perform a variety of tasks after the lessons. These assignments should incorporate open-ended questions that will require the students to think and formulate their ideas in writing. Since students who are primarily used to answering closed questions find it difficult to deal with open questions (Dohrn & Dohn, 2018), classroom discussion of the answers that students have written would encourage them. This would make it easier for them to participate in the discourse and develop the abilities of argumentation and verbal articulation that are vital for cognitive development (Chin, 2007).

One of the limitations of this study is its small number of participants: seven case studies of seven classrooms. But, since the teachers and the students had a variety of characteristics, the similar picture of the discourse patterns that emerged from the teachers' questions could reinforce the hypothesis that this pattern would also be true of other classrooms. However, in order to make such a broad generalization, it is necessary to study additional teachers and classes. Similarly, all the teachers in this study were physics teachers. It is therefore important also to examine the discourse among teachers who teach other disciplines and other age groups.

Another limitation relates to the fact that this study was conducted only in whole classes. Examining lab classes, exercise lessons, and group work would allow for a deeper understanding of the discourse that develops following teachers' questions. Another limitation, also related to method, concerns the fact that in five of the seven classes only audio-recordings were used, with no classroom observation. The recordings do not allow for evaluation of other types of communication such as gestures or body language which are significant in analysing classroom discourse. Incorporation of video recording and direct observations would help overcome this limitation.

In conclusion, increasing teachers' awareness of the types of questions they ask and the patterns of discourse to which they lead will contribute to the construction of knowledge and to the development of students' thinking. Therefore, in the process of teachers' professional development it is important to consider how to strengthen this awareness and how to lead open and productive discourse in the classroom.

Address for correspondence: Ester Aflalo and Ayala Raviv, Hemdat College of Education, PO Box. 412, Netivot, 80200, Israe.l Tel. 972-8-9937697 Fax. 972-8-9937688
Email:<ester@hemdat.ac.il>

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