Thesis for the degree

Doctor of Philosophy

Submitted to the Scientific Council of the
Weizmann Institute of Science
Rehovot, Israel

עבודת גמר (תזה) לתואר

דוקטור לפילוסופיה

מוגשת למועצה המדעית של
מכון ויצמן למדע
רחובות, ישראל

By
Eran Zafrani

מאת
ערן זפרני

חסמים ומשאבים להטמעה של ארגומנטציה דיאלוגית בכיתות מדעים

Constraints and affordances for the implementation of dialogic argumentation in science classrooms

Advisor:
Prof. Anat Yarden

מנחה:
פרופ' ענת ירדן

May 2022

סיוון תשפ"ב

Acknowledgements

Learning is an immensely powerful process. Schools comprise one of the strongest social institutions in modern society because they provide opportunities for learning that shape the lives of students in meaningful and consequential ways. But schools would not have been able to function, let alone rise as a social institution, without the community of teachers who provide such opportunities for learning. I take this opportunity to thank the community of mentors who supported my learning and who paved the path for my development as a science education researcher.

First and foremost, I am grateful to Prof. Anat Yarden who took me under her wing and provided me with ongoing mentoring, support, and constant counseling. In her commitment to rigorous research, mentoring of students, and writing for knowledge dissemination, Anat models how the mission of academia should be pursued and attained. Always benevolent and generous with her insights, Anat's expertise in the study of learning by engagement with scientific practices, designing teachers' professional development courses, and qualitative methodologies, helped me find a theoretical home and provided a methodological apparatus for my research. I thank her all heartedly for her kindness, fellowship, and for lending her expertise to patiently guide this research project.

The members of my advisory committee, Prof. David Fortus and Prof. Boris Koichu, were also central to me as advisors and mentors and deserve deep thanks for their support of my study. Their keen and thoughtful insights engendered this research and were instrumental in informing the analyses in the following pages. Likewise, Dr. Gilat Brill is an invaluable mentor and colleague. I cannot offer enough thanks for her encouragement, advice, and support.

I owe much of the thinking developed here to participating in a thriving research community that is interested in improving processes of teaching and learning. From my time at the Weizmann Institute of Science, I thank the Science Education department and its faculty, staff, and students for providing me a home in which I could develop and think about my research interests. Particular thanks go to my colleagues from the biology group. Above all I thank them for their friendship, but I also recognize that I owe them an intellectual debt. Their brilliance and earnest curiosity profoundly sharpened my thinking about schools and learning as they challenged it.

This research would not have come to realization without the participation of teachers and students whose experiences comprise the data for this study. I extend a hearty thanks for their generous involvement in this study.

Pursuing a PhD is not only rewarding, but also a challenging and sometimes stressful endeavor. It is my experience that having loved ones in your life who accompany you through this process is critical. To this end, I am deeply indebted to my parents, Lea, and Yosef, and to my siblings, Arik, Vered, and Zohar, who provided a deep well of support. Thank you for providing important mental sustenance, care, and reassurance during this challenging period. Finally, to Lior, the way you move around in the world - intensely battling social injustice and fearlessly advocating for those who suffer from institutionalized discrimination - taught me how to live more courageously than I might otherwise and forever changed me in the process. I could not have done any of this without you. In case that I don't remember to say it daily, I am fortunate to have you as my partner and best friend.

Declaration

I hereby declare that this thesis summarizes my independent and original research.

Eran Zafrani

Table of Contents

List of abbreviations

Abbreviation	Definition
CDC	Centers for Disease Control and Prevention
GEM	Growth and Effectiveness Measures
IRE	Initiation-Response-Evaluation
NGSS	Next Generation Science Standards
NRC	National Research Council
SSI	Socioscientific issues
TPD	Teachers' professional development

List of tables

List of figures

List of publications from this dissertation

Type of publication	Title
Peer reviewed journal articles	Zafrani, E., & Yarden, A. (2022). The potential for reconciling pedagogical tradition and innovation: the case of socioscientific argumentation. *Instructional Science* (under review). *
	Zafrani, E., & Yarden, A. (2022). Dialog-constraining institutional logics and their interactional manifestation in the science classroom *Science Education*, *106*(1), 142-171. doi: https://doi.org/10.1002/sce.21687 *
Peer reviewed conference presentations	Zafrani, E., & Yarden, A. (2021). How dialog constraining institutional logics are conveyed through classroom discourse. Paper presented at the American Educational Research Association (AERA) Annual Conference. Orlando, Florida (on line). *

***Acknowledgements:** Research for these studies was supported by grants from the Israel Science Foundation (ISF) grant number 2699/17

Constraints and affordances for the implementation of dialogic argumentation in science classrooms

Abstract

The last decades have witnessed a growth of research demonstrating the efficacy of dialogic argumentation in supporting student learning in science. Following such documented potentialities, a call for the implementation of argumentation in science classrooms has been advanced in local and global reform-minded documents. However, we continue to find substantial evidence that teachers rarely allow for the incoming of dialogic pedagogy into their classrooms, and instead maintain the incumbent pedagogy of teacher-centered instruction. In two distinct and complementary empirical studies, this dissertation set out to investigate why it is so difficult - and what would it take - to dislodge the dominant teacher-centered pedagogy and modes of interaction for the incoming of dialogic argumentation. I attend to this puzzle by drawing on insights and concepts derived from the field of sociology of organizations, which is concerned with the systematic study of organizations as situated within broader social institutions that shape their practices, expectations, and norms.

The first empirical study (in Chapter 2) focuses on implementation constraints. It seeks to understand why dialogic argumentation has not been adopted as a legitimate means of instruction by science teachers. To answer this question, this qualitative case study looks inside schools and science classrooms to examine the mutually constitutive relationships between macro-level phenomena, such as the taken-for- granted institutional mandates that teachers and schools call upon to maintain their legitimacy in society, and micro-level routinized teacher–student classroom interactions. Integrating ethnography with the analysis of classroom interactions, I seek to capture the social structuring that informs instruction and classroom interactions. Based on an inductive analysis of observations, interviews with teachers, and documents, three types of macro-level institutional logics that mediate against the implementation of dialogic argumentation emerged. These included the logics of (a) accountability, (b) tracking, and (c) the profession. These logics give rise to instructional practices that run counter to the pursuit of dialogic argumentation. Classroom observations were analyzed to examine how these logics are conveyed through institutionally bounded interactions between teachers and students. Shaped by these institutional logics, instruction in classrooms is narrowed to mostly direct instruction of terminology and absolute facts, and is stratified into

various status levels according to classroom tracking. I argue that teachers may resist dialogic argumentation primarily because it violates the fundamental rules, norms, and practices that grant them individual and organizational legitimacy. This contextualization of teacher–student interactions as motivated by institutional logics may explain in greater detail the absence of dialogic argumentation from science classrooms.

The second empirical study (in Chapter 3) focuses on implementation affordances. Recognizing that instructional practices that can be perceived by teachers as potentially threatening appropriate organizational conduct may encounter resistance, an extracurricular environment was established to: (a) afford teachers opportunities to experiment with dialogic argumentation while being liberated from some of the constraints of schooling, and (b) find ways to carry out this practice in ways that are broadly consistent with the elements deemed valuable inside schools, thereby, potentially improving the chances of its adoption by teachers. This study focuses on socioscientific argumentation, with which students' engagement is required in order to meet the challenges of the modern world. Classroom interactions emerging from this pedagogy may be at odds with how schools and teachers are accustomed to defining quality learning, thus creating tension and potentially undermining implementation. The literature suggests that argumentative talk that diverges from science knowledge and rationalistic patterns of reasoning toward subjective claims, as well as instances of unproductive argumentation, are at the root of these tensions. Enactments of teacher-led and peer-led socioscientific argumentation in an extracurricular environment were examined using two analytical frameworks related to the content and form, respectively, of the students' arguments.

I explore, qualitatively, how enactments of socioscientific argumentation in this environment could be more harmonious, and more easily integrated with contemporary schooling practices. The findings show that in teacher-led argumentation, the students relied on science knowledge more prominently when teachers extended their elicitation of responses with follow-up interrogative questioning. In peer-led argumentation, talk tended to collapse into confrontational disagreement or uncritical agreement, obscuring instances in which students relied on science knowledge. To expand from the extracurricular environment more permanently into schools, I discuss the significance of teachers' use of productive talk moves toward integrating socioscientific argumentation as a core instructional practice.

A unified discussion (in Chapter 4) seeks accumulativeness and integration among the findings from both studies to formulate an institutionally sensitive response that could potentially advance the implementation of dialogic argumentation. This response account for

the perceived legitimacy of dialogic argumentation, for the knowledge and competency needed from teachers to carry dialogic activities in productive ways, and for the interactional mechanisms that can sustainably mediate instruction in science classrooms towards dialogic argumentation and away teacher-centered pedagogy.

חסמים ומשאבים להטמעה של ארגומנטציה דיאלוגית בכיתות מדעים

תקציר

מחקרים עדכניים מראים שלארגומנטציה דיאלוגית במדעים יש תרומות רבות ללמידת תלמידים. בעקבות מחקרים אלו, מסמכי מדיניות עדכניים דורשים מבתי ספר ומורים לספק לתלמידיהם הזדמנויות לארגומנטציה דיאלוגית. יחד עם זאת, ממצאים רבים מצביעים על כך שהוראה דיאלוגית המקדמת ארגומנטציה כמעט ואינה מתורגלת בכיתות המדעים, ובמקומה שולטות צורות מסורתיות יותר של הוראה ממוקדת-מורה שאינה דיאלוגית. באמצעות שני מחקרים אמפיריים נפרדים אך משלימים, עבודת דוקטורט זו בוחנת מדוע הוראה ממוקדת-מורה משתמרת ומה נדרש מבתי ספר ומורים כדי לקדם ארגומנטציה דיאלוגית בכיתות המדעים. כדי לענות של שאלות רחבות אלו, עבודת מחקר זו נשענת על רעיונות ותובנות משדה המחקר של סוציולוגיה של ארגונים שבוחן כיצד התנהגות ארגונית מושפעת ומעוצבת על ידי המוסדות החברתיים אליהם ארגונים משתייכים.

המחקר האמפירי הראשון (פרק 2) מתמקד בחסמים להטמעה של ארגומנטציה דיאלוגית. הוא בוחן מדוע הוראה באמצעות ארגומנטציה דיאלוגית אינה נתפסת כפרקטיקה לגיטימית על ידי מורי מדעים ובתי ספר. כדי לענות על שאלה זו, מחקר איכותני זה המתרחש בבתי ספר ובכיתות המדעים מתאר ומסביר את מערכת היחסים ההדדית בין תופעות תרבותיות-חברתיות ברמת המאקרו, בדמות לוגיקות מוסדיות שהפכו להיות מובנות מאליהן ואשר בתי ספר ומורים מצייתים להן לשם קבלת לגיטימציה מהסביבה שלהם, לבין אינטראקציות למידה רוטיניות בין מורים תלמידים ברמת המיקרו. מחקר זה בוחן את תהליכי ההבניה החברתית של שיח כיתה דרך שילוב בין שיטות מחקר אתנוגרפיות וחקר אינטראקציות המתקיימות בהקשרים מוסדיים.

ברמת המאקרו, ניתוח אינדוקטיבי של תצפיות השתלמות, ראיונות עם מורים, ומסמכים ברמת הכיתה ובית הספר, מעלה שלוש לוגיקות מוסדיות שמורים נשענים עליהן כדי לתאר התנהגות ארגונית לגיטימית ואשר חותרות תחת ההטמעה של ארגומנטציה דיאלוגית. לוגיקות אלו כוללות את (א) הלוגיקה של אחריותיות, (ב) הלוגיקה של הסללה, ו-(ג) הלוגיקה של הפרופסיה. לוגיקות אלו מציבות מטרות למורים שאינן נמצאות בהלימה עם המטרות של ארגומנטציה דיאלוגית. ברמת המיקרו, תצפיות כיתה נותחו כדי לבחון איך לוגיקות אלו מעצבות אינטראקציות למידה בין מורים ותלמידים. ניתוח של שיח הכיתה מראה שלוגיקות אלו נותנות לגיטימציה לסביבה שבה מורים שואלים שאלות סגורות ממוקדות תוכן וטרמינולוגיה (אחריותיות), לשיח הממוקד בידע אינטואיטיבי בכיתות במסלולים שאינם מיודעים לתלמידים מצטיינים (הסללה), ולדפוס שיח שבו המורה הוא המקדם העיקרי של הלמידה אשר עושה את מירב העבודה האינטלקטואלית בשיח הכיתה (הפרופסיה). ממצאים אלו מראים שמורים עלולים להתנגד להטמעה של ארגומנטציה דיאלוגית משום שהיא נתפסת על ידם כחותרת תחת החוקים, הנורמות, והפרקטיקות המעניקים להם ולבית ספרם לגיטימציה. בחינה זו של אינטראקציות יומיומיות בין מורים לתלמידים כמשפיעות וכמשמרות לוגיקות מוסדיות ברמת המאקרו עשויה לתרום להבנה של היעדר שיח המקדם ארגומנטציה דיאלוגית בכיתות המדעים ועשויה לתרום להרחבת ההבנה של עיצוב אפקטיבי יותר של השתלמויות מקצועיות של מורים בנושא זה.

המחקר האמפירי השני (פרק 3) עוסק במשאבים והזדמנויות להטמעה של ארגומנטציה דיאלוגית. מורים עלולים להתנגד לפרקטיקות הוראה הנתפסות על ידיהם ככאלו המסכנות את התנהלות ארגונית תקינה. לכן, מחקר

זה נערך בסביבה חוץ-קוריקולרית המספקת: (א) הזדמנויות למורים להתנסות בארגומנטציה דיאלוגית כאשר הם משוחררים במידה מסוימת מהחסמים המוסדיים הקיימים בבית הספר, ו-(ב) אפשרות למצוא תנאים שבהם ארגומנטציה דיאלוגית יכולה להפיק תוצרי למידה המוערכים בתרבות הבית-ספרית הקיימת, ולכן גם להגדיל את הסיכויים שמורים יאמצו אותה כפרקטיקה להוראה גם מעבר לתחומים של הסביבה החוץ-קוריקולרית. מחקר זה מתמקד בארגומנטציה סביב נושאים מדעיים-חברתיים איתם תלמידים ייאלצו להתמודד. אינטראקציות למידה העולות במהלך ארגומנטציה על נושאים מדעיים-חברתיים יכולות להיות שונות בתוכנן ובמבנה שלהן מאלו העולות במהלך שיעור המדעים הרגיל. בעיקר, התוכן של שיח הכיתה יכול להיות ממוקד בידע סובייקטיבי של התלמידים לגבי הנושאים הנידונים, כמו אינטואיציות, תחושות אישיות, וניסיון העבר שלהם, במקום בדפוסי הנמקה רציונליסטיים ומיקוד בידע מדעי אובייקטיבי. כמו כן, מבנה האינטראקציה יכול להיות ווכחני או פשרני, במקום חקרני. כאשר פרקטיקות הוראה מעלות שיח כיתה המתרחק מזה המוכר והמוערך על ידי מורים, הן עלולות ליצור אצל מורים התנגדות.

ניתוח איכותני של אירועים של ארגומנטציה מובלת-מורה וארגומנטציה מובלת-תלמידים נערך באמצעות שתי מסגרות אנליטיות המתייחסות לתוכן ולמבנה של הארגומנטציה. דרך מסגרות אלו, נבחנה הדרך שבה אינטראקציות ארגומנטיביות המתאפשרות בסביבה חוץ-קוריקולרית יכולות להיות יותר בהלימה עם מטרות הלמידה השגורות בבית הספר. הממצאים מראים שבארגומנטציה מובלת-מורה התלמידים נסמכו על ידע מדעי אובייקטיבי כדי לבסס את הטיעונים שלהן כאשר המורים אתגרו את הטיעונים שלהם עם שאלות חקרניות עוקבות. בהיעדר שאלות אלו, ההסתמכות על ידע סובייקטיבי הייתה דומיננטית. בארגומנטציה מובלת-תלמידים, שיח ארגומנטיבי שנטה למבנים ווכחניים או פשרניים הפיק תוצרים סופיים הנסמכים על ידע סובייקטיבי והסתיר תהליכים שבהם טיעונים הנסמכים על ידע מדעי אובייקטיבי כיוונו את הארגומנטציה. הדיון מתמקד בשימוש של מורים במהלכי שיח פרודוקטיביים לארגומנטציה כאמצעי התומך במעבר אפשרי של ארגומנטציה מהסביבה החוץ-קוריקולרית אל תוך הליבה של בית הספר.

בדיון מאחד (פרק 4), נערכת אינטגרציה של הממצאים משני המחקרים האמפיריים כדי לייצר תגובה אפשרית להתנגדות של מורים ובתי ספר לארגומנטציה דיאלוגית המתחשבת בחסמים מוסדיים להטמעה. תגובה זו דורשת התייחסות ללגיטימיות של ארגומנטציה דיאלוגית בבתי ספר, לידע ולמיומנויות הנדרשים ממורים כדי לערוך ארגומנטציה דיאלוגית בצורה מיטבית, ולמנגנוני שיח היכולים לכוון בצורה בת-קיימא הוראה בכיתות המדעים לכיוון דיאלוגי במקום לכיוון ממוקד-מורה.

CHAPTER 1. Overview of the entire study

1 Setting the problem

1.1 The state of dialogic argumentation in science education

Relating to the notion that to truly understand science requires an induction of students to the epistemologies, norms, and dispositions of scientists, teachers have been increasingly called to engage their students with authentic scientific practices. Since it is through argumentation that scientists communicate and disseminate their work to peers and advance knowledge by scrutinizing theories and weighing alternative explanations (Newton, Driver, & Osborne, 1999), argumentation is identified as a core epistemic practice of science (Bricker & Bell, 2008) and is central to the discourse of scientists (Driver, Newton, & Osborne, 2000). On the level of policy, policymakers and recent reform documents, such as the Next Generation Science Standards (NGSS, 2013), and the National Research Council (NRC, 2012), highlight the concept of argumentation as a core practice in science education. In Israel, the inclusion of argumentation was also represented as a key goal of science teaching in national educational policy documents (Israeli Ministry of Education, 2009) as well as had a curricular response (Israeli Ministry of Education, 2018).

On the level of student learning, the last two decades have witnessed a growth of research demonstrating the efficacy of dialogic argumentation in supporting student learning in science (Bencze, Pouliot, et al., 2020; Driver et al., 2000; González-Howard & McNeill, 2020; Lowell, Cherbow, & McNeill, 2022; Macagno, Mayweg-Paus, & Kuhn, 2015; Nussbaum, 2020; Pimentel & McNeill, 2013; Ryu & Sandoval, 2012; Sadler & Donnelly, 2006; Simon, Erduran, & Osborne, 2006; Zohar & Nemet, 2002). In these studies, the descriptions of students' learning outcomes are largely tied to two central imperatives for what school systems need to produce and the effectiveness of dialogic argumentation in realizing these imperatives.

First is the educational imperative. This imperative is governed by the theoretical notion that engagement with argumentation can advance a better understanding and appreciation of the epistemologies, norms, and values that organize scientific conduct (Edelson et al., 2021; McNeill, González-Howard, Katsh-Singer, & Loper, 2017; Miller, Manz, Russ, Stroupe, & Berland, 2018). Beyond the theoretical arguments, empirical studies have shown that dialogic argumentation can contribute to improved students' epistemic understanding of science, which

is consequential to the presentation of science ideas as open for scrutiny instead as final-form facts (Kuhn, 2010; Nussbaum, 2020; Ryu & Sandoval, 2012; Sandoval, Enyedy, Redman, & Xiao, 2019). As well, as students are required to formulate and share their understandings on science phenomena with peers, dialogic argumentation also emulate the collaborative communal efforts of scientists, thus enculturing students to the habits of mind and norms of talk of science (Driver et al., 2000; McNeill & Berland, 2017).

Second is the democratic imperative. This imperative is governed by the notion that students, as members of the public at large, need to be able to act as concerned and active citizens living in democratic societies (Bencze, Pouliot, et al., 2020; Bencze, Sperling, & Carter, 2012). This imperative could not have come into existence at a more pertinent time as crises seem to have entered the world more prominently and permanently, forcing students to face problems such as climate change, depleting natural resources, and potential mass biodiversity loss. Guided by this imperative, students are tasked with navigating this world and, if they can, offer solutions to make it a better place (Zafrani & Yarden, 2017). Schools and teachers need to do their part in helping them to do so (R. Cohen, Zafrani, & Yarden, 2020).

In this imperative, knowledge and competency in argumentation are considered as prerequisites for scientifically informed negotiation and resolution of issues that relate to real-world social implications of science (Rundgren, Eriksson, & Rundgren, 2016; Sadler & Donnelly, 2006), termed in the science education literature as socioscientific issues (SSI) (Driver et al., 2000; Zeidler, Sadler, Simmons, & Howes, 2005). Studies following this field of inquiry showed that students' engagement in activities that include argumentation in the context of SSI can lead to critical and scientifically informed reflection on such issues (Furberg & Silseth, 2021; Sadler & Donnelly, 2006; Venville & Dawson, 2010).

Schools and teachers, therefore, have the educational justifications and – some might even say the democratic obligation (Bencze, Pouliot, et al., 2020; Klopfer & Aikenhead, 2022; Teo, 2019) - to provide their students with opportunities to engage with dialogic argumentation. However, research in science education considers progress on both imperatives to be mediocre at best. Teachers rarely allow for the incoming of dialogic pedagogy into their classrooms, and instead maintain the incumbent pedagogy of teacher-centered instruction (Henderson, McNeill, González-Howard, Close, & Evans, 2018; Katsh-Singer, McNeill, & Loper, 2016; Knight-Bradsley & McNeill, 2016; McNeill, Lowenhaupt, & Katsh-Singer, 2018; Osborne, 2013; Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013; Segal, Snell, & Lefstein, 2017; Zohar & Alboher Agmon, 2017).

1.2 From teacher-centered instruction to dialogic argumentation

Having both the justifications and perhaps obligations to do so, why is dialogic argumentation not habitually and prominently employed in science classrooms? This dissertation suggests that this is because advancing these imperatives, meritorious as they may be, is not considered a legitimate part of the activity of schools. That is because dialogic argumentation may diverge from teachers' normal way of operating and conflicts with the norms, prevailing practices, and commonly shared meaning about the work of teaching.

For instance, to create a culture in which dialog conducive learning and teaching could thrive, the educational and democratic imperatives assign new roles to students as science learners. Contrasted with traditional science education, in which students are viewed as passive participants and which emphasize memorization and repetition of science facts (Driver et al., 2000), dialogic argumentation demands sustained involvement with open-ended problems and aims to engage students as active participants in collaborative construction and critique of science knowledge claims (Berland & Reiser, 2011; Erduran & Jiménez-Aleixandre, 2008; Iordanou, 2016; Sandoval et al., 2019).

The roles which teachers need to fill in the classroom also should undergo a fundamental shift, as they are required to leave behind the longstanding view of themselves as transmitters of knowledge (P. H. Scott, Mortimer, & Aguiar, 2006), and to function instead as facilitators of argumentative interactions through posing open-ended questions, challenging students' ideas, and helping them navigate the process of collaborative knowledge construction (McNeill & Pimentel, 2010). Dialogic argumentation, thus, requires teachers to teach science in ways that are dramatically different from how their instruction is currently conducted, thus asking them to push against work tradition and normative practices.

The adoption of these new roles also carries fundamental consequences to how interactions between teachers and students, and amongst students, are managed and conducted in the classroom. The dominant interactional pattern of traditional classrooms typically follow the teacher-centered *initiate-response-evaluation* (IRE) structure (Cazden & Beck, 2003; Lemke, 1990; Mehan, 1979). In this transmissional pattern, learning is achieved when students participate as individuals to offer an uncritical resolution of closed-ended problems posed by their teachers (Poole, 1992). Deeply entwined with traditional schooling, the IRE structure ensures that students' contributions do not divert from "correct" science content, as well as minimize threats to the orderly management of the lesson (P. H. Scott et al., 2006). However, it may hold little capacity to endorse students' epistemic agency and to bring forth opportunities

for collaborative knowledge construction (Miller et al., 2018; Sandoval, Kawasaki, & Clark, 2021).

The practice of dialogic argumentation, on the other hand, emphasizes the social nature of learning and endorses a view of knowledge that is created in the context of collaborative interactions with diverse others by asking students to build and negotiate understandings about science ideas (Berland & Hammer, 2012; McNeill & Berland, 2017). In this way, both the educational and democratic imperatives draw upon social interactions and relationships to support science learning.

Moreover, affording the widest range of opportunities for all to engage with such processes is at the heart of these innovative reforms. From an equity oriented stance, these documents require that not just the most meritorious, but *all* students receive an opportunity to engage in dialogic argumentation (NGSS, 2013; NRC, 2012). To create a forward momentum with formal demands for pedagogical change not in idiosyncrasy, but across diverse school organizations, reform efforts include innovative curriculum frameworks (Edelson et al., 2021), and teachers' professional development (TPD) courses (Wilkinson et al., 2017), set to advance the implementation of learning by engagement with authentic dialogic argumentation. Thus, these reform documents not only depart from how schools traditionally organize instruction and interactions in the classroom, but also depart in the definition of the target audience that will get access to these new ways of learning. However, inside a schooling system that is often tracked (Hodge, 2019), the goals of dialogic argumentation have been mostly realized in high-track classrooms with the most meritorious students (Katsh-Singer et al., 2016; Snell & Lefstein, 2018).

Therefore, the change towards dialogic argumentation is ambitious in its *nature* and qualitative intentions, in that it requires dramatic divergence from contemporary teacher-centered practices. However, it is also ambitious in its *scope* and quantitative intentions, in that it represents an attempt at large-scale and field-wide implementation.

Realizing these qualitative and quantitative aspirations "on the ground", where it actually matters, appears to be a daunting task. Teachers are the ones tasked with translating reform mandates into changes in learning within schools. However, while showing potentialities to transform performance on the level of students learning, and while being explicitly endorsed on the policy level, dialogic argumentation still struggles to penetrate and settle in the intermediate level of classroom practice (Henderson et al., 2018; Nielsen, 2012b; Teo, 2019), where it can be merged into the core of professional practice of teaching. Instead,

many schools and teachers still ascribe to the notion of teaching as transmission, where much of science instruction and classroom interactions follow prevailing teacher-centered pedagogy that include students learning to a set of predetermined facts and processes from their teacher and the type of interactions that are facilitated in science classrooms usually follows an IRE pattern (González-Howard & McNeill, 2020; Teo, 2019).

But what is it, exactly, that creates a culture of schooling so foreign to the practice of dialogic argumentation, that formal demands for its implementation appear to bounce off the school walls? Why does dialogic pedagogy can be easily ignored, while teacher-centered pedagogy seems like a fundamental feature of science education? Studies that can answer these questions and that explore how to move down the hierarchy from the level of reform mandates into the level of classroom practice, where it can affect the level of student learning, are surprisingly sparse (Burch, 2007). Consequently, what happens in between formal demands for pedagogical change and observed responses by schools and teachers is not fully understood (Bridwell-Mitchell, 2013, 2015; Everitt, 2017).

What is known is the *outcome*. A considerable gap exists between the empirical findings that elucidate the many potentialities that dialogic argumentation holds for learning, and reform aspirations that build on these potentialities on one side, and how infrequently this pedagogy is actually exercised in science classrooms on the other side. To date, research considers progress on this front to be partial at best (González-Howard & McNeill, 2020; Henderson et al., 2018; Knight-Bradsley & McNeill, 2016; McNeill, Marco-Bujosa, González-Howard, & Loper, 2018; Osborne et al., 2019; Sandoval et al., 2019; Wilkinson et al., 2017).

What we lack knowledge on is the *process* of educational maintenance (Bridwell-Mitchell, 2015), in which teacher-centered, transmission instruction remains to be the dominant practice. Knowledge on this process can be used as a potential lever for change. Aiming to bridge the hole at the heart of science education reform, and to make headway with the implementation of dialogic argumentation, this study explores the murky conditions under which dialogic argumentation can be marginalized, deflected, and ignored in the schooling system, or be more readily accepted and accommodated by science education teachers.

2 The overarching question: learning from the status quo and finding ways to break out of its cycle

It appears that changes in pedagogical practice have not kept pace with prescriptions, despite being grounded in intense intellectual (i.e., the conceptualization, exploration, and

measurement of the effect of dialogic argumentation on learning) and financial investments (i.e., reform mandates and ensuing field level efforts). A tension persists between performance expectations set for teachers and schools by reform-minded pedagogical ideals "out there", and how they perform "on the ground", where learning actually occurs. This persisting tension presents a puzzle to those working in the field of science education, and is what essentially prompted the overarching question of this dissertation:

> *Why don't more schools, and the teachers who work in them, seek to incorporate dialogic argumentation more prominently into their science classrooms, and what can be done to help them to do so?*

There is a degree of correspondence between the two parts of this question. As the chapters to come will show, the ability to answer the latter part of the question that deals with potential levers for change and affordances for the implementation of dialogic argumentation, may rest on the effectiveness of answering the former that deals with understanding the pervasive constraints to implementation that maintain instructional status quo. Hence, this dissertation offers an exploration in two distinct, yet complementary empirical studies that address the two parts of the overarching question.

3 Scope and organization of the dissertation: an exploration in two studies

To explain the maintenance of teacher-centered instruction and encourage the advancement of dialogic argumentation in science classrooms, both studies draw on insights and concepts derived from the field of sociology of organizations. Sociological studies of organizations hold an immense contribution to our understanding of educational organizations and their behavior (Bingham & Burch, 2019; Burch, 2007; J. W. Meyer & Rowan, 1977). This field fundamentally attends to the systematic study of organizations as situated within broader social institutions that shape their ideologies, responsibilities, expectations, and actions (DiMaggio & Powell, 1983; Everitt, 2017).

Orientation to the forces that shape the day-to-day work of teachers and schools, and the ways in which teachers make sense of them, may help to create a more nuanced understanding of classroom realities necessary for the advancement of dialogic argumentation. Yet, insights derived from this field are largely absent from literature concerned with defining the work of educational organizations, namely teaching and learning (Everitt, 2017; B. L. Johnson & Owens, 2005). The untapped potential is vast. Juxtaposing these seemingly separate lines of research and transporting concepts and frameworks from the sociology of organizations

into the field of science education may hold the potential to generate new and important insights regarding the implementation of dialogic argumentation. Both studies also share similarity in their reliance on a research tradition concerned with classroom interactions as indicators of learning and classroom culture. The primary theoretical purpose of studies belonging to this tradition is to reveal the sequential organization of talk in classrooms, and how this organization is dependent upon the particular setting in which the talk occurred (Cazden & Beck, 2003; Edwards & Westgate, 1994).

To not persist the false hope that research combined with policy can alone fix problems of practice, both studies that comprise this dissertation are united by the following conceptual proposition: the ways in which schools are arranged as organizations serve to regulate which instructional practices can be advocated, and which cannot. Instructional practices that offer solutions that are consistent with the interests and internal missions of schools are elevated, while those that are viewed as external or as undermining the schools' ability to achieve their missions, are likely to be marginalized, diluted, or ignored altogether (Bingham & Burch, 2019; Bridwell-Mitchell, 2015; Coburn, 2004). This process works independent of the technical merit of new practices (J. W. Meyer & Rowan, 1977; Yurkofsky, 2021). Implied in this proposition is the argument that the absence of dialogic argumentation may be consequential to it being interpreted inside schools as falling outside a justifiable basis for implementation. The opposite side of this argument claims that if dialogic argumentation can be received by teachers and schools as more aligned with their mission statements, they are more likely to respond with more substantive modes of implementation.

To illustrate how this process unfolds, this dissertation proceeds in two tracks: in Chapter 2 I look inside schools to examine how, in the pursuit of organizational legitimacy, the practice of dialogic argumentation is systematically separated from the core activities of schools. The study in this chapter is titled: *"Dialog-constraining institutional logics and their interactional manifestation in the science classroom" (Zafrani & Yarden, 2022a).* It details the misfit between traditional schooling culture and teachers' practices, and classroom discourse that supports argumentation. In this chapter I draw on insights from the *new institutional theory* of organizations to explicate the mechanisms by means of which teacher-centered instruction is imbued with value and taken-for-grandness, while the practice of dialogic argumentation is interpreted as illegitimate at work.

To implement dialogic argumentation, then, teachers must alter taken-for-granted practices; however, because of that goal, implementation requests are likely to provoke

contestation and resistance. To address this conundrum, the study depicted in Chapter 3 is set in an extracurricular environment shielded from organizational conflicts and tensions, in which teachers and students could participate in dialogic argumentation in ways that otherwise may be disapproved inside schools. This study is titled: *"The potential for reconciling pedagogical tradition and innovation: the case of socioscientific argumentation"* (Zafrani & Yarden, 2022b). Recognizing that successful implementation requires a greater integration of dialogic pedagogies beyond the extracurricular setting, this study identifies conditions for the integration of dialogic argumentation into the culture of schooling as a core instructional practice. To do so, it examines how dialogic argumentation on SSI can be enacted not in conflict, but in ways that cohere with- and produce outputs valued by the internal standards of contemporary schooling. This state, I argue, represents a critical juncture on the path toward successful implementation as it could potentially improve the acceptability of dialogic argumentation by teachers.

Together, these two chapters provide a framework for discussing the constraints (i.e., how schools' organizational behavior exclude dialogic argumentation from the feasible set of proposed instructional practices), as well as the affordances for successful implementation of dialogic argumentation. I conclude with Chapter 4, which weaves the two studies together to discuss the theoretical and practical implications of this dissertation's empirical analysis.

4 Research contexts and key concepts

Both of the studies were conducted as part of a larger research project, termed DIALOGOS. This inter-university project examines efforts to help teachers change their discourse practices towards a more dialogic pedagogy and to promote argumentation in schools. Since the problem of teacher-dominated classroom talk is not unique to science classrooms (Cazden & Beck, 2003), the project bears an interdisciplinary focus. Therefore, the phenomena under study is examined across focal disciplines in schools that include: mathematics, science, and language arts. Both studies detail efforts and findings only for the science discipline.

While within each chapter I describe in detail the research contexts and theoretical concepts brought to bear upon each of the studies, a summary here is in order. The following paragraphs, then, functions as a kind of orientation to the more focused treatments in the studies themselves.

4.1 Research context Chapter 2

The study in this chapter explicitly draws on insights and concepts from the new institutional theory to depict the mutually reinforcing relationship between two levels of organizational conduct: the macro-level institutional forces operating on educational organizations, and the micro-level learning interactions taking place in the science classroom. It looks across these levels to better understand factors constraining the implementation of dialogic argumentation. My aim in this study is, then, to explore the reciprocal relationships between macro-level institutional logics and micro-level routinized teacher–student interactions, and to examine how such social structuring may impede dialogic argumentation.

This study was conducted *in-situ*, centering on an attempt towards a pedagogical change inside schools and classrooms and which was aligned with the formal science curriculum. This study is based on data collected during the academic year of 2018/19. Two lower-secondary schools were the sites of investigation in this study. Both schools provide 7^{th} -12^{th} grades non-vocational education and are in the center of Israel in a town of approximately 23,000 residents from communities of above-average socioeconomic background. The focal participants were eight science teachers who agreed to participate in a 60 hours TPD course. The TPD course was composed of two strands: Strand A (20 hours) was generic and introduced teachers from all disciplines to basic tenets of argumentative and collaborative talk with the purpose of making the theoretical underpinning of dialogic teaching explicit. Strand B (40 hours) was disciplinary and focused on tenets of argumentation particularly relevant to the teaching of each discipline. I served as one of the instructors in the disciplinary strand of the course for science teachers.

4.2 Key concepts for Chapter 2

4.2.1 Dialogic argumentation

Since the concept of argumentation involves several and diverse meanings in the educational literature, it is important to first clarify how it is framed in this study. The emphasis on dialogic practice, where student-to-student talk is seen as collective, supportive, and constructive has influenced this study. That is, rather than viewing argumentation as the rhetoric art of proposing logically valid and well-structured arguments supported by evidence (Erduran, Simon, & Osborne, 2004), argumentation is framed as a dialogic process or a social activity in which individuals construct arguments through interactions with others who hold differing views (Berland & Reiser, 2011; González-Howard & McNeill, 2020).

The dialogic focus emphasizes the collaborative dimension of science instruction by focusing on how students who have different positions about phenomena make sense of it and how they work to convince their peers of their position and try to arrive to an agreement (Alexander, 2008), which therefore promote both the construction and critique of said ideas (Kuhn, 2010). The dialogic aspect of argumentation, therefore, sees knowledge as an entity which is co-constructed by a cohort of individuals who work as a collective, where different opinions should be treated as alternatives worthy of exploration rather than as competitors to be eliminated (Michaels, O'Connor, & Resnick, 2008).

Advancing the notion of argumentation in its dialogic form has received extensive research focus in recent years which resulted in multiple theoretical justifications and empirical data on learning processes affected by this practice. Under these efforts, empirical studies showed that learning activities in which learners interact with peers in constructive dialogs were associated with better learning outcomes associated with students' conceptual understandings of science (Venville & Dawson, 2010; Zohar & Nemet, 2002). In addition, argumentative talk stands in contrast to the naïve conceptualization of science as the accumulation of uncontested and absolute knowledge, instead of presenting scientific knowledge as socially and discursively constructed (Driver et al., 2000). It is, therefore, argued for supporting students' development of more accurate conceptions of the epistemological foundations of science (Berland, Russ, & West, 2020; Iordanou, 2016; Macagno et al., 2015; Ryu & Sandoval, 2012). As well, from an equity perspective, scientific argumentation holds the potential of offering a more inclusive approach to science education. By providing space for individuals' perspectives that are not traditionally represented in the science classroom, argumentation paves a path for all students to participate in science (Furberg & Silseth, 2021; Katsh-Singer et al., 2016; Snell & Lefstein, 2018; Yerrick & Ridgeway, 2017). For these reasons, argumentation has come to be advocated as both the means and the goal of science education (Berland & Reiser, 2009; Kuhn, 2010).

4.2.2 The new institutional theory

Early theorists of institutions viewed organizations as closed, self-contained, systems that develop practices and structures to pursue organizational efficiency (H.-D. Meyer & Rowan, 2012; Weber, 1947). New institutionalists, on the other hand, present a conceptual shift toward viewing organizations as open systems who interact with their environment. A hallmark of this theoretical thought is its emphasis on structures and practices that persist despite their deviation from organizational efficiency. Rather than on efficiency, new institutionalists argue,

organizations develop practices, norms, and values based on social legitimacy or appropriateness (J. W. Meyer & Rowan, 1977). The secureness of legitimacy, in turn, ensures organizations that resources valuable for their survival will be granted by important stakeholders in their environment (DiMaggio & Powell, 1983). These scripts for how organizations in a given institutional field should and ought to operate become taken-for-granted as objective and abiding; they become entrenched as the way these organizations act (Zilber, 2016).

The adherence to institutional scripts for organizational structuring and action is observed, for example, in organizations that belong to the fields of law (McPherson & Sauder, 2013), health (Heinze & Weber, 2016; Reay & Hinings, 2009), corporations (Sonenshein, 2016), hi-tech (Zilber, 2007), and education (H.-D. Meyer & Rowan, 2012). Although varying in context and focus, these studies articulate how social legitimacy and compatibility act as mechanisms for stability and rationalize behavior for organizations who operate in these fields.

The means by which organizations can be legitimated is conformation to pervasive social ideas about how they and their members should act (R. Scott, 2013). Thus, from a new institutionalist perspective, the key constraint for schools is the need to maintain and communicate their legitimacy to their environment. Organizations can achieve legitimacy by conforming and complying to macro-level ideas about how they and their members should act (Reay & Hinings, 2009; Zilber, 2016). These behavior organizing ideas are defined as *institutional logics*, a concept within the new institutional theory that describes a set of taken-for-granted master principles that shape practices, provide missions, and underpin what is deemed as legitimate behavior (Reay & Jones, 2016; Thornton & Ocasio, 2008). Multiple logics may coexist in the same setting (Colaner, 2016), and research attention is mostly focused on how logics, in the aggregate, guide organizational behavior (Reay & Hinings, 2009).

Institutional logics, then, shape the actions of organizations, and of the individuals who work in them, by defining both the content and the meaning of legitimate organizational conduct. Through an institutional analysis we can, therefore, identify the constraints under which schools operate, and which reformers may confront when they attempt to modify or replace deeply entrenched organizational practices. Focusing on institutional logics may, therefore, be useful to analyze the deep-seated conceptualizations regarding teaching that maintain teacher-centered instruction and constrain the shift towards dialogic argumentation.

4.2.3 Institutional talk

Emerging within the academic context of sociology, the study of talk as institutionalized sought to extend the reach of sociology to studies of verbal interactions (Berger & Luckmann, 1966; Sarangi & Roberts, 2008). Studies of institutional talk argue that through interactional routines in work related settings, existing institutional understandings are maintained and reproduced (Heritage, 2005). Though it represents a relatively minor branch of the new institutional theory, where scholars are mostly preoccupied with articulating macro-level social forces, in recent years the interactional level began to receive more attention (Cornelissen, Durand, Fiss, Lammers, & Vaara, 2015).

The articulation of institutional logics can be used to discern the relationship between the interactional and institutional levels. Macro-level institutional logics not only prescribe what constitutes taken-for-granted organizational missions, but also prescribe legitimate means and practices by which these missions could be achieved (Thornton & Ocasio, 2008). Such practices endure, partly, because of their capacity to fulfill widely shared ideas about how organizations should operate (Bridwell-Mitchell, 2013). Therefore, institutional logics do not only exist "out there" at the macro-level, but take tangible realization "on the ground" by enactments of standard procedures, habitual actions and routines that signal the legitimacy of organizations (Binder, 2007). This means that organizational activities both shape, and are shaped by, institutional logics in reproductive ways.

Inside schools, verbal interactions between teachers and students at the micro-level of classroom instruction are the main practice by which the educational project is achieved (Cazden & Beck, 2003; Lemke, 1990). Interactional practices, then, reflect the legitimacy of the school organization; to the degree to which micro-level interactional structures of learning activities cohere with the prescriptions of macro-level institutional logics, they may be more readily accepted by teachers as the taken-for-granted ways of teaching. In light of the above, classroom interactions can be analyzed not only for their role in learning, but also for shaping and reflecting institutional understandings (Arminen, 2017).

To gauge the dynamics of institutional and interactional levels, this study attends to a conversational construct that most studies would describe as "traditional": the IRE pattern (Cazden & Beck, 2003; Lemke, 1990; Mehan, 1979). This pattern of talk is often the habitual interactional practice in schools and had been previously framed as a form of institutional talk (Heritage, 2005; Sarangi & Roberts, 2008; Seedhouse, 2004). IRE impose mostly teacher-controlled classroom interactions and afford little student-to-student interactions, and can

present science as a set of final form ideas (Pimentel & McNeill, 2013). It can, therefore, be inauthentic and divorced from both the epistemologies and communal culture of science.

Framing IRE as a form of institutional talk means that it evolved over time under the influence of the institutional order, and that it is organized to facilitate the accomplishment of the core activities and goals of the institution in which it occurs (Drew & Heritage, 1992; Poole, 1992; Seedhouse, 1996). Since the goals and activities of organizations are rationalized by institutional logics (Zilber, 2016), the properties of IRE depend upon not only on the goals and activities it is used to serve inside schools, but also upon the larger ideas by which these activities are informed. The study of institutional talk, then, is focused on the ways in which macro-level institutional understandings become observable in the micro-level patterning of IRE (See Appendix A for data that illustrate forms of institutional talk that is additional to the data in Chapter 2).

4.4 Research context for Chapter 3

A common finding in organizational studies is that exposure to demands and prescriptions that are external to institutional scripts, is a source of tension and conflict for organizations (Binder, 2007; Sonenshein, 2016). For educational researchers, one interesting conceptual puzzle that emerges from this finding is how school organizations with limited resources and very dominant institutionalized practices can become more pluralistic in their instruction (Bingham & Burch, 2019) and incorporate practices that are not always compatible with institutional mandates (Bridwell-Mitchell, 2013).

The study in Chapter 3 raises the following proposition to address this puzzle: innovative practices that are antagonistic to schooling mandates, may be perceived by organizational actors as threatening appropriate conduct (Heinze & Weber, 2016; Malhotra, Zietsma, Morris, & Smets, 2021). In schools, this means teachers may address demands to implement an innovative pedagogical practice that deviates from the socially acceptable templates for schooling to the extent that this pedagogy is aligned with the interests and missions of their schools. Born out of this proposition is the question whether teachers can find ways to integrate dialogic argumentation into their teaching in ways that correspond with what constitutes valued and appropriate instruction in their schools. Reporting a case study focused on enactments of SSI argumentation in an extra-curricular environment, the aim of the study in Chapter 3 is to explore how teachers may enact SSI argumentation, not in conflict, but in pursuit of outcomes valued when judged according to the standards of contemporary schools.

The study in Chapter 3 takes place in an extra-organizational and extra-curricular context of “Climax days”, during which students came to a site outside of their schools for a full school day to debate unresolved, open-ended, questions that pertain to issues with societal significance that are enmeshed with science, mathematics, and philosophy. This study is based on data collected during the academic year of 2019/20. The participants in this study were six 7th grade science teachers who teach in high-track classrooms and their students (n=130) from four lower-secondary schools that serve students from a city with high socioeconomic status.

A 60 hours TPD course was designed to not only expose teachers to the underlying principles of dialogic pedagogy, but also to prepare them towards the management of climax days. Each climax day was composed of three parts, each of two academic hours. The first and second parts of the day are dedicated to disciplinary modules, and the third to an interdisciplinary module.

The DIALOGOS research team developed the lesson plans for each discipline as well as the interdisciplinary lesson plan (see Appendix B for all science lesson plans). Five climax days were planned and carried out, with the fifth day conducted online due to COVID-19 pandemic restrictions, in which students were asked to learn about and negotiate the issues of: (1) genetic passports and encryption, (2) urbanization and ecological conservation, (3) mandatory vaccination, (4) human genetic modifications, and (5) fake news. The first and third climax days were selected for fine-grained analysis in this part of the study (see Appendix B for all 2019/20 science lesson plans).

We continued to work with these schools in the subsequent years, though data collected from this period is beyond the scope of this dissertation. In the academic year of 2020/21, we continued the format of climax days with the same cohort of students (who were by then in the 8th grade). However, the structure of climax days changed to be fully interdisciplinary, with disciplinary lesson plans delivered during school time. We maintained this structure for the academic year of 2021/22, but this time access to climax days was extended to high-track students across all grades of the lower-secondary schools (7th-9th). Across this period of research, four additional climax days were developed to include: (6) Re-opening schools in times of COVID-19, (7) Ethics in sports, (8) Equitable distribution of resources, and (9) Climate change (see Appendix C for all 2020/21 and 2021/22 science lesson plans).

4.5 Key concepts for Chapter 3

4.5.1 SSI argumentation

The basic assumption of underlying much of the advocacy for SSI argumentation, a sub practice of dialogic argumentation that centers on societal dilemmas enmeshed with science (Sadler & Donnelly, 2006), is that it allows students to actively use scientific knowledge in solving multifaceted societal problems (Bencze, Pouliot, et al., 2020). As negotiating such issues involves understanding the content of an issue, requires the use of evidence-based reasoning, and provides a context for understanding scientific information through a moral and ethical prism, it can provide opportunities for critical inquiry. In such an inquiry, students engage in collaborative and open deliberation about science ideas and knowledge (Nielsen, 2012b), and make up for a fertile ground for enactments of dialogic argumentation (Sadler & Donnelly, 2006).

This advocacy for SSI argumentation, then, is rooted in the notion that it can enable students to collaboratively formalize positions and defend them against competing claims, which was documented to exert positive educational effects in students' conceptual understanding of science (Bathgate, Crowell, Schunn, Cannady, & Dorph, 2015), informed decision making (Evagorou, Jimenez-Aleixandre, & Osborne, 2012), and improved moral character (Zeidler & Sadler, 2007). For these reasons, schools and teachers bear the responsibility to provide their students with opportunities to engage with SSI argumentation.

4.5.2 Socioscientific reasoning

SSI lie at the intersection between scientific and social problems and do not have clear-cut solutions (Kolstø, 2001). Consistent with these qualities, when negotiating SSIs students can make connections between their subjective intuitions, emotions and personal experiences in ways that are not confined to the realm of objective science knowledge (Rundgren et al., 2016; Zeidler & Sadler, 2007). However, in science classrooms, reliance on objective forms of knowledge, termed in the literature as rationalistic reasoning (Sadler & Zeidler, 2005), may be considered as more fitting and desired than reliance on subjective knowledge (van Der Zande, Brekelmans, Vermunt, & Waarlo, 2009). However, previous studies made explicit the difficulties students may encounter when asked to negotiate SSI in ways that are informed by science, such as in using scientific evidence (Tidemand & Nielsen, 2017) and in drawing on science concepts pertaining to the issue under discussion (Dawson & Venville, 2013). As a

result, "superficial" and less scientific argumentation may prevail in classroom discussions on SSI (Dawson & Venville, 2013), potentially inducing conflicts and distancing it from being accepted as a core instructional practice.

The more fundamental the change in classroom talk from its habitual form, the more it will conflict with the standards of contemporary education and with teachers' long standing beliefs about teaching and learning (Wilkinson et al., 2017). This may bring to rise virulent resistance to implementation demands (Kilinc, Demiral, & Kartal, 2017). In addition, the success of past educational reforms have been arguably consistent with the values of the teachers who were tasked with their implementation (D. K. Cohen & Mehta, 2017). Therefore, a full accounting of implementation efforts needs to be accountable not only to the intention of educational reformers but also for consistency with the contemporary standards of the educational field. Hence, emphasizing students' reliance on rationalistic reasoning may be needed for the advancement of SSI argumentation in classroom realities.

4.5.3 Organizational free spaces

A common and major challenge for the advancement of organizational change is that the logic by which the change is motivated and the logics that define habitual organizational conduct may be founded on the bases of conflicting rationales (Reay & Hinings, 2009). Therefore, external pressures for change may be perceived as sources of tension for organizational actors, emerging from having to incorporate potentially antagonistic practices that may challenge their organization's pursuit of legitimacy (Sonenshein, 2016).

The literature of organizational studies identifies a compartmentalized structural approach as one key to handle this conflict (Frederiksen, Gottlieb, & Leiringer, 2021; Heinze & Weber, 2016; Perkmann, McKelvey, & Phillips, 2019). This compartmentalized approach entails the establishment of temporary, standalone, organizational free spaces, which buffers actors from sanctions for carrying practices that conflict with regular organizational conduct (Perkmann et al., 2019). Organizational free spaces define an alternative and specialized mission and bestow resources to support and sustain this mission, including human and physical capital (Heinze & Weber, 2016). Its establishment allows actors to examine how the new practice can produce outputs valued by the standards of their home organization (Sonenshein, 2016). In instances of system-wide resistance and failure to transform organizational practices, the establishment of such free spaces may buffer from initial opposition to implementation demands (D. K. Cohen & Mehta, 2017)

Previous studies showed that the establishment of such free spaces allowed different organizational actors to engage with activities illegitimate in their fields. These include, for example, health professionals enacting practices that belong to the field of integrative medicine (Heinze & Weber, 2016), for-profit corporations addressing social welfare issues (Sonenshein, 2016), and partnerships between industry and university professionals who operate by competing demands (Perkmann et al., 2019). In education, the establishment of organizational niches or subsystems was documented to achieve more success in creating rigorous and challenging learning experiences for students than system-wide reforms (Mehta & Fine, 2019a). This is especially true for reform mandates that diverged sharply from institutionalized conceptions of teaching and learning, which failed system-wide but achieved success in specialized niches (D. K. Cohen & Mehta, 2017).

Applying this approach to the context of this study meant that instead of probing deep within the culture of schools and classrooms, we created the extra organizational environment of climax days. In this environment, teachers were allowed to enact activities and interactions that are more conducive to SSI argumentation, including teacher-led argumentation, and peer-led small group argumentation. Though these activities dislodge practices that favor teacher-centered instruction –which might be iconoclastic to the conduct of their home schools – the establishment of the free space meant that teachers could experience them without violating organizational conduct.

5 Chapter summary

In this chapter I presented the need to consider how to advance the implementation of dialogic argumentation, not just in individual classrooms but across the educational field. The two papers included in this dissertation draw on qualitative data to provide an exploration of how this goal may be attained. Both studies follow the following argument: to the degree that dialogic argumentation will be valued by teachers, it has an increased potential to be institutionalized into the schooling system. Conversely, to the degree that it will remain to be viewed as an extracurricular practice, it may be ignored or kept entrenched in the periphery of schooling.

The first paper follows this heuristic and suggests that, inside schools, a complex interplay of institutional logics that provide order and structure to teachers' work may protect teacher-centered instruction and make the practice of dialogic argumentation appear illegitimate. In the second paper, an analysis of enactments of argumentation activities in an

extracurricular environment, an organizational free space, may provide an initial exploration into how organizational actors can craft an acceptable balance between the conflicting expectations of the work of contemporary schooling and the practice of dialogic argumentation.

I believe that the diversity between the two studies that comprise this dissertation can encourage a perspective from which it is possible to develop a range of analytical connections and assumptions about how to advance the implementation of dialogic argumentation and its related educational and democratic imperatives.

CHAPTER 2. Dialog-constraining institutional logics and their interactional manifestation in the science classroom[1]

"The fabric of schooling is woven of linguistic interaction" (Adger, 2001, p.503)

1 Introduction

Though the practice of dialogic argumentation is recognized for its apparent importance and potential for students' learning (Berland & McNeill, 2010; Driver et al., 2000; Venville & Dawson, 2010), and despite calls in recent reform mandates (Israeli Ministry of Education, 2009; NGSS, 2013), it rarely happens in science classrooms (González-Howard & McNeill, 2020; Henderson et al., 2018; Knight-Bradsley & McNeill, 2016; McNeill, Marco-Bujosa, et al., 2018; Osborne et al., 2019; Sandoval et al., 2019; Wilkinson et al., 2017). Explanations for this absence of argumentation mainly follow two lines. One attributes the lack of argumentation to system-wide challenges of implementation in a school culture in which instructional norms, practices, and expectations are constituted by teacher-controlled pedagogies (Henderson et al., 2018; Miller et al., 2018). The other attributes it to teachers' individual professional capacities and beliefs, which make it difficult to adopt argumentation as a legitimate form of instruction, and lead to a preference for traditional forms of teacher–student interactions (Knight-Bradsley & McNeill, 2016).

To advance the implementation of dialogic argumentation in science classrooms, we examined the cultural conditions in schools, and teachers' interactional practices that are established under these conditions, not separately but as a mutually constitutive phenomenon. We created a dialog between two converging genres of inquiry. One was rooted in the *new institutional theory* of organizations. This theory argues that schools work less from technical considerations and more from the need to obtain social legitimacy and maintain the trust and confidence of the public at large (J. W. Meyer & Rowan, 1977). Such public legitimacy is achieved by conforming to taken-for-granted macro-level norms and rules that penetrate organizations and influence their behavior (DiMaggio & Powell, 1983), and provide the "rules of the game" (Everitt, 2017) for organizational conduct. The other genre is grounded in interactionist perspectives, which seek to highlight the ways in which micro-level day-to-day

[1] This chapter is a modified version of paper published in *Science Education* 106.1 (2022): 142-171

talk and interaction may be pervaded and motivated by social order and cultural understanding (Gee, 2014; Heritage, 2005).

We therefore argue that a better understanding of why dialogic argumentation has not been adopted by teachers as a common instructional practice requires attention to both macro- and micro-level perspectives. Consequently, this study seeks to examine how dialog-constricting institutional mandates undergird the instructional practices of lower-secondary school teachers, and how routine teacher–student classroom interactions are bounded and motivated, in part, by these mandates.

2 Theoretical framework

The concept of argumentation has two central meanings in science education. One, grounded in the philosophical work of Toulmin (2003), refers to the structural element of generating and developing scientifically reasoned arguments supported by evidence (Erduran & Jiménez-Aleixandre, 2008; Erduran et al., 2004). The other refers to the dialogic component, which emphasizes students' engagement in collaborative knowledge construction and the critique of conflicting ideas (Berland & Reiser, 2011; González-Howard & McNeill, 2020), and how teachers can provide opportunities for such collaborative modes of reasoning and argumentation (McNeill, Katsh-Singer, González-Howard, & Loper, 2016; McNeill, Marco-Bujosa, et al., 2018). The former has been emphasized in educational research (Kim & Roth, 2018; Nussbaum, 2020; Ryu & Sandoval, 2015), where studies illuminated the conditions under which students can develop and improve the rhetorical and logical structure of their arguments (Grimes, McDonald, & van Kampen, 2019; Roberts & Gott, 2010). In this study, we place the emphasis on the latter, where argumentation is conceptualized as a dialogical genre of classroom discourse (Kim & Roth, 2018), which necessitates a focus on the dynamic interactional relationships between teachers and students (Alexander, 2008). More specifically, we take both a broad and fine-grained look at the social relations and structures that underlie teacher–student interactions and may prevent the emergence of dialogic argumentation in the science classroom.

2.1 Dialogic argumentation in science classrooms: benefits and pitfalls

Argumentation has been recognized as a central tenet of authentic scientific practice in science education research (Asterhan, 2018; Berland & Hammer, 2012; Driver et al., 2000; González-Howard, McNeill, Marco-Bujosa, & Proctor, 2017). Engagement with argumentation was

shown to advance students' understanding of scientific ideas and epistemologies (Berland et al., 2020; Knight-Bradsley & McNeill, 2016; Newton et al., 1999; Simon et al., 2006), provide an opportunity for students to "talk science" and adapt to the norms of talk in the scientific community (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Ryu & Sandoval, 2015), and negotiate and offer solutions to current social concerns which are enmeshed with science (Bencze, El Halwany, & Zouda, 2020; R. Cohen et al., 2020; Zafrani & Yarden, 2017). Following such documented potentialities, a call for the implementation of argumentation in science classrooms has been advanced in current reform-minded documents (Israeli Ministry of Education, 2009; NGSS, 2013).

However, gaps between the ideal spaces and practices that support argumentative discourse and traditional classroom culture persist (Henderson et al., 2018; McNeill & Berland, 2017). For example, students who participated in dialogic argumentation exhibited improved epistemic understanding of science through the presentation of competing explanations that were open to peer scrutiny (Chen, Benus, & Hernandez, 2019; Iordanou, 2016; Ryu & Sandoval, 2012), as well as an improved conceptual understanding of scientific phenomena (Bathgate et al., 2015; Zohar & Nemet, 2002). Science teachers have a central role in promoting such epistemologically authentic experiences for their students (McNeill, González-Howard, Katsh-Singer, & Loper, 2016) and in scaffolding classroom argumentation for them (Macagno et al., 2015; Mayweg-Paus, Macagno, & Kuhn, 2016). However, teachers may hold persistent epistemological beliefs that portray science as an unequivocal body of knowledge. These beliefs may be incompatible with the consideration of competing ideas (Kilinc et al., 2017; Sengul, Enderle, & Schwartz, 2020; Wilkinson et al., 2017) and may give rise to pedagogy of content transmission and coverage in pursuit of factually correct answers (McNeill & Berland, 2017; Russ & Berland, 2018).

Engagement in dialogic argumentation also allows students to verbally externalize their thinking as a resource for others to build on (McNeill & Berland, 2017). It can, therefore, also be productive in simulating how scientists engage in collaborative communal efforts when trying to explain natural phenomena (Macpherson, 2016; Sandoval et al., 2019). The advancement of these collaborative norms also depends heavily on teachers. For example, Sandoval et al. (2019) showed that the effectiveness of argumentation depends on teacher support of collaborative sense-making processes in which the authority to construct knowledge is distributed. Despite its promise, even when enacting activities that address argumentation, teachers may adapt lessons in ways that align with authoritative, teacher-led modes of

instruction, which place students in the role of individual receivers of knowledge (González-Howard & McNeill, 2019; McNeill, Marco-Bujosa, et al., 2018; Sandoval et al., 2019).

While there are some differences among these challenges, they share a fundamental link between traditional schooling culture and teachers' practices, and how both are misaligned with a classroom discourse that supports argumentation. This is problematic because for argumentation to emerge in classrooms, it has to be considered a meaningful practice within the classroom and the schooling culture (Sandoval et al., 2019). In this study, we suggest that such misalignment cannot be understood without considering the complex interplay of external, macro-level forces that permeate schools and shape the values, rules, and norms that make up the current schooling culture (Bridwell-Mitchell, 2013; J. W. Meyer & Rowan, 1977) and the micro-level discursive practices raised by these forces (Heritage, 2005).

2.2 The institutional level: teachers' work from a macro-level perspective

How, despite the variations in teachers' biographies and school localities, is instruction shaped in such systemic and isomorphic ways toward teacher-centrality and against dialogic argumentation? To answer this question, we draw upon insights from the *new institutional theory* of organizations. This theory views organizations (i.e. schools) as social entities that develop practices, norms, and values in pursuit of legitimacy in the eyes of important stakeholders in their environment who will, in turn, grant them valuable resources for their survival (DiMaggio & Powell, 1983; J. W. Meyer & Rowan, 1977). In this school of thought, it is argued that organizations obtain legitimacy by conforming to pervasive social ideas about how they and their members should act, and which organizational missions they should pursue (Bridwell-Mitchell, 2013, 2015). Such conformity ensures that they are perceived as functioning and compatible within the expectations of the society in which they operate (J. W. Meyer & Rowan, 1977). Although this legitimacy-seeking behavior ensures the survival of the organization, it constrains its freedom to adopt innovative practices, thus stabilizing and routinizing organizational behavior (Burch, 2007). As they conform to the same institutional mandates, organizations across localities bear a striking resemblance in their social structuring and organizational practices (DiMaggio & Powell, 1983).

The social ideas to which organizations conform are defined as *institutional logics* – a concept in the new institutional theory that describes a set of taken-for-granted prescribed notions that appear natural and abiding and that organizations and individuals are expected to follow (Thornton & Ocasio, 2008; Zilber, 2016). In aggregate, institutional logics provide the

building blocks for social institutions (Colaner, 2016). Organizational missions and practices that are consistent with the rationalizations of prevailing institutional logics are expected to be promoted and maintained. Missions and practices that contradict or threaten logics, on the other hand, may be marginalized or ignored altogether (Malhotra et al., 2021; Thornton & Ocasio, 2008).

In schools, the institutionalization of teacher-centered pedagogy can be explained by its legitimacy-producing alignment with pervasive institutional logics. For example, success in advancing students' scores on standardized tests may assert schools' legitimacy with the public at large (Marsh, Allbright, Bulkley, Kennedy, & Dhaliwal, 2020). However, it may also lead teachers to focus mainly on the transmission and acquisition of isolated facts as preparation for standardized tests (Segal et al., 2017; Zohar & Alboher Agmon, 2017; Zohar & Cohen, 2016).

In addition, schools educate a heterogeneous population of students with considerable differences in capabilities, who are often separated into specialized programs. Within these programs, high-tracked placements have become a resource for academic prestige and legitimation of schools (Attewell, 2001; Oakes, 2005). Although educational reformers struggle for equal opportunity for all students to engage in rigorous curricula, teachers who work in a stratified environment may adopt different pedagogies when instructing low or high tracked classrooms. Studies show that when instructing low-performing students, teachers tend to adopt more didactic pedagogies (Lewis & Diamond, 2015; Mehta & Fine, 2019a). On the other hand, there is work showing how teachers designate collaborative learning activities for students in high-tracked placements (Katsh-Singer et al., 2016; Snell & Lefstein, 2018).

Moreover, for teachers, recognition of competence and collegial esteem, and therefore individual legitimacy, is earned by the adoption of practices and customs of teaching that are learned by observing and conversing with peers (Bridwell-Mitchell & Fried, 2020; Everitt, 2017; Lortie, 1977). These customs may emphasize teacher control and authoritative forms of instruction (P. H. Scott et al., 2006), rather than students' agency and collaborative knowledge construction (Stroupe, 2014). Therefore, schools' and teachers' search for social legitimacy seems to undermine the accreditation of dialogic argumentation as a legitimate form of instruction.

In this study, rather than tracing the extra-organizational origins of institutional logics from field-wide guidelines and scripts, we endorse an embedded representation (where individuals are embedded in organizations which are permeable to institutional logics, see Figure 2.1). This analytical stance emphasizes the importance of individual active sense-

making in understanding social reality in local settings (Armanios & Eesley, 2021; Binder, 2007). It therefore identifies institutional logics as they circulate *within* organizations and are interpreted by individuals (Haedicke & Hallett, 2015). The macro-level perspective therefore explores how, through discussion about their work, organizational players (i.e., teachers) assign force and meaning to institutional logics "on the ground" (McPherson & Sauder, 2013; Zilber, 2016).

2.3 The level of teacher–student interactions: teachers' work from a micro-level perspective

Within organizations, then, the goals and conventions dictating how work is to be done become infused with legitimacy granted by conformity to institutional logics. When this process of legitimation takes place, organizational practices, such as teacher-centered pedagogy, may become entrenched because of players' unwillingness to compromise the chances of organizational survival. In the classroom, verbal interactions between teachers and students are the main practice by which education is achieved (Wortham, 2008). Therefore, our understanding of the school as a social institution, where the attainment of legitimacy provides the rules of conduct, must also include classroom talk and interaction. It can therefore be argued that the degree to which the structure of teacher–student interactions is coupled with institutional logics may determine their potential to produce organizational and individual legitimacy. As such, the level of coupling may also determine the likelihood of this interactional structure being institutionalized and routinely appearing in classrooms.

Accordingly, in this study we adopt an analytical standpoint that view communicative events as holding the potential to maintain or alter institutional reality (Berger & Luckmann, 1966; Gee, 2014). Placing classroom communication at the center of institutional analysis may offer an examination of the ways in which micro-level classroom interactions between teachers and students actively construct meaning within institutionalized settings through language.

In studies of workplace communication, the ways in which micro-level interactions are organized by macro-level institutional order are observed in courtrooms (McPherson & Sauder, 2013), medical organizations (Heritage, 2005; Ten Have, 1991), police interrogations (Tracy & Robles, 2009), and classrooms (Brooks, 2016; Garton, 2012; Poole, 1992; Seedhouse, 2005). However, most interactional studies tend to ignore the institutional order, and are primarily concerned with explicating the order and language of the interactions (Sarangi & Roberts, 2008). Similarly, in institutional theory, the interactional level is only theorized in a limited

way (Cornelissen et al., 2015; McPherson & Sauder, 2013). Here, we aim to bridge the institutional–interactional divide and join studies that examine how certain aspects of the institutional level impinge on the interactional level.

To stress the connection between routine interactions in science classrooms and institutional logics, we focus on a conversational construct which is related specifically to classrooms, and which persists throughout different localities and populations: the *initiate-response-evaluation* (IRE) pattern (Cazden & Beck, 2003; Lemke, 1990; Mehan, 1979). Because of its enduring qualities, the IRE pattern has been referred to in the literature as a form of institutional talk (Heritage, 2005). In contrast to naturally occurring interactional conduct, institutional talk is bounded by an institutional reality and is organized to facilitate the accomplishment of the core activities and goals of the institution in which it occurs (Drew & Heritage, 1992; Seedhouse, 1996).

Thus, in schools, teachers adhere to IRE not just for the sake of regularity, but to get practical tasks done. As the new institutional theory argues that the tasks that need to be accomplished are set to achieve aims that are rationalized by macro-level institutional logics, the study of institutional talk in schools should focus on the ways in which institutional logics become observable in interactional practices that are prevalent in classrooms. If we examine IRE from this perspective, it can be seen as more than a recurring sequence of pedagogical interaction; it can also be considered to reflect and reproduce the institutional logics that rationalize and infuse it with legitimacy. The IRE pattern inherently undermines dialogic explorations by prioritizing authoritative teacher talk over collaborative student–student interactions (Chen et al., 2019; González-Howard & McNeill, 2019). Therefore, breaking out of this pattern in the classroom in favor of an interactional one that is conducive to dialogic argumentation can be difficult, since it may be perceived by teachers as a legitimacy-eroding practice. In summary, whereas the macro-level perspective explores how the work of teaching is described among teachers, the micro-level perspective explores how the work of teaching is performed in routinized teacher–student classroom interactions.

3 Aim and research questions

Our study is both culture-oriented and interaction-centered in the sense that it views classroom interactions as embedded within a wider institutional sphere (Figure 2.1). Therefore, our overarching aim is to explore the reciprocal relationship between macro-level institutional logics and micro-level routinized teacher–student interactions, and to examine how such social

structuring may impede dialogic argumentation. This aim allows us to explore questions that are less apparent when examining macro-institutional and micro-interactional phenomena separately. We therefore ask:

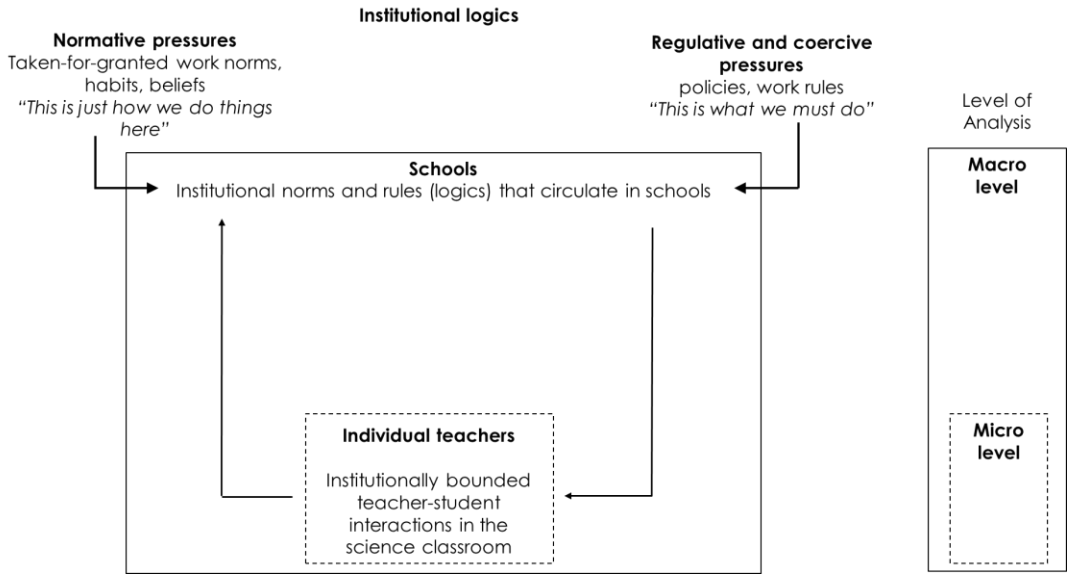


FIGURE 2.1 An institutional perspective on teacher–student interactions. Arrows mark the mutually constitutive effects that institutions and classroom interactions exert on one another.

i. ***From a macro-level perspective:*** What institutional logics for appropriate science instruction can be identified in teachers' expressions and how do they constrain dialogic argumentation?
ii. ***From a micro-level perspective:*** How do the different components of the IRE pattern serve to facilitate institutional activities and reflect dialog-constraining institutional logics?

4 Methodology

This study was conducted in two lower-secondary schools in Israel. As it attempts to explain the same phenomena in two sites (i.e., cases), this study can be referred to as a collective case study. In collective case studies, a number of cases are combined for the purpose of focusing on themes that unite and differentiate them (Stake, 1995). The crux of the matter in this study is not the potential difference between the schools and among the teachers who work in them. Rather, we aim to account for the commonalities and shared meanings of schooling across schools and individuals. Therefore, we worked toward the identification of joint patterns of organizational behavior across the cases.

To methodologically capture the institutionally informed contexts of science teaching, we employed a dual-lens conceptual approach to research teachers' practices. Analysis of

macro-level institutional influences on organizational action usually corresponds to ethnographic methods (Zilber, 2016). Such analysis may provide rich descriptions of school culture, but it can fall short in explaining the ways in which the culture is enacted and communicated daily by individuals in school settings. For this reason, we sought a dialog between ethnographic methodologies and interactional methodologies for the qualitative analysis of routine classroom interactions (Heritage, 2005).

4.1 Research context

This study is part of a larger research project examining efforts to promote dialogic argumentation in lower secondary schools through teachers' professional development (TPD). In Israel, teachers engage in ongoing professional development as part of national efforts to professionalize teachers with respect to the demands of the occupation and to ensure high-quality teaching, in terms of both disciplinary content understanding and pedagogy (Avidov-Ungar, 2016). The context of TPD seems prolific for research that centers on institutional logics, because TPD exposes the teacher to a different set of expectations and demands than those usually highlighted in the school's day-to-day conduct. Such conditions may reveal teachers' deeply ingrained assumptions about instruction which might otherwise be hidden in the daily conduct of schools (Coburn, 2004; Haedicke & Hallett, 2015).

The TPD course was composed of two strands, for a total of 15 meetings (60 hours) across the two schools. Strand A (20 hours) was generic and introduced teachers from several disciplines (e.g., science, mathematics, language arts, history) to the basic tenets of argumentative and collaborative talk with the purpose of making the theoretical underpinning of dialogic teaching explicit. To advance teachers' appreciation of dialogic teaching, this strand introduced teachers to the rationale and potential of dialogic pedagogy, providing various analytical tools to examine teacher–student dialog, such as accountable talk (Michaels et al., 2008) and exploratory talk (Mercer & Wegerif, 1999). The idea here was to expose the teachers to a diverse repertoire of classroom interactional patterns and talk moves that deviate from IRE. Strand B (40 hours) was discipline-specific. Here, we presented argumentation as a practice that is inherent to scientists' work. For this purpose, we adapted talk moves and analytical tools from strand A for the exploration of scientific phenomena in general classroom discussions, through collaborative engagement with discipline-specific texts (Yarden, 2009), and for the negotiation of controversial socioscientific issues (Zeidler et al., 2005). In addition, with the intention of presenting dialogic argumentation as attainable, a joint analysis of examples of

real classroom interactions was conducted for the exploration of tensions with, and opportunities for dialogic interactions.

The two schools participated together in the TPD course during the academic year of 2018–2019. Both schools belong to a large educational network, provide 7th- to 12th-grade education, and are in the center of Israel in a town of approximately 23,000 residents from communities of above-average socioeconomic background. The first school, *Ganim* (pseudonym) serves 1216 students and employs 114 teachers, more than 50% of which have at least a master's degree. The second school, *Ramot* (pseudonym), serves 1200 students and employs 109 teachers, more than 40% of which have at least a master's degree. Both schools have been awarded recognition for excellence in education, and rank above the national average for matriculation exam eligibility (Israeli Ministry of Education, 2017). Due to their recognized excellence, network executives identified these two schools as suitable for participation in our study.

4.2 Participants

The focal participants in this study were eight lower-secondary science teachers from Ganim and Ramot who were identified as suitable and asked by the school administration to participate. In that sense, the participant-selection methodology was purposive sampling (Etikan, Musa, & Alkassim, 2016). The participants represent a range of teaching experience, with five participants having more than 15 years of experience (Table 2.1).

TABLE 2.1 List of participants

School	Participant code	Interviewed	Experience (years)	Classroom observation details	
				Grade	Academic track
Ganim	GanimTeacher1	✓	5–10	9	General
	GanimTeacher2		>20	8	High
	GanimTeacher3		1–5	8	General
				8	High
	GanimTeacher4	✓	15–20	8	High
				8	High
Ramot	RamotTeacher1	✓	15–20	9	Low
				9	Low
				9	Low
	RamotTeacher2	✓	>20	7	High
				9	High
	RamotTeacher3		5–10	7	General
	RamotTeacher4	✓	>20	9	High
				9	High
				9	High
				9	High

4.3 Data sources and analysis

A dual-lens conceptual approach to researching teachers' practices calls for an integration of analytical methods. Accordingly, each level of analysis—the macro- and micro-level—is informed by different forms of data and imposes different interpretive methodologies. Whereas the purpose of the micro-level analysis is to assign functions to routine discursive forms, the role of the macro-level analysis is to identify and assign institutional meaning to said functions.

4.3.1 Macro-level analysis

For the identification of macro-level institutional logics invoked by the teachers, we examined ethnographic data in which teachers talked about their work. For this purpose, the TPD meetings were videotaped and transcribed, and constituted the site for participant observation. Individual ethnographic interviews were conducted based on initial findings made by observations, and allowed for an insider view of the school culture (Carspecken, 2013), with informal conversations serving as the supporting data source. Additional organizational documents (photographs of bulletin boards, schools' newsletters, texts from the schools' official websites) were collected to provide depth to the findings.

In this phase, techniques for inductive grounded theory building were used to analyze the data (Glaser & Strauss, 2017). First, descriptive codes were assigned inductively to the data. Second, the generated codes were grouped into broader categories. The final stage of the analysis involved a systematic clustering of the categories into overarching and discernible institutional logics. At this stage, existing literature was used as a tool to interpret actual data and to determine how well they describe previously identified logics (Reay & Jones, 2016). To help increase the trustworthiness of our analysis, we had additional researchers independently code our data until agreement was achieved regarding codes, categories, and identified institutional logics. Disagreements were negotiated or resulted in modifications of the analysis.

4.3.2 Micro-level analysis

For the micro-level interactional analysis, 16 lessons from the classrooms of eight teachers, for a total of 19 academic hours, were observed and transcribed. Observations were conducted in both high- and low-track classes (Table 2.1) to account for the possibility that differences in teacher–student interactions might be related to the students' academic abilities. After transcribing and reviewing the recordings, classroom interactions that were identified as

providing rich information for in-depth analysis, and specifically, that presented repeating features of classroom interactions, were chosen.

Transcriptions were then coded twice: first, according to the IRE sequences of the interactions, with attention to the level of complexity of teachers' questions, the cognitive demands represented in the students' replies, and teachers' evaluative responsiveness to the students' replies. Teachers' questions and their paired student replies were coded for their level of cognitive demand. Closed-ended questions that asked students for mere recall of isolated facts, or that prompted for terminology-level understanding, were coded as making low cognitive demands. In contrast, open-ended questions that engaged students in actively participating by thinking and clarifying their answers were coded as cognitively demanding.

For the analysis of teachers' evaluation of student responses, we used Chin's (2006) categorization scheme: low-level evaluations were described as those in which the aim of the interactions was to reach the teacher's point of view, such as when the teacher accepts students' answers and proceeds to teacher-directed elaborations, or rejects students' answers and proceeds to explicit corrections; high-level evaluations were more constructive and allowed students to elaborate on their contributions, such as accepting the answer and proceeding to ask more related questions that overall extend the students' train of thought.

In a second coding process, to analyze how institutionally specific activities espoused by teachers are reflected in, and accomplished through classroom interactions, the broader institutional logics developed earlier were reexamined for reflectivity in the codes generated in the interactional micro-level analysis. In this phase, we examined how an exchange's component features may serve to accomplish and maintain an institutional logic. For example, our analysis explored the ways in which the nature of teachers' questions and evaluations is suited to the accomplishment of institutional tasks. Here, a "match" between macro-level logics and micro-level interactions was identified when the structure of the interaction and the language contained within it paralleled the activities and underlying assumptions advanced by a specific logic (Drew & Heritage, 1992). The coding process was carried out independently by two researchers and was negotiated until agreement was achieved.

This is not to say that there is direct causal reasoning between institutional logics and teacher–student interactions and that all oral exchanges that occur in the classroom are a direct outcome of institutional mandates. Rather, the goal of the micro-level analysis is to identify and explicate how routine classroom interactions are institutionally sensitive in that they may align with, and serve, institutional activities (Arminen, 2017), and how such interactions can

only occur in an environment in which they are infused with legitimacy and, therefore, considered productive for institutional conduct (Cornelissen et al., 2015).

When both macro- and micro-level perspectives are viewed jointly, the analysis of classroom interactions may reveal how particular forms of talk serve to constitute certain institutional understandings, while ethnography, at a higher analytical level, shows what kinds of understanding about schooling find their way into classrooms in the first place.

To answer the first research question, we detail how institutional logics were identified in teachers' statements. To answer the second research question, following each logic, specific micro-level classroom events are presented to elucidate how the different components of the IRE pattern may be reflective of that specific logic. We detail the content of the interactions and examine the type of institutionally informed tasks for which this structuring of interactions might be of service, and how such structuring undermines opportunities for dialogic argumentation.

5 Findings: available logics and how they are enacted in the classroom

Our analysis suggested that, from a macro-level perspective, teachers called upon three central logics that inform instruction to the detriment of dialogic argumentation in science classrooms: the logic of *accountability* (adherence to external measurement standards), the logic of *tracking* (classifying students according to academic ability), and the logic of *the profession* (body of knowledge, skills, and practices thought to achieve productive ends for a particular occupation). Table 2.2 illustrates our data structure, showing the codes, categories, and institutional logics from which we developed our findings. Taken together, these logics may underlie teachers' actions and shape their instructional practices and how they interact with students at the micro-level.

TABLE 2.2 Coding structure for the macro-level analysis

1st order codes descriptions	**2nd order broad categories**	**Representative data**	**Identified Institutional logics**
A. Covering the curriculum, achieving high scores on standardized tests B. Increased testing, test preparation, students' test scores as indicator of learning	1. Test driven classroom practices: sources of extra-organizational pressures and their influence on instruction	*In the end of it, my classroom has the best GEM score in the school. Looking at the data (of test results) I can see that I get what I aim for*	Logic of accountability
C. Valued knowledge (e.g., factual content knowledge, terminology) D. Dialogic argumentation as extracurricular enrichment	2. Teachers' perceptions of the focus of science teaching	*(Argumentation) doesn't fit with the curriculum. It may give some extra value but I'm not moving ahead with clarifying and explaining the content that I need to cover with my students*	
E. Descriptions of how low performing students are like (e.g., disruptive, need help, weak learners) F. Descriptions of how high performing students are like (e.g., curious, question askers, competitive, independent)	3. How teachers describe students across academic tracks in terms of abilities and behaviors, and how teachers' expectations are shaped according to descriptions	*In (high track classrooms), we have highly skilled students. Here (In low track classrooms), we are still teaching them basic learning skills*	Logic of tracking
G. Targeting pedagogies to students according to their track assignment (e.g., high-order knowledge for high tracked students) H. What dialogic argumentation will be like across tracks (e.g., hectic, devoid of learning, won't work, time wasting)	4. Students' ability to handle dialogic lessons across tracks	*We have students that when you ask them a question, they look at you with these blank faces. Do you have any idea how frustrating it is that you put in all of this effort and then they look at you like this?*	
I. Descriptions of classroom and instructional strategies that teachers perceive as beneficial (e.g., connect content with students' lives, individual seat work, lesson summaries, dictations)	5. Practical pedagogy and best practices	*I don't ask them to raise their hands (to answer a question) but instead I nominate them. The question could be something in the form of "fill-the-blanks"*	Logic of the profession
J. What a classroom should look like (e.g., quiet, orderly) K. What a teacher should be like (e.g., the main source of knowledge, be able to control the classroom) L. What students ought to be like and do (e.g., demonstrate knowledge, quiet, well behaved) and how they are like in the classroom (e.g., disengaged, taking advantage of autonomy, dependent on the teacher)	6. Professional norms and challenges	*When you divide them for group work, two students will do the work, because they are good students and they will do anything that you ask of them, but the rest will join the party and take advantage of the situation to not do anything. That means that one third of the classroom is working and two thirds are partying*	

5.1 The logic of accountability

Accountability test results, as well as school rankings, are often reported to the public. Therefore, the degree to which schools and teachers maintain accountability measures may influence public opinion about their efficiency, and may therefore drive conforming organizational actions (Diamond, 2012; Peurach, Cohen, Yurkofsky, & Spillane, 2019).

For the participants in our study, accountability legitimately prescribes what they can teach. For these teachers, aligning the science curriculum with state-based assessments for the purpose of measuring school quality was a central goal. The national science curriculum of Israel was designed with the intent of placing an emphasis on social aspects of science and science-laden technology (Israeli Ministry of Education, 1992), and includes requirements to engage students in practices that are valuable to scientific thinking and reasoning, such as logical and critical thinking, drawing conclusions, structuring scientific arguments supported by evidence, and listening to, and critiquing peers' arguments (Israeli Ministry of Education, 2018).

However, tailoring instruction to standards is an interpretive process (Spillane, 2009) and, as the science curriculum in Israel is also content-intensive (Zohar, 2013) and curricular coverage is often used to enhance student achievement on standardized tests (Everitt, 2017; Zohar & Alboher Agmon, 2017), teachers often view the core of the science curriculum in a way that avoids demands that go beyond basic content coverage. When teachers operate from an accountability logic, then, they may gear instruction towards improvement of standardized test outcomes for the sake of external legitimacy.

5.1.1 Accountability from an institutional perspective

Teachers from both Ganim and Ramot described the external pressures stemming from standardized tests, primarily the national test of schools' growth and effectiveness measures (GEM) which is administered to students in the 8th grade. Teachers revealed how these pressures are communicated aggressively by the administration as "dictates from above" (GanimTeacher1) or through a "chain of command" (RamotTeacher2) as explicit demands to improve the school's test scores. Providing a basis upon which school goals are built, the structure of standardized tests and the knowledge that they represent often led teachers to emphasize the link between curriculum coverage and test preparation. For example, a teacher from Ramot said:

> *I find myself always wanting to finish [cover the content]. When students ask me questions that are beyond [the curriculum content], I say: "I apologize, but we have to move on" because I know I have the [GEM] test deadline. (RamotTeacher2, Interview)*

This excerpt explains how accountability pressures are translated in the classroom into a push for curriculum coverage which, at times, comes at the expense of instructional autonomy to experiment with less orthodox pedagogies. This means that the content of classroom learning may be separate from the teachers' professional opinion, instead providing them with the parochial role of filling the gaps in students' content knowledge.

In addition, teachers' pedagogical decision-making was based on a linear progression of knowledge and skills. Before moving on to more demanding curricular tasks, teachers argued, students should first display mastery of "basic terms and concepts" (GanimTeacher4), or "basic science knowledge" (RamotTeacher4). The teachers linked this traditional teaching practice directly to success on standardized tests. For example, a teacher from Ganim said:

> *In the end, you have the GEM test, and the students need to give a technical explanation and that's it. In most of the exams, the questions are based only on the basic theoretical material. So, I give it to them…and it's technical and boring and they have to know the minute details. (GanimTeacher1, Interview)*

Thus, despite curricular endorsement of progressive pedagogies, broadly covering the curriculum and having to display that coverage in the form of students' scores on standardized tests means that teachers rarely drift from conventional instruction of discrete content items. As the teacher in the excerpt above stated, teaching science as a collection of facts can also be heavily structured around technical terminology. This notion was corroborated by other teachers, for example:

> *Science deals with a lot of terms and if you can get a grip on the terms you will know what's going on. (GanimTeacher4, TPD)*

Consequently, to make success in standardized tests more attainable, another practice that teachers adopted included emphasizing accurate terminology usage in their classrooms. The extent to which this strategy is played out in teachers' instruction is exemplified in the following conversation (TPD):

> *GanimTeacher4: When the [GEM test] assessment indicator is published, it requires that the students' answers be phrased in a very specific way.*
>
> *GanimTeacher2: When [students] didn't use the correct wording [on their answers].*

GanimTeacher4: The instructions are clear: "if the student didn't write this and didn't write that…" If you read [a student's] answer you can tell that he got the general idea, but for the test—his answer is disqualified.

GanimTeacher2: If he didn't write down the specific word.

GanimTeacher4: This means that, first and foremost, you will hear me say: "use the correct scientific terms." I always say that. These things have exact terms which students need to use later in the test. If they don't use them, they're going to get zero points for the question.

GanimTeacher1: Take, for example, a question from last year's test. It was a fill-in-the-blanks question about how polar bears move closer to land and change the color of their coat: "climate is (blank) and it makes the bears (blank)." My students wrote that climate changes, not warms, or cools, changes. And I had to disqualify their answers even though they are correct. All the questions are like that!

This and the previous excerpts reveal that promoting test success through the transmission of content-focused knowledge may be the product of an institutionalized organizational response to standardized curriculum and testing. Accountability, as the teachers described, was not just a means for achieving organizational legitimacy, but was also used as a strategy for the design of school goals and lesson plans. Within this school mission, dialogic argumentation was described by teachers as a practice that "does not fit with preparation for the GEM test" (GanimTeacher4), "impractical" (GanimTeacher1), "extracurricular enrichment" (GanimTeacher3), and coming at "the expense of teaching the curriculum" (RamotTeacher4).

5.1.2 Accountability from an interactionist perspective

With accountability as the basis for instructional decision-making, what do teacher–student interactions look like on the ground? As the macro-level analysis showed, institutional tasks that are derived from the logic of accountability included the acquisition of basic scientific terminology, which was considered valuable knowledge, as well as emphasizing the accuracy of the students' replies. Therefore, when teachers employ interactional means that are seen to embody such orientations, they may be responsive to the logic of accountability.

The example in Table 2.3 represents an instantiation of the demand for accuracy, as well as the consequences of this demand for classroom talk. In this lesson, 8th-grade students were handed worksheets with several questions that required information regarding various interactions between two objects. As the students struggled with the idea that both objects inflict an equal force on one another, the teacher briefly reviewed the law of interaction, which was presented in this, and a previous lesson:

TABLE 2.3 Demand for accuracy in evaluations

1	GanimTeacher3	The law of interaction, what does it say?
2	Student B	That two objects inflict equal and opposite force on one another.
3	GanimTeacher3	Try again, but be more accurate.
4	Student B	(reading verbatim from her notebook) Two objects inflict a force on one another that is equal in magnitude and opposite in direction.
5	GanimTeacher3	Equal in magnitude and opposite in direction, OK? If a carpenter hits the hammer on the nail, the magnitude of the force is?
6	Students	(in chorus) Equal
7	GanimTeacher3	When a fly hits a wall, the magnitude of the force is?
8	Students	(in chorus) Equal
9	GanimTeacher3	Why? Why is it equal?
10	Student C	Because of the law
11	GanimTeacher3	Great. Because the law of interaction states that in the center of interactions forces work in equal magnitudes and in opposite directions. You must remember this. If someone wakes you up from your sleep, you must be able to say it.

For presentation purposes, the data in this and the following examples have been minimally simplified. Omissions include repetitions and noncurricular utterances.

The content of the interaction. Though the initial question is phrased in a way that could invite students' interpretations (line 1), the unfolding of the segment reveals that the teacher is asking the students a low-level question, i.e., one which prompts students to recall the definition of the law of interaction as it was introduced in the previous lesson. When a student's reply is unsatisfactory (2), the teacher rejects it and explicitly adds the purpose of accuracy (3), which drives the student to read the appropriate definition from her notebook (4). This reply is accepted by the teacher (5). Students are then drilled on similar low-order questions to prove that the concept has been understood (5–8).

A series of utterances interspersed throughout this interaction reveal that the task at hand is oriented toward the accomplishment of institutional goals that correspond to the logic of accountability. First, the teacher made it explicit in her evaluations that students' replies must be accurate for them to be positively evaluated (3), second, the method of consulting an authoritative text as a source for answers was introduced, or reaffirmed, as beneficial for positive evaluation (4-5), and third, the teacher mentions that memorizing the accurate definition of the law of interaction is imperative for an unspecified reason (11). These are different evaluative means, but they serve a similar purpose in creating a sense that the sole focus of the interaction is memorization, and that students can reply only with previously introduced information in the most correct way. Given these conditions, the evaluation move in this interaction constitutes an obligation of accuracy and may therefore function to accomplish tasks rationalized by the logic of accountability.

Another accountability-related institutional activity that teachers mentioned pertained to students' acquisition of basic science facts and terminology. Similar to the demand for accuracy, the range and content of students' acceptable replies may also be narrowed through teachers' attempts to accomplish this activity. The example in Table 4 represents a recurring interactional pattern which reflects this emphasis on terminology in classrooms. The subject being discussed in the lesson was ionic and covalent bonds. Earlier in the lesson, RamotTeacher4 had established the difference between the chemical bonds. In the excerpt in Table 2.4, the task that the interaction is designed to achieve is contextualization of the concept of ionic bonding as grounded in observable phenomena: how table salt dissolves in water.

TABLE 2.4 Terminology-oriented classroom interactions

1	RamotTeacher4	I have sodium chloride. What is sodium chloride?
2	Students	(in chorus) Salt
3	RamotTeacher4	Table salt. The sodium will have what charge?
4	Students	(in chorus) Positive
5	RamotTeacher4	Positive, because that is a (waiting for students to complete the sentence)
6	Students	(in chorus) Metal
7	RamotTeacher4	Metal. The chloride will have what charge?
8	Students	(in chorus) Negative
9	RamotTeacher4	Because?
10	Student A	Nonmetal
11	RamotTeacher4	Exactly. When I dissolve it in water (pauses until all students are quiet)…When I dissolve NaCl in water I have water molecules around (goes to the blackboard to illustrate how water molecules surround NaCl molecules). As for the water molecules, we know that the hydrogen is usually delta positive and the oxygen is delta negative. How will the water organize around the NaCl molecule?
12	Student B	The oxygen to the Na and the umm…
13	RamotTeacher4	Good. So, we have many water molecules, and the oxygen surrounds the sodium…Quiet. And surrounding the chloride, I will have hydrogen. What we will get is something like this (illustrates on the blackboard how the sodium and chloride are ionized).
14	Student A	Should we write this down?
15	RamotTeacher4	One moment. (to a disruptive student) You will also complain that you don't understand during the next quiz because you don't listen. (to the classroom) Each water molecule has a very weak attraction force. But we have many water molecules. And the attraction force of many water molecules is very strong. We also know that water particles, what do they do all of the time? They (waiting for students to complete the sentence)
16	Student C	Move
17	RamotTeacher4	Good, they move. There's a gliding motion. So, if some of the water molecules glide in one direction, and other molecules in the other direction, the NaCl will dissolve.

The content of the interaction. The teacher's questions are of a low order and mostly call for factual and short answers in the form of single words that comprise scientific terminology (2, 4, 6, 8, 10). The person who is actually making sense of the phenomena under discussion is the teacher who, after affirming the correctness of the students' replies, achieves this through direct instruction (11, 13, 15, 17), while students are expected to fill in the missing terminology-related information through recall. At times, the teacher employs a particular questioning procedure and phrases his questions as incomplete sentences (5, 15). Such questions have only one correct answer and verbally demand students to give single-word replies, using the appropriate terminology, in what more clearly represents a verbal instantiation of a written "cloze" test question (Poole, 1992).

Beyond mentioning that attention is required for success on the test (15), this interaction suggests that the type of knowledge deemed valuable for learning, in many instances, consists of science terminology. The point here is not only that students' replies consist of terminologies, but that the phrasing of the initiation moves essentially demands a terminology-based reply. As found in the macro-level analysis, teachers' accountability-motivated stance on what counts as valued academic performance included students' acquisition and use of basic scientific terminology. Embedded in this macro-level aim, terminology-focused questions can be assigned an instrumental function. That is, it can be argued that such a line of questioning may contribute to the attainment of valued academic performance rationalized by the logic of accountability (see Table S1 in Appendix A for an additional example of this form of interaction).

How such interactions undermine dialogic argumentation. In both examples, classroom interactions made valuable science knowledge appear in the form of end products—definitions or terminology—which needed to be memorized and accurately recalled upon request. These interactional devices not only characterize science knowledge as objective and technical, but also constrain the students to specific ways of thinking and speaking.

By demanding accuracy, the teachers' evaluations of students' replies aimed for a specific point of view and stifled the possibility of students voicing their understanding. Eliciting the use of terminology may certainly serve an important purpose in school science, but it represents the language of the subject matter more than its knowledge corpus. Such instruction is prevalent, and the underlying epistemology encouraged students to think of science not as a work in progress, but as a list of vocabularies. Therefore, when acquisition of

this type of knowledge is the primary constituent of both classroom interactions and students' success in school, opportunities for dialogic argumentation may decrease.

5.2 The logic of tracking

While not all school systems are tracked, the deep structure of tracking is part and parcel of modern education through more implicit stratification tools. For example, deep-seated prejudice related to students' racial characteristics (Diamond, 2012; Mehta & Fine, 2019a), social class (Anyon, 2017), or gender (Everitt, 2017; Jungwirth, 1991) is seen as an important driver of teachers' instructional decisions regarding high-status knowledge distribution and differences in opportunities to be exposed to a rigorous curriculum. The practice of structuring curriculum and pedagogy according to preconceptions regarding students' ability seems to be an integral and natural part of how schools are organized (Oakes, 2005), and it can therefore be considered institutionalized.

Both Ganim and Ramot employ an explicit tracking system, which may grant them organizational legitimacy in two ways. First, parents of high-ability students lobby for the practice of tracking by defending high-track classes. Second, high-track classrooms attract honor students from the elementary schools in town and thus grant both schools with human capital. Operating from this logic, teachers may assume that students are differentially equipped by their track placements to engage in higher-order learning. Therefore, teachers may make unequal pedagogical and managerial decisions and distribute school knowledge differently across high- and low-track classrooms based on meritocratic ideals. When this happens, opportunities to participate in dialogic argumentation become contaminated through prejudice to the detriment of students in low-track classrooms.

5.2.1 Tracking from an institutional perspective

To the degree that teachers agreed to consider implementing dialogic argumentation in their classrooms, it was aimed exclusively to the high-track classrooms. This notion was repeated in both schools separately and independently from one another. School administration in both schools targeted the high-track classrooms for participation, as they saw the students in these classrooms as sufficiently proficient to engage in dialogic argumentation. Students in high-track classrooms were described by teachers as "highly motivated" (GanimTeacher1), "naturally curious" (GanimTeacher2), or willing to "fight tooth and nail" to achieve success (RamotTeacher2). In contrast, students in low-track classrooms were considered as lacking the

basic competencies needed for productive classroom participation. In terms of behavior, students in low-track classrooms were described as uncooperative, disruptive, or unwilling to make an effort. Describing the feeling of entering a classroom dominated by such management issues, a teacher said:

> *There's a consensus regarding [low-track] classrooms. No teacher will come out of there saying: "it was a pure joy." Before you enter the classroom, you take a deep breath and then walk in. When we, the teachers, talk amongst ourselves it's like "did you survive today?" (GanimTeacher4, Interview)*

In terms of curricular understanding, teachers made statements regarding the potentially weak knowledge base of students in low-track classrooms, mentioning their lack of understanding of basic scientific terminology or basic concepts of science. As teachers tended to hold a linear and sequential approach to learning, arguing that students must first master the basic contents before turning to more demanding tasks such as argumentation, the dispositional characteristics attributed to low-track students distanced them from opportunities to engage in argumentation.

Teachers responded to the challenging conditions in low-track classrooms by modifying instructions and expectations. They simplified and scaled down curricular demands to match the perceived ability of the students. For example, one teacher told us that she guided students in the low-track classroom through a question "in the same way that I would teach a 5-year-old" (GanimTeacher1). Localizing the challenge of instructing these students, she said that they "simply don't care" about learning. A teacher from Ramot provided a more detailed account of how she managed instruction in a low-track classroom:

> *They answer in very short sentences that don't exhibit a lot of knowledge. When I asked them once to give detailed answers it was very hard for them. What I do, both in tests and in written assignments, is that I break the question down into small segments. Each segment requires just a short answer. So, for example, I will write "What happens in the graph at the point where it goes up? What happens at the other point in the graph?" I don't ask for the entire process. Instead, I break it down into a number of small details. Otherwise, it's too hard for them. In strong classrooms, when I write the test, I write the questions in increasing levels of difficulty—knowledge, inference-making, questions that require a deeper understanding of the material. In [low-track classrooms] it's more knowledge and less inference-making. I can dictate the answer and tell them "this is how you should phrase your answers" and maybe two students will do that. (RamotTeacher1, Interview)*

In this case, attempting to match the level of the questions to the level of students' concurrent understanding required simplification of the information into its discrete units. This provides a particular view of school science as a rigid series of items to be understood, instead

of processes in which these items play a role. Consequently, she believed that the option of allowing students in low-track classrooms to engage in scientific argumentation was unrealistic:

> *When I teach in a [high-track] classroom, the students have higher language abilities, higher vocabulary. Here [in the low-track classroom], it's something else. I told you the same thing in the [TPD] course. [Argumentation] doesn't suit any classroom. (RamotTeacher1, Post-lesson conversation)*

Underlying this pattern of practice is the assumption that students in low-track classrooms cannot engage in rigorous and demanding science content. The result is that students may be given fewer opportunities to display their mastery of science. In contrast, the attributes of high-track students were deemed to be more aligned with the practice of dialogic argumentation, such as their inquisitive and collaborative characteristics:

> *In [high-track] classrooms, when a student raises a question, this pulls other students into asking questions as well. This won't happen in a different classroom. (RamotTeacher1, Interview)*

or their embodiment of the overall qualities needed for a model student:

> *[High-track] students aspire to excellence in all areas of learning, as well as to being moral and considerate human beings. (Ramot newsletter)*

Indeed, high-track students were exposed to many extracurricular opportunities that demanded complex participation, such as: editing a school science journal, participating in debate teams, instructing students in lower grades, or meeting industry leaders (Ramot newsletter). Thus, given the differences across tracks, the track to which students are assigned may have a critical influence on their opportunities to engage in argumentation.

5.2.2 Tracking from an interactionist perspective

Students' passive participation and basic comprehension of science facts and terminologies were expected across all tracks. There is little evidence in the data that learning activities were structured in support of argumentation in types of classrooms. However, we argue here that opportunities to engage in dialogic argumentation were curtailed even further for students in low-track classrooms. A recurring pattern of interaction in low-track classrooms involved the teacher asking questions that invited mere guessing, use of common sense, or making free associations on the part of the students. Such questions were asked across both extremes of the tracking system, though more sporadically than in the high- and general-track classrooms.

In the lesson from which the following excerpts were taken (Table 2.5), low-track students were handed worksheets entitled *"The importance of breakfast".* The source of this worksheet was traced to a bank of teaching resources published by the Israeli Ministry of Education (2010). Materials in this bank are not considered as mandated curriculum and are designed to assist teachers with creating lesson plans that correspond to the science curriculum.

The source worksheet described a study that examined the relationship between the time of breakfast consumption, concentration of blood glucose, and students' success on a given questionnaire. Students were asked to recognize the dependent and independent variables, interpret the data, and offer research questions. The final question in the source material presented students with a socioscientific dilemma: "Should the government provide students with a free lunch?" The students were asked to provide one data-based argument for, and one against, their decision. While the source material presented explicit demands for sense-making and argumentation, the worksheet that was handed out to the students in this lesson was edited to omit these demands in favor of more simplified forms of knowledge and didactic instruction. For example, the research question and variables were identified by reading and answering multiple-choice questions from the worksheet with the whole classroom. Interestingly, the question that invited arguments on a socioscientific dilemma was edited out of the adapted worksheet and was replaced with a question that asked students to note the differences between simple carbohydrates and complex carbohydrates in terms of metabolism. To make the content relevant, the question was phrased as follows (Table 2.5, line 1).

TABLE 2.5 Common-sense-oriented student replies in a low-track classroom

1	RamotTeacher1	Let's go over question number four. "Write four types of foods that can provide students with available energy. *Explain* (emphasis added) why you chose these foods."
2	Student A	Chocolate
3	RamotTeacher1	Why chocolate?
4	Student A	Because it has lots of sugars.
5	RamotTeacher1	Bread also has lots of sugars.
6	Student A	The sugar in the chocolate breaks down faster.
7	RamotTeacher1	Very good! What else? I asked for four types of food.
8	Student B	Energy bar
9	Student C	I wrote cheese sandwich and egg sandwich.
10	Student D	Salad and cheese
11	Student E	Candies. I wrote candies.
12	Student F	Snickers bar
13	RamotTeacher1	OK. Who else wrote down different snacks? Chocolate, why chocolate?
14	Student A	Because of the sugars. It breaks down faster.
15	RamotTeacher1	Very good. It breaks down. Very good.

The content of the interaction. The question asks students to categorize different types of food into simple and complex carbohydrates (1). It is disconnected from the topic of the worksheet that preceded it, and it bears little connection to students' mastery of science. As the knowledge expected from the students is not difficult, at best this type of knowledge display may be recommended as engaging as it fills a school task with day-to-day knowledge. As such, this question bears lower cognitive demands than recall. Accordingly, students' replies were more trivial and distanced from the disciplinary body of knowledge. In this sequence, most students' replies simply list the names of different snacks (2, 8, 9, 10, 11, 12). Even when the teacher's evaluations are more constructive, asking for elaborations (3, 13), given the nature of the opening question, student A's replies (4, 6, 14) can also be categorized as trivial and disconnected from the content of the lesson that preceded it. Thus, even when the teacher begins on a path toward dialog with a student that could develop into argumentation, the interaction moves instead in the direction of trivial conversation.

The fact that the interaction is taking place in a low-track classroom is not enough to claim that it is motivated by the logic of tracking. In other studies, the instructional practices of teachers in low-track classrooms were shown to be derived from a more egalitarian logic (Hodge, 2019). Teachers in our study, as shown by the macro-level analysis, held preconceived low expectations of low-track students that may have driven them to implement a scaled-down and reduced version of the science curriculum when teaching them. In a post-lesson conversation, RamotTeacher1 disclosed that the purpose of the worksheet was to connect science with these students' lives and to be less demanding in terms of content. The worksheet in this example was adapted in accordance with these low expectations and, as the teacher may have found scientific reasoning and argumentation too difficult for low-track students, the nature of the interaction shifted toward students' use of common knowledge. Therefore, we consider this interaction to be informed by the logic of tracking as it exemplifies a structure of interaction that is simplified and reduced and which, in our observations, was unique in its extensiveness across low-track classrooms (see Table S2 in Appendix A for an additional example of this form of interaction).

How such interactions undermine dialogic argumentation. The notion that is conveyed in such interactions is that students in low-track classrooms are deficient in their basic understanding of science, and low-order questions that call for mere recall can, at times, be too demanding for them. As teachers tended to believe that students must first master the basic facts of science before they can continue to engage in argumentation, this notion may reduce low-

track students' opportunities to engage in argumentation even more than those afforded students in other tracks. In this example, both the content that was omitted from the worksheet and the content that replaced it indicate that this teacher pushes toward interactions that distance low-track students from engaging in argumentation.

5.3 The logic of the profession

Emphasizing valued expertise and role expectations and obligations, the logic of the profession frames both how work-related problems are viewed and how effective solutions are conceptualized (Bridwell-Mitchell, 2013). It therefore emphasizes professional competence, or the ability to do the work of teaching well. The attributes that make one professionally competent relate to their normative stance: the degree to which the associated practices are valued, shared, and granted meaning by practitioners in a community of practice (Lortie, 1977). It follows that when individual teachers strive to gain recognition as competent members and therefore, legitimacy, they will adopt practices dictated by normative assumptions about the profession (Everitt, 2017). Operating from this logic may lead science teachers to rely on tradition and common practice, and therefore to adopt a more professionally traditional position in the science classroom that focuses on content transmission and classroom management. Consequently, if dialogic argumentation is perceived as inconsistent with the professional norms of teaching, teachers will be less likely to adopt it as a legitimate instructional practice.

5.3.1 The profession from an institutional perspective

When asked, teachers seemed to rationalize their practices by relying on some aspects of constructivist pedagogy. For example, the notion that students' experiences gained outside of school are a meaningful source to draw on for the contextualization of abstract science knowledge was repeated multiple times by our participants. However, other constructivist aspects fundamental to the implementation of dialogic argumentation were perceived as disconnected from classroom reality. Mainly, that the implementation of dialogic argumentation is unlikely to be practical for reasons related to disciplinary management of the classroom and students' ability to handle independent knowledge construction.

Teachers associated various forms of group work with the problem of students' misconduct. Group work, teachers argued, may benefit only the most dedicated students while encouraging academic freeloading by others who may "slack off" (GanimTecher3) or "take advantage of the situation to not do anything" (GanimTeacher1). Because group work may

exacerbate the chance of students' off-task behavior, teachers preferred classroom arrangements that serve teacher oversight, such as individual work, over the grouping practices that are productive for dialogic argumentation.

The pedagogical orientation toward teacher centrality may also be promoted through a persistent belief that students tend to undermine their own learning potential. Operating from this belief, teachers often expressed the view that students are unwilling, or unable, to put forth rigorous academic effort. Students were often described as "not caring about much more than the test scores" (RamotTeacher4), attempting to "choose the easiest way" (GanimTeacher2) to succeed in school, asking for teacher summaries of lengthy texts, or waiting for the teacher to "bail them out" (RamotTeacher1) of a challenging assignment. When presented in the TPD course with an activity that required students to read texts describing a collection of different traits, and then collaboratively decipher the notion that some traits are inherited and some are acquired and elaborate on this notion in their own words, one teacher commented that the texts were too long for students to read and that:

> *We never do that [type of activity], but not because we don't want to. It's because the students can't handle it. We work only on content, and they can't even handle that! They can't remember what a melting point is and what a freezing point is, the most basic stuff. Now, you ask me to give them texts? (GanimTeacher1, TPD)*

Disappointed by what happens in their classrooms, and localizing the source of the problem to the students, teachers were more likely to take it upon themselves to be the primary pedagogical carriers rather than to engage in a potentially frustrating effort:

> *They expect me to do everything. They want answers, and they want you to give them the answers. They consider you to be the final authority. (RamotTeacher2, Interview)*

The pedagogical belief underlying this and previous quotes follows a logic rooted in professional culture that casts teachers at the center of the learning event and students as inexperienced novices. In contrast, the practice of dialogic argumentation in classrooms calls for more symmetrical teacher–student power relations by requiring students to perform active sense-making independently of the teacher's knowledge and understanding. Therefore, deeply ingrained assumptions about what teachers should do, what students can do, and what behavior students should exhibit in the classroom may be inconsistent with dialogic pedagogy and practices.

5.3.2 The profession from an interactionist perspective

As the macro-level analysis showed, teachers' accumulated experience in the classroom led them to believe that, in the reality of the classroom, students willingly shift pedagogical power upward to the teacher. This perception of their day-to-day work may produce an asymmetrical form of communication dominated by teachers. We see this asymmetry as reflected in teachers' tendency to utilize an interactional routine that has been identified as "funneling" (Wood, 1998). In this form of discourse, the teacher is doing most of the intellectual work and students' ideas are left unexplored and unelaborated, thus conveying important cultural information on the roles of teachers and students.

We can see how funneling unfolds in the reality of the classroom in the following example, taken from a lesson summarizing a learning unit that dealt with the concept of photosynthesis (Table 2.6). Students were asked to answer a series of summarizing questions from the textbook. Here, students were answering a question about the relationship between different environmental parameters and the rate of photosynthesis.

TABLE 2.6 Funneled classroom discourse

1	GanimTeacher1	If I increase the CO_2 concentration, will the photosynthesis rate increase linearly? I mean, will it always go up?
2	Student A	No
3	Student B	Yes
4	GanimTeacher1	Always?
5	Student C	Each plant will react differently.
6	Student D	The plant will die.
7	GanimTeacher1	No. Die? How come? (laughs)
8	Student B	Yes. Yes. You know what? Yes.
9	GanimTeacher1	Why?
10	Student B	I have a gut feeling.
11	Student E	Maybe the plant won't be able to grow leaves as quickly.
12	GanimTeacher1	Good. What absorbs the CO_2?
13	Student B	Plants
14	GanimTeacher1	Obviously, but what organelle?
15	Student F	Ohhh, the chloroplast
16	GanimTeacher1	Good. (shooshing) Is the number of chloroplasts in the cell infinite?
17	Students	(in chorus) No
18	GanimTeacher1	So, we have a finite amount. It might be a large amount, but still finite. Therefore, only that same finite amount can absorb CO_2 for photosynthesis. If at a given time all chloroplasts are saturated with CO_2, there will be no point in providing more. That means the rate of photosynthesis is at its peak and will plateau.

The content of the interaction. The sequence starts with the teacher asking a question that calls for the students to hypothesize about the consequences of an experimental situation (1). This

elicits disagreement between two students (2, 3), potentially offering a rare opportunity for argumentation. In the following, however, the teacher largely ignores or rejects some of the students' replies which she judges to be insufficient or simply wrong (5–10). As the sequence unfolds, the teacher gradually takes responsibility for advancing the intellectual work through a set of closed questions (12, 14, 16). She then ends the sequence by providing detailed scientific information via direct instruction (18). Through this process, the teacher is positioned as a knowledgeable individual who is doing most of the intellectual work to assist students, while students are tasked with providing previously introduced low-level information.

What is visible in this interaction is that epistemological inequalities are created and intensified as the interaction unfolds through the design of the teacher's questions. After the responses to her initial question failed to produce an acceptable reply, the teacher took the initiative of moving the sequence toward closure. To support the students' giving the expected answer, the level of questioning progressively lowers, and the teacher's responsibility to lead the intellectual work increases. The knowledge necessary to produce the answer to the original question changes to accommodate the perceived cognitive abilities of the students. In the process, an interactional sequence that started with asking the students to hypothesize on the relationship between two subjects ended with a rhetorical question (16) and direct instruction. Therefore, this pattern of interaction may provide a glimpse into how the role asymmetry between teacher and students is at least partially structured through interaction (see Table S3 in Appendix A for an additional example of this form of interaction).

How such interactions undermine dialogic argumentation. The practice of dialogic argumentation in the classroom requires students to contribute to the construction of explanations of scientific phenomena. Having epistemological asymmetry coupled with classroom interactions meant that the teachers, and not the students, were doing the work of sense-making when the classroom was learning about a scientific phenomenon. Moreover, while argumentation-supporting discourse treats students' ideas as starting points for further interactional explorations, the goal of a funneled discourse is to reach the teacher's point of view, which means that students' ideas are sieved accordingly. These consequences of asymmetrical role relations ensure that the teacher will have more power in directing the conversation.

6 Discussion

6.1 Institutional resistance to dialogic argumentation

Our interest in this study was to understand why dialogic argumentation has not been adopted as a legitimate means of instruction by science teachers. To answer this question, we needed an integrative approach that brings together the institutional level and the interactional level. Though these levels are often theorized separately (Sarangi & Roberts, 2008), in this study we offered a more holistic approach. Our approach acknowledges that the overarching institutional order in which teachers work may bind and regulate how they interact with their students, to the detriment of dialogic argumentation. Moreover, we argued that the institutional order is not simply mandated from above but is actively produced through interactions between teachers and students.

To base this claim, we used new institutional theory to examine how macro-level phenomena, such as the taken-for-granted ways in which individual teachers rationalize their work (J. W. Meyer & Rowan, 1977), influence their actions at the micro-level and are tangibly realized in contextualized teacher–student interactions (Heritage, 2005; Seedhouse, 2005). Classroom interactions, then, were not just examined as expressions of the individual participants, but as potentially formative of institutional reality.

The new institutional theory argues that schools and teachers adopt practices that conform with institutional logics as a means of signaling their legitimacy to their organizational environment (Thornton & Ocasio, 2008). In the case at hand, the revealed institutional logics of accountability, tracking and the profession worked together to drive specific organizational missions and tasks in the search for organizational and individual legitimacy, and to justify teachers' resistance to dialogic argumentation. The data indicate that these identified logics may have interactional means that are set to achieve said tasks, and which run counter to the pursuit of dialogic argumentation (Table 2.7). Through this process, logics are communicated and maintained in the classroom reality, where certain forms of classroom interactions may be legitimized, while others are ruled out. Below we describe why operating from these logics is constrictive from the perspective of what is known about supporting student participation in dialogic argumentation.

TABLE 2.7 Summary of findings

Characteristic	Logic of accountability	Logic of tracking	The logic of the profession
Source of legitimacy	Policy environment, external supervision	Appeal of excellency and prestige that draws human capital into schools	Esteem of colleagues and supervisors
Organizational mission	Improve students' scores on standardized tests, improve school ranking	Handle the needs and academic capacities of diverse student groups in compulsory education	Advance students' learning and achievement using valued instructional practices
Organizational tasks	Covering the curriculum, designing lesson plans backwards from standardized tests	Separating students for instruction by ability and matching curriculum level to track level	Valued instructional practices maintain teacher-centrality and tightly controlled classrooms
Interactional instantiation	High emphasis on accuracy and correct use of science terminology	Interactions in low-track classrooms encourage low-level participation which relies on students guessing and common-sense	Teachers are doing most of the intellectual work in classrooms which hinders opportunities for students' collaborative knowledge construction
Constraints to dialogic argumentation	Science is held as a collection of closed-end absolute facts to be accurately transmitted to students	High ability students are the only ones considered as capable of dialogic argumentation. Other students are alienated from participation	In comparison to teacher-controlled lessons, dialogic argumentation symbolizes to teachers the violation of classroom order and reduced learning

The epistemology of uncertainty and critique must enter classroom discourse (Chen et al., 2019) for students to be able to raise and argue for competing explanations of scientific phenomena (Berland et al., 2020; Iordanou, 2016; Ryu & Sandoval, 2012). However, how teachers are motivated and legitimized to act in the classroom is dependent in part upon their ability to improve school performance on standardized tests. This state can conflict with conditions that are supportive of dialogic argumentation. Operating from the logic of accountability, teachers may strategically link instruction to broad curriculum coverage in a way that emphasizes memorization and the presentation of science knowledge as unequivocal and pristine, all in the service of improving students' test results. In the classroom, where knowledge is objectified into discrete units of information and is narrowed to mostly acquisition of terminology and facts in the service of test improvement, uncertainty and critique may not be desired.

In addition, in the reality of schools, students are often separated into specialized tracks, and the existence of prestigious elite tracks serves as a source of institutional legitimacy (Attewell, 2001). In this system, opportunities to engage in dialogic argumentation may be allocated based on previous academic merit, and not to *all* students as demanded by reform-minded documents (Katsh-Singer et al., 2016; NGSS, 2013). In this study, those teaching in

low-track classrooms typically reported perceived incompatibility between argumentation and their students' abilities and behaviors. In the classroom, prejudice regarding low-track students' abilities may legitimize a form of classroom interactions in which trivial day-to-day knowledge reigns over disciplinary knowledge, thus perpetuating gaps in knowledge that preclude engaging in dialogic argumentation.

Finally, a key requirement of dialogic argumentation is to allow students to engage with, and respond to the ideas of their peers in the classroom (McNeill & Berland, 2017). This encourages the development of community-specific discourse and norms of talk (Driver et al., 2000). In their search for professional legitimacy, however, teachers may take a teacher-centric position to exhibit their professional competence (Everitt, 2017). As students were perceived as difficult to manage and incapable of co-construction of knowledge, the teacher-centered position was rationalized as professionally justified. Conforming to these professional norms meant that, in the classroom, teachers took it upon themselves to be responsible for knowledge dissemination in a way that virtually demanded asymmetrical interactions with their students. Contrary to dialogic ideals, such a professional stance reinforces the positioning of students as individual receivers of knowledge.

Dialogic argumentation may thus be associated with contenting definitions of the purpose of education, referring to appropriate teacher–student interactions and the teacher's role, which are the opposite of the institutional definitions on which teachers rely for professional guidance. Therefore, teachers in our study seemed to view dialogic argumentation as violating their professional sense of how instruction should be constructed. Teachers, then, may resist using dialogic argumentation in their classrooms, not for technical-rational reasons, but because it violates the fundamental rules, norms, and practices that grant them individual and organizational legitimacy.

6.2 Institutionally informed responses to resistance

If the pursuit of dialog runs counter to the pursuit of institutional schooling, how can initiatives and professional development programs that seek to encourage dialogic argumentation in science classrooms handle resistance to a change that is not legitimate with their target audience?

From a new institutional perspective, designing TPD courses that rely strictly on the technical merits of a pedagogical approach may be less efficacious, without careful consideration of the institutionalized norms, rules, and values that guide teachers' day-to-day

work. The assumption that if teachers are presented with alternative pedagogical ideals, they can change the institution in which they are embedded, requires reexamination. We therefore carefully argue that understanding whether a demand for change will undermine institutional understandings of education may help teacher educators achieve better teacher acceptance of innovative pedagogies. From this stance, pedagogies that offer solutions to problems of practice that are consistent with institutional mandates will be more readily adopted by teachers, than those that have the potential to erode their institutional legitimacy (Burch, 2007). In that sense, designing TPD courses that address teachers' resistance by presenting pedagogical innovations in a way that resonates with teachers' norms and existing practices, could potentially mitigate teachers' concerns regarding innovative pedagogies.

For example, the question of how to create opportunities for low-track students to engage in argumentation while simultaneously helping them build expertise in foundational scientific knowledge may not be answered by a frontal assault on tracking. Instead, a more effective strategy would include the modification of instruction to best suit students who may feel alienated from the school culture, without narrowing and simplifying it (Hodge, 2019). In addition, if teachers perceive accountability pressures as overwhelming their capacity to implement dialogic argumentation, this concern should be handled deliberately between teachers and teacher-educators with the intention of finding innovative ways to utilize dialogic pedagogies in service of testing practices (Segal et al., 2017).

Work in this vein poses immense challenges for teacher educators. Not only does the schooling culture that supports dialogic argumentation appear very different from what is needed to achieve institutional legitimacy, but also access to the prevailing institutional logics that teachers call upon in their work precludes such a strategy. However, as this approach privileges the work lives, concerns, and expertise of teachers for the establishment of a common value system shared among teachers and teacher educators, it might prove worthwhile. Such guidance might allow teachers to maintain their sense of professionalism, while also suggesting strategies to initiate and maintain the process of pedagogical change. Although such an institutionally informed strategic response requires further examination, we carefully argue that without the incorporation of institutional understanding into TPD courses, the potential of dialogic argumentation may remain unrealized in many classrooms.

7 Limitations of the study

Being qualitative, the methodology did not allow for an examination of the degree to which

these logics were enacted, but it did allow us to articulate the meanings assigned by the participants to each logic. One potential limitation of this research is the assumption that the identified factors, at both the macro- and micro-levels of analysis, perfectly reflect institutional logics. To overcome this obstacle, we followed interpretive techniques that call for researchers to explain the pattern of observed behaviors "on the ground" through a process of constant comparison to previously identified institutional logics "out there" (Reay & Jones, 2016). Therefore, while subjective interpretation of data may be unavoidable, the identification of institutional logics was done in accordance with the existing literature, which may support the validity of our subjective interpretation (Glaser & Strauss, 2017; Reay & Jones, 2016). This analytical approach may, however, constrain analytical insights to those connected to established theories and blind researchers to alternative interpretations.

Another limitation concerns the sampling strategy. Gathering data from only a small number of schools means that this analysis may conflate school-context factors such as norms, culture, and performance, which may be relevant chiefly to the observed schools. In that sense, it suffers from limitations pertaining to ecological validity. One potential consequence of this limitation is that the findings cannot allow for generalizations, nor can they entirely rule out alternative explanations for the observed phenomena.

CHAPTER 3. The potential for reconciling pedagogical tradition and innovation: the case of socioscientific argumentation[2]

"All my knowledge of the world, even my scientific knowledge, is gained from my own particular point of view, or from some experience of the world" (Merleau-Ponty, 1962, p. viii)

1 Introduction

With the turn of the century, social dilemmas enmeshed with science seem to be more prevalent. The accelerating climate crisis, cutting-edge and risky biotechnological innovations and, most recently, the COVID-19 pandemic and the related public debate, all represent ongoing dilemmas that demand our immediate and collaborative attention. Given these issues' societal urgency, and because schools comprise a powerful social institution, we explored how we could organize—for teachers and students—the collaborative and thoughtful deliberation of such issues in the science classroom.

In this study, we use the term socioscientific issue (SSI) to denote dilemmas that combine scientific and societal aspects (Zeidler et al., 2005). SSIs are ill-structured, open-ended problems which encompass an inherent uncertainty with regard to paths for their resolution (Owens, Sadler, Petitt, & Forbes, 2021). As such, multiple and conflicting perspectives can weigh in when such solutions are negotiated (Sadler & Donnelly, 2006). Because of their complexity, the inclusion of SSI teaching in science education has the potential to promote argumentation as a dialogic process in which students construct arguments through interactions with peers who hold differing views (Bencze, Pouliot, et al., 2020).

Despite its accommodation of societal needs (Zafrani & Yarden, 2017) and policy demands (Bencze, Pouliot, et al., 2020; R. Cohen et al., 2020), SSI argumentation has encountered difficulties reaching the level of classroom practice (Kilinc et al., 2017; Tidemand & Nielsen, 2017). It can be incompatible with contemporary schools' definition of how "quality" learning is best achieved. Such incompatibility pertains to both the place of SSIs in the core curriculum, where content knowledge is emphasized over the social implications of science (Bencze, Pouliot, et al., 2020; Klopfer & Aikenhead, 2022), and the place of dialogic argumentation in the core practices of science instruction, where teacher-controlled modes of interaction prevail (González-Howard & McNeill, 2019; Pimentel & McNeill, 2013). This

[2] This chapter is a modified version of a paper submitted to *Instructional Science*

mismatch is problematic because when a new practice is introduced that is not supported by the teachers, they may refrain from putting in the required effort and commitment to incorporate it (Bridwell-Mitchell, 2015). Indeed, teacher resistance to SSI argumentation may arise from its clash with entrenched norms and practices (Kilinc et al., 2017; Teo, 2019; Tidemand & Nielsen, 2017).

Teachers and schools are then faced with the following trade off: maintaining traditional instruction may lead to pedagogical obsolescence, but implementing innovative pedagogies may yield low returns in terms of how schools are accustomed to measuring learning (Bingham & Burch, 2019). How, then, can SSI argumentation be implemented when teachers may not perceive it as valuable?

Research in the field of organizational studies has identified approaches to making successful changes in practices, including aligning demands for change with the interests of the organization (Perkmann et al., 2019), and reconfiguring existing practices, rather than replacing them with new ones (Sonenshein, 2016). Accordingly, we argue that a critical first step toward successful implementation of SSI argumentation may necessitate its reconciliation with contemporary schooling norms and goals; this might allow teachers to use it in accordance with commonly understood meanings of instruction. However, we lack detailed knowledge on how these two elements might be combined.

To move ahead with this reconciliation, we focused here on teachers' professional development (TPD) efforts to guide teachers in implementing SSI argumentation by creating conditions under which they can make sense of this contested practice and adjust it to their working conditions. Thus, we first aimed to reduce the barriers of the schooling culture and its related contradictions with SSI argumentation. We investigated the potential of a learning environment in an extracurricular setting that is partially detached from the barriers of schooling, a free space in which teachers can experiment with new practices in ways that may not be possible in their day-to-day teaching. However, we did not want to keep SSI argumentation entrenched in "the periphery of the system in specialized niches" (Tyack & Cuban, 1995, 87) where it can be identified as idiosyncratic and ignored by the rest of the school system (D. K. Cohen & Mehta, 2017). Therefore, we utilized this environment to extract and decipher the conditions under which SSI argumentation can generate outputs that reaffirm the functioning of the school organization. In this way, we argue, SSI argumentation can potentially be implemented more consistently in the school culture.

2 Theoretical framework

2.1 Key impediments to advancing SSI argumentation

Broadly put, argumentation in science education sets goals in terms of both *what* students are talking about (i.e., the scientific content of arguments), and *how* students argue (i.e., the deliberative form of argumentation). These goals correspond with advancing the construction of arguments that are truthful to scientific knowledge and ways of thinking (Evagorou & Osborne, 2013; Venville & Dawson, 2010), and with developing norms that support participatory democracy through dialog and deliberation (Evagorou, Nielsen, & Dillon, 2020).

We argue that the incompatibility of SSI argumentation with current schooling objectives and practices may impede the attainment of these goals. Therefore, a necessary first step is the articulation of contemporary schooling objectives. This is achieved by focusing on tensions of practice at the science and dialogic fronts. We then explore the potential of an extracurricular learning environment to reduce these tensions by providing a protective boundary within which teachers and students can experiment with SSI argumentation. We propose that under these conditions, we can begin to identify how SSI argumentation can be enacted in ways that cohere with—and produce outputs that are valued by—the standards of contemporary schooling.

2.1.1 Tensions at the science front

Engaging students in SSI argumentation can lead to a critical and scientifically informed reflection on real-word dilemmas that also builds on their subjective social and cultural experiences (Balgopal, Wallace, & Dahlberg, 2017), personal interests (Furberg & Silseth, 2021), and moral beliefs (Zeidler & Nichols, 2009). However, science education needs to prepare students to argue in ways that expand their reliance on subjective knowledge and beliefs to more objective science knowledge (González-Howard & McNeill, 2020); this expansion may be difficult to achieve. For example, Sadler and Zeidler (2005) examined students' reasoning patterns in the context of SSIs and found that they relied on rationalistic patterns of reasoning and science knowledge for decision-making, but also on their emotions and intuition. Subsequent studies noted that emotion and intuition dominate rationalistic reasoning in students' argumentation (Dawson & Venville, 2009; Venville & Dawson, 2010). Recent studies have also noted the salience of students' reliance on personal experiences in their processes of

decision-making in the context of SSIs (Christenson, Rundgren, & Höglund, 2012; Grace & Ratcliffe, 2002; Rundgren et al., 2016). What these and other studies show is that science knowledge and ways of thinking may be backgrounded in SSI argumentation in favor of subjective knowledge claims (Aikenhead, 2006; Albe, 2008; Namdar & Shen, 2016; Ottander & Simon, 2021; Topçu, Yılmaz-Tüzün, & Sadler, 2011).

Students' understanding of SSIs, charged with subjective emotional and intuitive content, may be recognized for its contribution to learning (Furberg & Silseth, 2021). However, inside science classrooms, priority is accorded to objective science-based knowledge (Sadler & Donnelly, 2006; Tidemand & Nielsen, 2017; van Der Zande et al., 2009). In fact, students are often evaluated by their ability to refrain from taking their personal, non-scientific knowledge into account (Wu, 2013). We therefore argue that an over occurrence of arguments that rely on subjective reasoning may conflict with the commonly understood ways of how learning is best achieved in schools, potentially rendering SSI argumentation less valuable in these settings. Given that successful adoption of new practices is contingent on their value when judged according to dominant organizational objectives and ideas (Heinze & Weber, 2016), it is difficult to imagine that SSI argumentation will be adopted with such returns. Conversely, instances in which students employ rationalistic reasoning and science knowledge during argumentation may be considered more fitting in classrooms.

2.1.2 Tensions at the dialogic front

When it is productive, dialogic argumentation can lead to collaborative elicitation, evaluation, and coalescence of students' arguments (Felton, Crowell, Garcia-Mila, & Villarroel, 2019), which holds the potential for advancement of scientific reasoning (Lowell et al., 2022). Indeed, students' engagement in SSI argumentation has been shown to improve their ability to generate arguments that rely more on scientific knowledge than on intuition or emotion. For example, Arvola and Lundegård (2012) found that when discussing abortions, science content became more dominant when students were asked to clarify their standpoint during argumentation. In the context of gene therapy, Nielsen (2012a) found that students may invoke science content to advance their own positions and make their arguments appear more concrete. In the same vein, Rudsberg and Öhman (2015) showed that students invoke science knowledge during argumentation on climate change issues to clarify and add support to their own positions, as well as to challenge the other sides' arguments.

Such documentation of students' ability to assume more epistemic and interactional agency is what underlies much of the theoretical advocacy of dialogic argumentation in participant structures (the ways in which interactions can be organized in the classroom) that include interactions between learners (Kovalainen & Kumpulainen, 2005). Such participant structures include, for example, teacher-led collaborative discussions and peer-led small-group work. However, for the potential of these alternative participant structures to be realized, teachers may need to assume an integral role in their management. In this regard, previous studies have shown that teachers can navigate classroom talk and impact reasoning through the types of questions that they raise (Oliveira, 2010), the ways in which they follow up on students' answers (Pimentel & McNeill, 2013), and how they connect different arguments and positions (Lowell et al., 2022).

Nevertheless, in practice, dialogic argumentation can become counterproductive in certain situations. For example, rearranging participant structures to be conducive to argumentation may elicit participation by students who are entrenched in their prior beliefs and more interested in "winning" through confrontational talk than attempting to collaboratively coalesce competing arguments (Albe, 2008; Bathgate et al., 2015). In contrast, students may try to quickly achieve uncritical agreement, which distances them from a thoughtful resolution of problems (M. Johnson & Mercer, 2019). In both situations, little opportunity exists for students to exploit each other's contributions. This may not only be counterproductive in terms of argumentation, but may also generate resistance to implementation by signaling a loss of teachers' authority and control (P. H. Scott et al., 2006).

In addition, many teachers may lack the appropriate knowledge and skills to accommodate instruction that is more conducive to dialogic interactions and collaborative reasoning. This is true for teacher-led discussions, where teachers were documented to not be responsive to students' contributions (Pimentel & McNeill, 2013), or exhibited limited ability to compare and coalesce different contributions (Lowell et al., 2022). With regard to peer-led group work, productive talk may be stifled when teacher interventions provide direct instruction (Blatchford, Kutnick, Baines, & Galton, 2003) or too little scaffolding (Edwards & Westgate, 1994).

Advocating for dialog-conducive participant structure is, then, necessary to bring in dialogic SSI argumentation. However, learning in participant structures in which speakers' communicative rights are not monitored by the teacher, but rather shared more equally among participants, is uncommon in schools (Henderson et al., 2018), and may even be perceived as

illegitimate (Zafrani & Yarden, 2022a). It seems that productive classroom interactions not only yield high returns in terms of students' reliance on science knowledge, but can also potentially bestow value on learning in participant structures that are more conducive to dialog. In contrast, unproductive argumentation may elicit situations that can be deemed antagonistic to contemporary schooling habits.

2.2 SSI argumentation: from the extracurricular setting to the core of schooling

The literature suggests that a balance between science knowledge and opportunities for productive collaborative dialog is necessary to reconcile SSI argumentation with the culture of schooling. But when pedagogies are viewed by teachers and schools as threatening their norms of practice, they are more likely to be ignored or superficially implemented (Bridwell-Mitchell, 2015; Coburn, 2004) before teachers can have an opportunity to find this delicate balance in their classroom implementations. In this regard, the establishment of extracurricular free spaces—arenas that lie outside the traditional order of schooling—may afford teachers the opportunity to experiment with contested practices (Bingham & Burch, 2019). Part of the success of such environments is attributed to their relative freedom from the constraints of traditional schooling. That is, they are less tied to the formal curriculum and to the endeavor of covering it, less focused on assessment, and offer teachers and students ways to learn that schools generally do not (Mehta & Fine, 2019a; Stewart & Jordan, 2017). When resistance is recognized, the creation of such free spaces may be an important step toward promoting pedagogical change.

However, without extending its influence to the rest of the organization, the establishment of free spaces does not guarantee permanent large-scale change in practices (Heinze & Weber, 2016). Hence, in this study, we do not view the establishment of free spaces as an ultimate end. Rather, we view it as a temporary, innovation-focused niche where teachers can operate more autonomously, and SSI argumentation can germinate to later be extended more permanently into the core of schooling practices. In other words, instead of deepening the disconnect between core schooling practices and SSI argumentation, we aim to mend it.

3 Research purpose and questions

Here, we are examining the stage at which a pedagogical change toward implementing SSI argumentation has been initiated but not yet established, prompting the question: What are the conditions for successfully establishing SSI argumentation as a core instructional practice

within schools? To answer this question, we examine how SSI argumentation is conducted in a free space that allows for the emergence of participant structures conducive to dialogic interactions—teacher-led collaborative discussions and peer-led small-group work, focusing on qualitative data in the form of talk and interactions. We then illustrate how SSI argumentation in those structures can become better integrated with the goals that core schooling practices are normatively set to achieve.

This means that what comprises normative ends for classroom interactions constitutes a kind of benchmark against which we can compare what could possibly be attained by means of SSI argumentation. Therefore, we explore how different participant structures might elicit productive argumentation in which students rely on science knowledge more prominently than on subjective emotions, intuition, or personal experiences. We sought to answer the following research questions:

i. When enacting teacher-led and peer-led SSI argumentation, what kind of knowledge and reasoning did students rely on to base their arguments?
ii. How is argumentative talk differently organized in teacher-led and peer-led interactions, and how does its organization relate to students' use of science knowledge and rationalistic patterns of reasoning as the bases for their arguments?

4 Methodology

4.1 Context: the design and purpose of climax days

This study is part of a larger research project examining efforts to promote dialogic argumentation in lower secondary schools through TPD. A TPD course was designed during the 2019–2020 academic year to prepare 7th-grade teachers from four schools to manage full school days dedicated to dialogic argumentation, termed *"climax days*". Climax days took place at a site outside of the school, to which students came to argue open-ended questions that pertain to societal issues that are enmeshed with science, math, and philosophy.

Five climax days were planned and carried out, with the fifth day conducted online due to COVID-19 pandemic restrictions. On these climax days, students were asked to learn about and negotiate the issues of: (1) genetic passports and encryption, (2) urbanization and ecological conservation, (3) mandatory vaccination, (4) human genetic modifications, and (5) fake news (see Appendix B for all science lesson plans).

Each climax day was composed of three parts, two academic hours each. The first and second parts of the day were dedicated to disciplinary modules. In these modules, students from different schools were mixed between classrooms by their choice of interest. Each student took part in two out of three disciplinary sessions while arranged in groups of about 20 students from the four schools during the first part of the day (i.e., there were students who attended mathematics and science sessions, or mathematics and philosophy sessions, or philosophy and science sessions).

Since students often had little scholastic background, in the science module, science teachers introduced students to a discipline-specific body of knowledge which prepared them to offer scientifically informed arguments. Toward the end of the science module, an argumentation-producing question that required the use of science knowledge produced earlier in the module was presented. Similarly, mathematics and language arts teachers introduced students to academic knowledge in their subject matter.

The third part of the climax day was interdisciplinary. This part integrated content taught in the first two parts to discuss the interdisciplinary question of the day. In the interdisciplinary module, students were united in their home classrooms with the science, math, and language arts teachers who teach in their school. This design ensured that when students approached the interdisciplinary module, their home classroom contained students who had participated in all three disciplinary lessons and were prepared to negotiate the interdisciplinary question from these academic angles.

In this paper, we will focus exclusively on the science teachers and on students' negotiations of SSIs from the perspective of science. Students' negotiations and understandings of mathematical and philosophical ideas will be largely excluded from this paper, except when such ideas are part of long discussions on scientific ideas.

4.2 TPD design

The focus of the 60-hour TPD course was on preparing teachers to manage the climax days in terms of understanding dialogic pedagogy and practicing it with students, as well as in terms of understanding the conductance of the lesson plans of the climax day. The research team developed the lesson plans for each discipline as well as the interdisciplinary lesson plan. Prepared materials can be conducive to change in classroom instruction because they offer teachers concrete materials aligned with the change they seek to advance (McNeill et al., 2017). The authors are members of the team that developed the science as well as the interdisciplinary

lesson plans for the climax days and served as instructors in the TPD.

4.3 Participants

Six 7th-grade science teachers from four schools and their students (n = 130) participated in the climax days (Table 3.1). The schools are in central Israel, in a city with high socioeconomic status. The teachers, as well as their students, were chosen for participation in our study by district administration personnel because they belong to high-track classrooms. In that sense, the participant-selection methodology was purposive sampling (Etikan et al., 2016).

TABLE 3.1 List of participating teachers

Teacher's name (pseudonym)	**School (pseudonym)**	**Experience (years)**
Deanna	Broshim	15-20
Jenny	Ilanot	>25
Trish	Regavim	>25
Alice	Regavim	1-5
Christine	Sela	20-25
Beth	Sela	>25

4.4 Data sources

Posing criteria for the selection of climax days to serve as the focus of this study, we sought instances that contained variations in talk organization and reflected different participant structures. Based on these criteria, the first and third climax days were selected for analysis. These two climax days contained interdisciplinary activities that called for different interactional contexts: a teacher-led argumentative discussion on the first climax day, and peer-led small-group interactions on the third climax day. This way, students' reasoning and the talk moves used by teachers and students could be examined across various organizations of talk.

Examples of teacher-led argumentative discussions are taken from lessons led by teachers Jenny and Alice (Table 3.1). Due to technical constraints, all the examples of peer-led small-group interactions were taken from a single classroom led by the teacher Deanna, as it was the only lesson in which the group talk was captured in the high detail needed for verbatim transcription.

4.4.1 First climax day: genetic passports and encryption

In the disciplinary science module of the first climax day, students learned how certain genetic

disorders (e.g., a mutation that causes hemophilia) can be read in the genetic code. The activity began with a short text detailing the occurrence of hemophilia in British royalty. The students were then exposed to a table explaining the genetic code and were asked to translate a short segment of the genetic sequence of the gene that is responsible for the occurrence of hemophilia. Some sequences were altered to contain a mutation that leads to amino acid replacement. Through that, students could understand that hemophilia is caused by genetic mutations, and that given that the genetic sequence is available, such information can be discerned by experts. Using this knowledge, students were asked to decide if they agree to send a sample of their genetic information to a private genealogy company.

Using knowledge that they had acquired in this and other disciplinary modules, in the interdisciplinary module, students were required to work in teacher-led discussion groups to answer the question *"Should citizens' DNA sequence information be added to their biometric passports?"*.

4.4.2 Third climax day: mandatory vaccines

This day took place shortly before the COVID-19 pandemic became recognized as a global threat. In the disciplinary module, students participated in a science activity that asked them to work in pairs to understand the differences between the three scenarios of immune response to whooping cough: a primary response to bacteria unfamiliar to the immune system, a secondary response, and a response in a vaccinated individual. Students were then asked to work in pairs to collaboratively understand the differences between the scenarios. The students were then provided with data from the Centers for Disease Control and Prevention (CDC) on the successful mitigation of certain diseases by vaccines. These data illustrate the effectiveness of vaccines by giving annual numbers of vaccine-preventable diseases in the United States in the 20th century, compared with cases reported in 2017, showing that all of the diseases have been reduced by more than 90% (Centers for Disease Control and Prevention, 2018).

Students were then required to participate in a "catch" game that imitates the spread of a contagious infection in populations where (a) the majority is unvaccinated, and (b) the majority is vaccinated. The game led to a discussion of the phenomenon of herd immunity and its social implications for immunocompromised individuals. Students were then shown a video about an outbreak of measles in a community that is anti-vaccine, and were asked to devise reasonable replies supporting or disputing the individuals in the video.

In the interdisciplinary module, students had to deliberate on whether vaccines should be state-mandated. To assist students in reaching a decision, they were asked to construct a controversy map that illustrates the various stakeholders involved in the dilemma (Christodoulou et al., 2021). A line was drawn on the map, with one side for mandatory vaccinations and the other against. We provided cards detailing some of the stakeholders' identifications and claims (e.g., a statement by an Israeli legislator stating that vaccines are important for national health; a parent who claims that pharmaceutical companies are not impartial in their promotion of vaccines) and students were instructed to write their own claims on empty cards. Students were then asked to place the cards on the map according to the claims presented in them. Finally, each group was asked to reach a consensus regarding their group's position on the map justified by argument, and to share it with the classroom.

4.5 Data analysis

Video and audio recordings of teacher-led and peer-led dialogic activities were collected and transcribed verbatim. Data from students' artifacts produced during climax days also lent empirical support to the talk-oriented data. As the theoretical literature suggests, we paid attention to both *what* (i.e., the content) students and teachers were talking about when they discussed SSIs, and *how* (i.e., the form) they discussed them. Transcriptions were segmented into units of analysis, which were identified as sections in which argumentative teacher–student, or student–student dialog occurred. Units began when the interaction exhibited argumentation on a subject and ended with either a change of subject or when the argumentation was concluded.

These units were then analyzed in two dimensions. First, students' arguments were classified according to the typology reported by Sadler and Zeidler (2005), which differentiates students' arguments as relying on *rationalistic, intuitive* or *emotive* reasoning. *Rationalistic reasoning* describes considerations that draw on science understanding and language to make a reasoned analysis of the issue under discussion. Therefore, in this paper, reliance on rationalistic reasoning is used interchangeably with reliance on science knowledge. For instance, when a student's arguments exhibited science knowledge from the activity, it was coded as relying on rationalistic reasoning. *Emotive reasoning* is not irrational, but whereas rationalistic reasoning draws on science knowledge, the rationality of emotive reasoning is rooted in subjective emotion and care-based feelings, rather than in objective science knowledge (Zeidler & Sadler, 2007). Students' arguments that placed a premium on care for

others were coded as relying on emotive reasoning. *Intuitive reasoning* relates to an immediate response to an issue and reflects entrenched personal conviction. When students' arguments were not supported with knowledge claims, rational or emotive, they were coded as relying on intuition. To note its salience, the aspect of *personal experience* was also added to these categories, reflecting student arguments that relied on a connection of the issue to their daily lives or perceived personal relevance (Rundgren et al., 2016).

Because our concern was the integration of SSI argumentation in schooling contexts, rather than simply typifying students' reasoning, we aimed to bifurcate arguments into those exhibiting rationalistic reasoning and science-based knowledge and those exhibiting subjective knowledge and reasoning. Therefore, the idea here was to highlight instances in which rationalistic, objective considerations, as classified by Sadler and Zeidler (2005), dominated more subjective considerations based on emotion, intuition (Sadler & Zeidler, 2005), and personal experience (Rundgren et al., 2016). The coding process using this framework was carried out independently by the two authors and was negotiated until agreement was achieved.

Then we analyzed the argumentative talk moves used in an interaction with the coding scheme offered by Felton et al. (2019), which hones in on the ways in which speakers in arguments elicit, respond to and critique one another's thinking. The scheme presents codes for declarative talk moves (*declarative initiations*), questioning talk moves (*interrogative invitations*), responsive talk moves (*elaborative* and *non-elaborative responses*), and talk moves about the process of dialog (*meta-dialogic statements*). The idea here was to recognize the talk conditions under which argumentation supported or hindered collaborative reasoning that could bolster reliance on science knowledge.

In this scheme, effective discourse occurs when speakers produce talk moves that engage with, and act upon their partners' reasoning, thus promoting collaborative reasoning. For example, when participants employ talk moves that allow for the surfacing, critiquing, and coalescing of arguments to take place, effective dialogic argumentation is more likely to occur. Such talk moves include the use of elicitation of *positions* and their co-construction by *additions* and *advancements* made by peers (surfacing), requests for *clarifications, justifications,* or *substantiations* (critiquing), or expressions of *acknowledgement* and *accommodation* of differing positions (coalescing). Conversely, ineffective argumentative discourse undermines dialog and can be seen in talk moves that break down communication. This can happen when participants engage in confrontational talk and employ non-elaborative expressions of *disagreement* or *dismissal* of competing arguments, or simply *refuse* to respond. It can also

happen when participants attempt to reach a quick consensus through expressions of uncritical *agreement* and *reiteration* of unmerited arguments. The full coding scheme and the description of codes is available in Felton et al. (2019). The coding process using this scheme was carried out cooperatively by the two authors of this paper. Where disagreement arose, coding decisions were communicated explicitly until agreement was achieved

This moment-by-moment analysis of how students orient in relation to science knowledge and to each other's contributions could provide a holistic representation of the role of interactions in advancing students' reasoning and collaboration. Attentiveness to such productive orientation could pave a path toward the integration of SSI argumentation in, and its reconciliation with the structures of contemporary schooling.

5 Findings: learning interactions conducive (and not conducive) to science-based arguments

The sequences herein are representative of the whole data corpus. We begin by exploring how teacher-led collaborative discussions structure argumentation on SSIs in terms of students' reasoning (content) and in terms of their dialogism (form), using sequences 1.A–1.C. We then continue to explore how discussions are organized for the same components in peer-led argumentation, using sequences 2.A–2.C. Table 3.2 contains details regarding the sequences analyzed in this section.

TABLE 3.2 Details regarding the sequences presented in the Findings section

Sequence # (Table #)	**Name of climax day**	**Disciplinary / Interdisciplinary lesson**	**Science teacher present**	**Discussion type**	**Dialogic question negotiated**
1.A (Table 3.3)	1st Climax Day: Encryption	Disciplinary	Jenny	Teacher-led	*Would you be willing to give a sample of your DNA to a private company that provides genetic sequencing?*
1.B (Table 3.4)	1st Climax Day: Encryption	Interdisciplinary	Alice	Teacher-led	*Should citizens' DNA sequence information be added to their biometric passports?*
2.A (Table 3.5)	3rd Climax Day: Mandatory vaccinations	Interdisciplinary	Deanna	Peer-led	*Should the state be allowed to require that parents vaccinate their children?*
2.B (Table 3.6)			Deanna		
2.C (Table 3.7)			Deanna		

5.1 Argumentation in teacher-led discussions

5.1.1 Sequence 1.A

The first sequence is taken from the first climax day, toward the end of the disciplinary module led by Jenny (Table 3.3). The following transcript illustrates a teacher-led whole-classroom discussion. As such, it necessitates the teacher's management of a turn-by-turn interaction. With this structure, the teacher invites bids for the next turn, and holds the power to determine which turns are admitted into the discussion. The classroom discussion is focused on the question: *Would you be willing to give a sample of your DNA to a private company that provides genetic sequencing?* This sequence was initiated after the teacher, Jenny, had given the students time to talk in pairs about the question. When they came back to the whole-classroom discussion, students were invited to share their arguments and to base them on both the science content learned earlier and their peers' ideas.

TABLE 3.3 Sequence 1.A: first climax day, disciplinary module, teacher-led discussion

Turn #	Speaker	Utterance	Pattern of reasoning	Argumentative talk move
1	Jenny	*Would you be willing to give a sample of your DNA to a company that provides genetic reading?* **Based on all that you have learned and heard from each other, what do you think?**		Interrogative initiations: Position? **Interrogative initiations: Justify?**
2	Student A	*I don't think so. If I send a sample, then I will know what diseases I am going to have and all sorts of things* [:] *that will make me anxious. Like, I already know that my grandfather has diabetes, which puts me at a greater risk for it. Just this freaks me out and I don't want to find out about other stuff.*	Rationalistic [:] Personal experience	Elaborative responses: Position
3	Jenny	*So, you're saying that you have prior knowledge about something in your family that frightens you, I see.* **Anyone else?**		Elaborative responses: Interpret **Interrogative initiations: Position?**
4	Student B	*On the one hand, I want to learn about my family's history.* **But on the other hand, like [student A] said, this can make me anxious which I don't really…**	Personal experience	Elaborative responses: Position **Elaborative responses: Reiterate**
5	Jenny	*So, you're saying that it interests you but also scares you.* **Yes? (nominating**)		Elaborative responses: Interpret **Interrogative initiations: Position?**
6	Student C	*I think it is better to send it.* **Let's say that you send it and you find out that you have a high risk of having cancer. Knowing that, you can be more alert and have yearly examinations. And, your doctors also know and then they can tell you to get examined more often. And then they can find the cancer and start to treat it early, so that you can get better.**	Rationalistic	Elaborative responses: Counterclaim **Elaborative responses: Co-opt**
7	Jenny	*You're speaking about early diagnosis.*		Elaborative responses: Interpret

Notes:
* A shift from *italic type* to bold type font in utterances marks a change in the type of argumentative talk move.
** [:] marks a change in the type of reasoning used in the argument.

In this sequence, student A's argument begins with an assessment of the strength of genetic testing, thus exhibiting *rationalistic reasoning*. He then quickly moves on to ground his refusal to submit a sample for such a test in reasons stemming from his personal biography, thus reflecting reasoning motivated by *personal experience* (2). Student B frames her argument entirely on her *personal experience*, saying that she wants to learn about her genealogy but reiterating student A's reservations about finding out personal information (4).

Shifting our attention to the form of the interaction rather than its content, we can see that while Jenny tries to bring students' ideas to the surface using a talk move that nominates students and asks for their *position* (1, 3, 5), talk moves that push students to extend and expand their arguments were not an integral part of the discussion. Instead, after each argument is brought up, Jenny rephrases it in her own words using the talk move *interpret* (3, 5, 7), and then proceeds to the next elicitation of students' *positions*. This is important, as it shows that Jenny is actively listening to the students. However, as the interpretations were not followed by a request for elaborations, there were no opportunities for students to clarify their ideas. Consequently, students' arguments rarely implied robust scientific knowledge.

Also missing are talk moves by either Jenny or the students that push students to build on and critique each other’s ideas. As a result, students' differing positions were not compared or contrasted and remained in the form of a fragmented list. Without this critique, students could *reiterate* arguments built on *personal experience* brought up in previous turns (4). An exception to this pattern can be seen when student C *co-opts* his peers' arguments to offer a *counterclaim* in favor of genetic testing. He uses cancer as an objective example to support his approval of the test instead of examples that relate to subjective personal conditions (6). However, as Jenny simply *interprets* his contribution in her own words (7), this rare exception is not leveraged to elevate the discussion toward science knowledge.

5.1.2 Sequence 1.B

The following sequence (Table 3.4) is taken from the interdisciplinary module of the first climax day. Students were asked to decide if the Supreme Court should rule to add citizens’ DNA sequence information to their biometric passports. In this activity, the classroom was divided into three groups of about 10 students seated in a discussion group, each led by a different teacher. Unlike Jenny, Alice is using a broader repertoire of talk moves that is more responsive to students' arguments and which may, in some cases, have shaped students’ reasoning toward increased reliance on science knowledge.

TABLE 3.4 Sequence 1.B: first climax day, interdisciplinary module, teacher-led discussion

Turn #	Speaker	Utterance	Pattern of reasoning	Argumentative talk move
1	Alice	*We are going to hear if you are for or against.* ***You've learned a lot of content today and this content can assist you in making your decisions, alright?*** **It's not enough that you tell me your position, you also have to justify it, alright?**		Interrogative initiations: Position? **Interrogative initiations: Justify?**
2	Student A	*I'm for. It's very useful. I also used [fingerprint identification in the airport]. The system identified me right away.*	Personal experience	Elaborative responses: Position
3	Alice	*You're for. Can you justify your position? Why is it important to add it?*		Interrogative initiations: Justify?
4	Student A	*Erm…because of identity theft. It's very useful to know for certain that you're you.*	Rationalistic	Elaborative responses: Justify
5	Alice	*So, what [student A] is saying is that it can prevent identity theft because the DNA tells me if that is the right person.* **[Student B], would you like to comment on that?**		Elaborative responses: Interpret **Interrogative initiations: Respond?**
6	Student B	*I think it's a good idea. I also used [fingerprint identification] in the airport.* [:] **And the whole thing about identity theft, I think it's very important to prevent that.**	Personal experience [:] Rationalistic	Non-elaborative responses: Agree **Elaborative responses: Reiterate**
7	Alice	*You think that identity theft should be prevented.* **Yes?**		Non-elaborative responses: Reiterate **Interrogative initiations: Position?**
8	Student C	*I also think that we should use it. Like [student B] said,* **I think that using your DNA is much safer than passwords and whatnot. Because of technology, hackers can hack your computer, but your body is yours and they can't mess with it.**	Rationalistic (1)	Elaborative responses: Agree **Elaborative responses: Advance**
9	Alice	*What do you mean?*		Interrogative initiations: Clarify?
10	Student C	*That your DNA is yours and not anyone else's.*	Rationalistic (2)	Elaborative responses: Clarify
11	Alice	*Your DNA is yours only.* **Can you explain?**		Non-elaborative responses: Reiterate **Interrogative initiations: Clarify?**
12	Student C	*That there is zero chance that someone else has the same DNA. They use that to protect your information.*	Rationalistic (3)	Elaborative responses: Clarify

Notes:
* A shift from *italic type* to bold type font in utterances marks a change in the type of argumentative talk move.
** [:] marks a change in the type of reasoning used in the argument.
*** When a pattern of reasoning or the employment of a talk move is advanced over several turns, the coding will be accompanied by a number in parentheses (e.g., turns 8, 10, 12).

Alice frequently asked responding students to elaborate. For example, student A referred to his previous *personal experience* in using the airport's fingerprint authentication system and used this experience to base his argument in favor of DNA databases (2). Alice then asks for *justifications* for his position (3). In reply, student A uses a more objective argument, explaining that such a database might prevent identity theft (4), thus relying on a more *rationalistic* reasoning. This argument is then *advanced by* student C, who connects it more explicitly to the subject matter by referencing DNA and claiming that biometric authentication is stronger than the use of passwords (8). Pushed by Alice for clarifications (9, 11), he further advances his rationalistic reasoning, arguing that DNA contains information unique to each person and could, therefore, assist in distinguishing people (12).

Alice's elicitation of elaborations on students' thinking may have progressively pushed them to base their arguments on science knowledge. Most notably, student C was allowed to advance his reasoning across three turns (8–12), which may have led to more robust rationalistic reasoning. Similar to Jenny's discussion, less frequent in this sequence is the use of talk moves that connect and compare students' contributions. Such an attempt is only made once in this sequence when Alice calls on a specific student to *respond* to student A's argument (5).

5.1.3 Summary of findings from teacher-led argumentation

Both Jenny and Alice seemed to value students' opinions and signaled to their students that their opinions matter. Yet, students' opinions also contained bald assertions that often relied solely on their subjective personal experiences. When such contributions were left unchallenged, they were granted equal status in the discussion as those that relied on science knowledge and rationalistic reasoning. Through that process, discussions may have deviated away from science and toward subjective knowledge claims, potentially hampering the perceived value of such discussions in the classroom. When confronted with requests for clarifications, students' arguments seemed to exhibit more reliance on science knowledge, which makes this talk move integral to making SSI argumentation compatible with current organizational practices. Moreover, in both sequences, students had only limited opportunities to comment on their peers' arguments, and their contributions remained firmly directed at the teachers, hampering the level of critique in the classroom.

5.2 Argumentation in peer-led small groups

For argumentation in peer-led small groups, teachers circulated among the groups and were

only occasionally present for the discussions. Accordingly, the following sequences are characterized by the absence of teacher's turns, and by students' use of a repertoire of talk moves usually reserved for teachers. That is, students not only answered questions, they also asked them, thus potentially allowing for more critique to enter the discussions. As such, communicative rights are not monitored by a single individual in a series of predetermined turns but seem to be shared more equally among participants who negotiate the terms of their interaction moment by moment.

Taken from the interdisciplinary module of the third climax day, the following transcripts illustrate how students in three groups (out of four from one classroom) negotiated the dilemma: *Should the state be allowed to require that parents vaccinate their children?* In comparing the following sequences to teacher-led discussions (sequences 1.A and 1.B in Tables 3 and 4), we can examine how organization of participant structures away from teacher management may hold potential for the advancement of rationalistic reasoning, but also impinge upon dialogism.

5.2.1 Sequence 2.A

In the next sequence (Table 3.5), student A presents an argument for mandatory vaccination substantiated by the CDC data on the effectiveness of vaccines presented in the disciplinary science module. Though substantiated, her peers systematically refuse to acknowledge her argument and to incorporate it into their group's position.

TABLE 3.5 Sequence 2.A: third climax day, interdisciplinary module, peer-led discussion, group 1

Turn #	Speaker	Utterance	Pattern of reasoning	Argumentative talk move
1	Student A	*[Reading her argument card] I am for mandatory vaccination. If everyone gets vaccinated, then eventually the disease will vanish from the world.*	Rationalistic (1)	Elaborative responses: Position
2	Student B	*Is that true? [said decisively, with a tone implying "I don't think that is true"]*		Non-elaborative responses: Dismiss
3	Student C	*No. It doesn't work like that.*	Intuitive	Non-elaborative responses: Dismiss
4	Student A	*Yes, it does. That's what happened with smallpox.*	Rationalistic (2)	Elaborative responses: Substantiate
5	Student B	*But not because they got vaccinated.*	Intuitive	Non-elaborative responses: Dismiss
6	Student A	*It was because they got vaccinated.*	Rationalistic	Non-elaborative responses: Disagree
7	Student B	*It was because they all got sick and died.*	Intuitive	Elaborative responses: Counterclaim
8	Student C	*They got sick and died.*	Intuitive	Non-elaborative responses: Reiterate
9	Student A	*But then they realized that they need to vaccinate everyone before they get sick and then it vanished from the world.*	Rationalistic	Elaborative responses: Advance
10	Student B	*But everyone is getting the flu vaccine, and people are still getting sick.*	Rationalistic	Elaborative responses: Counterclaim
11	Student A	*I don't understand what you're saying. What don't you agree with?*		Interrogative initiations: Clarify?
12	Student B	*It won't just vanish like that. If everyone will be vaccinated, it will vanish. You wrote that.*	Intuitive	Non-elaborative responses: Counter unsubstantiated claim
13	Student A	*And? If everyone gets vaccinated, you won't have people that infect others. The flu spreads when someone infects you. When someone coughs on you. Think that from the start no one can get sick because they are vaccinated, then they also can't infect you.*	Rationalistic (3)	Elaborative responses: Advance
14	Student C	*It can't vanish.* **What you wrote is incorrect**.	Intuitive	Non-elaborative responses: Reiterate **Non-elaborative responses: Dismiss**
15	Student A	*What's incorrect?!? I honestly don't understand.* **Alright! You know what?!? there's no argument.**		Interrogative initiations: Clarify? **Meta-dialogic statements: Refuse**

Notes:
* A shift from *italic type* to bold type font in utterances marks a change in the type of argumentative talk move.
** When a pattern of reasoning or the employment of a talk move is advanced over several turns, the coding will be accompanied by a number in parentheses.
*** In certain turns, the pattern of reasoning does not stand alone and could be identified only in relation to the following turn that revealed more clearly the student's reasoning (e.g., turns 3, 7)

Student A presents a claim that mass vaccinations can potentially eradicate certain diseases (1). Based on the data, this argument was coded as exhibiting *rationalistic* reasoning. The two other students in her group immediately *dismiss* her argument as incorrect (2, 3). Student A then cites the eradication of smallpox as evidence (4). Regardless, student B continues to dismiss the argument (5), then offers a *counterclaim* that smallpox was eradicated because all infected individuals died from the disease (7). Student A, in response, further advances her argument, stating that vaccinations, and not mortality, eradicated smallpox (9).

Student B then shifts the focus of the discussion to the flu, offering the *counterclaim* that it has not been eradicated, even though flu vaccines exist (10). Since it weighs factual disadvantages of vaccines, this argument was coded as informed by *rationalistic* reasoning. At this point, student A further pushes student B to *clarify* her disagreement (11). Instead of providing clarifications, student B reverts to an *intuitive* response and dismisses student A's claim without providing any additional elaborations (*counter unsubstantiated claim*). Student A further *advances* her *rationalistic* argument with a detailed explanation for why mass vaccination can prevent the spread of the flu (13).

As student C continued to *dismiss* student A's argument (14) who, in turn, *refused* to further participate in the discussion (15), the interaction collapsed. The confrontational tone of the argumentation led to its premature closure, as student A gave up her argument and replaced it in the group's controversy map with an argument that states that "getting vaccinated will significantly reduce the number of infected individuals" (Figure 3.1, blue callout).

If we combine student A's utterances from across the discussion, we can see that she raised a data-based claim (vaccines can eradicate certain diseases), provided a specific example for that principle from data (eradication of smallpox), and offered a mechanism through which this principle is achieved (prevents sick individuals from infecting others). She also challenged her peers to elaborate on their disagreement by asking for clarification. However, there is little verbal evidence of active listening by her peers. In fact, it appears that they were more interested in being confrontational with student A than in hearing and responding to her argument.

To justify mandatory vaccinations, other cards prepared by this group's members contained arguments that were less specific in their relation to science knowledge and less grounded in data. It was these arguments, however, that were more visible to the teacher and to the classroom than the ones raised during group argumentation. Their increased visibility relative to more scientific arguments can, therefore, potentially undermine the perceived value of SSI argumentation.

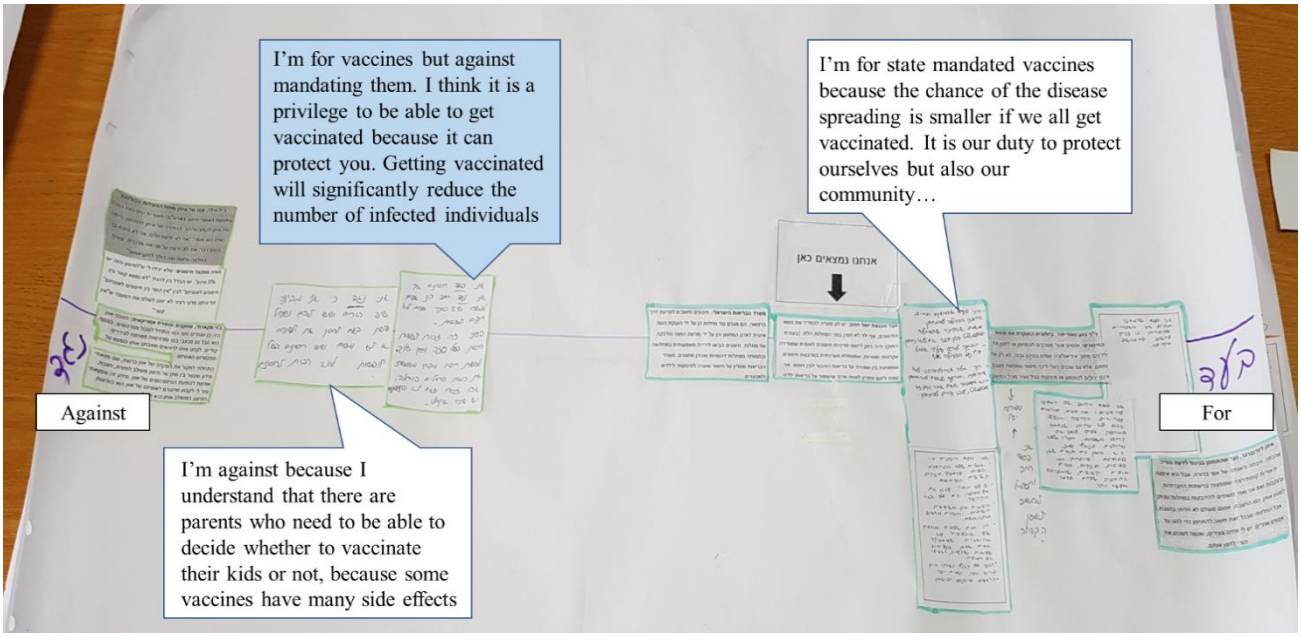


FIGURE 3.1 A photograph of the students' map, group 1. Callouts showcase translations of selected arguments. Blue callout is student A's final argument.

5.2.2 Sequence 2.B

The next sequence (Table 3.6) also illustrates confrontational talk, but with the added value of turns that illustrate productive argumentation. Here, we can see how arguments made by students E and F become increasingly advanced and substantiated when they seek to collaboratively advance their position, being in favor of mandatory vaccination, over the opposing student D.

TABLE 3.6 Sequence 2.B: third climax day, interdisciplinary module, peer-led discussion, group 2

Turn #	Speaker	Utterance	Pattern of reasoning	Argumentative talk move
1	Student F	*If there's a disease that's deadly and those who do not get vaccinated put the whole world at risk, then we should make it [vaccination] mandatory.*	Rationalistic (1)	Elaborative responses: Position
2	Student E	*It's better that the bacteria in your body be killed than be alive and kill you.*	Rationalistic	Elaborative responses: Advance
3	Student D	*But you can't force someone to get vaccinated. You can't tell them what to do with their bodies.*	Intuitive	Elaborative responses: Counterclaim
4	Student E	*Depends on the type of disease. If it's deadly, like smallpox, which by the way is extinct, but if it still existed today…*	Rationalistic (2)	Elaborative responses: Add substantiate (1)
5	Student D	*You can recommend getting vaccinated, but you can't just force people.*	Intuitive	Elaborative responses: Accommodate
6	Student F	*But they don't just put themselves at risk, they also put everyone else at risk.*	Emotive	Elaborative responses: Counterclaim
7	Student E	*Have you been in the math module? Look [draws an illustration explaining how R0 is calculated]. People marked with X are vaccinated and people marked with ○ are not vaccinated. This guy [points at his illustration], he wasn't vaccinated, so he got sick. These guys are vaccinated, so they're fine. These vaccinated guys saved all of these unvaccinated guys. They stopped the spread of the disease! There's a certain number of people who need to get vaccinated so that people like Mr. [student D], who don't want to get vaccinated, won't have to. It's R0 minus 1 divided by R0. So, 4 minus 1 divided by 4. So, three quarters of the world population need to get vaccinated.*	Rationalistic (3)	Elaborative responses: Add substantiate (2)
8	Student D	*I'm not saying that you shouldn't get vaccinated at any cost. Sometimes you need to get vaccinated,* **but it depends! Flu – against. Covid - probably for.**	Rationalistic	Elaborative responses: Acknowledge **Elaborative responses: Accommodate**
9	Student F	*But that's exactly our point! That's why we placed [our group's position card] in the middle [of our map]!*	Rationalistic	Elaborative responses: Acknowledge
10	Student D	*But you can't force people!*	Intuitive	Elaborative responses: Reiterate
11	Student E	*But it endangers other people!*	Emotive	Elaborative responses: Reiterate

Notes:
* A shift from *italic type* to bold type font in utterances marks a change in the type of argumentative talk move.
** When a pattern of reasoning or the employment of a talk move is advanced over several turns, the coding will be accompanied by a number in parentheses.

Earlier in the activity, student D stated that he is anti-vaccine because his parents refuse vaccines in favor of the non-interventional mechanism of illness recovery. To persuade him to be for vaccines, student F offered an argument that relied on *rationalistic* reasoning (1), stating that vaccines against deadly diseases should be mandatory, as unvaccinated individuals put others in their surroundings at risk. Student D remained firmly entrenched in his position, offering a counterclaim that did not offer reasoning beyond *intuitive* objection (3). Student E added *rationalistic* strength and data-based *substantiations* to student F's argument, stating that smallpox vanished after the discovery of vaccines (4).

At this point, student D softened his positionality by *intuitively* stating that vaccination can be recommended but not mandated, thus *accommodating* his peers' position (5). To further persuade him, student E stated a *substantiated* and *rationalistic* argument that relied on the mathematical calculation of basic reproduction ratio, which was introduced to students in the math module (7). Student D then revised and *accommodated* his argument to incorporate the weighted, *rationalistic* calculations in favor of vaccines that relied on his peers' arguments, and not just intuitive resistance (8).

This sequence, however, ended with a confrontational tone. Both sides returned to ignoring each other’s positions, as can be noted by the one-sided *reiteration* of previously stated claims (10, 11). To resolve their differences, the students opted for a voting strategy. To mark the group's positionality, each student assigned a numerical value to their position ranging between zero (total resistance) and 100 (complete support of mandatory vaccinations). The average of the group's positioning on the line was then calculated. Student F stated that she and student E *acknowledged* student D's opposition when they positioned themselves in the middle of the controversy line, which for them indicated that some, but not all vaccines should be mandated (9).

Despite his peers' acknowledgement and their scientifically based and data-substantiated arguments, student D assigned the value 30% to his position (in turns following the sequence presented in Table 3.6), placing his group's position on the resisting side (Figure 3.2). Moreover, most of their scientifically backed considerations, those whose appearance could potentially bestow value on SSI argumentation in the teacher's eyes, did not appear in their concluding remarks presented to the whole classroom. Instead, they stated that "It's not right to force someone to get vaccinated against their will, but sometimes you might have to because they can put everyone else at risk."

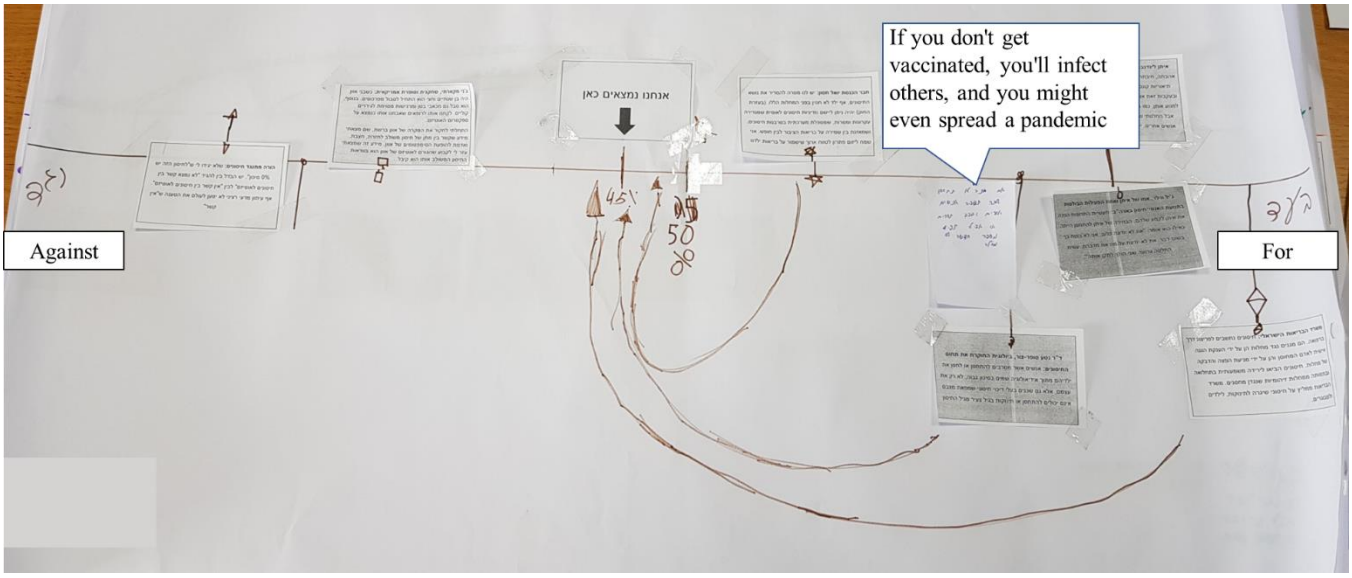


FIGURE 3.2 A photograph of the students' map, group 2.

5.2.3 Sequence 2.C

In the following sequence (Table 3.7), students exhibit uncritical agreement with each other's claims, even when such claims contrast with their own positions and with science knowledge learned earlier in the day. Though not confrontational, the result of such interactions may also background scientific knowledge and foreground students' subjective experiences.

TABLE 3.7 Sequence 2.C: third climax day, interdisciplinary module, peer-led discussion, group 3

Turn #	Speaker	Utterance	Pattern of reasoning	Argumentative talk move
1	Student G	*I'm for vaccines, but I don't think they should be mandatory.*	Intuitive	Elaborative responses: Position
2	Student H	*I'm also for vaccines but against mandatory vaccination*. **In the end, if you don't want to get vaccinated, it's your problem.**	Intuitive	Non-elaborative responses: Reiterate **Elaborative responses: Add**
3	Student G	*It's not only their problem. There are people with cancer and babies (who are vulnerable).*	Emotive	Elaborative responses: Counterclaim
4	Student I	*Unvaccinated people can also harm others in their surroundings.*	Rationalistic	Elaborative responses: Counterclaim
5	Student G	*I said the same thing.* **Basically, if you don't want to get vaccinated, it's your problem because you will be the one getting infected, and if you're vaccinated then you're protected.** [:] *But then there are people with cancer and babies who can't get vaccinated and it's just not fair.*	Intuitive [:] Emotive	Non-elaborative responses: Agree **Elaborative responses: Advance** Elaborative responses: Counterclaim
6	Student J	*I get that you can harm people around you, I also wrote that,* [:] **but you also have to think about yourself. Like, I've had several vaccines and they make me feel sick.** *I think that it should be elective. I don't think you should force it on people who don't want it.*	Emotive [:] Personal experience	Elaborative responses: Acknowledge **Elaborative responses: Counterclaim** Elaborative responses: Position
7	Student K	*There are also people, like my dad, who are afraid of needles and can even faint if they see a needle.* [:] **I think that if most of the population is already vaccinated, then we shouldn't force it on people.**	Personal experience [:] Rationalistic	Elaborative responses: Add **Elaborative responses: Position**
8	Student J	*My dad got the flu vaccine and a few minutes later his hand started to hurt.* [:] *It also takes like a month until it starts working and you can get infected in that period.* **So, I don't think we should force it on people.**	Personal experience [:] Rationalistic	Elaborative responses: Add **Elaborative responses: Position**

Notes:
* A shift from *italic type* to bold type font in utterances marks a change in the type of argumentative talk move.
** [:] marks a change in the type of reasoning used in the argument.

Throughout most of the sequence, these students exhibited uncritical agreement with each other. This is evident in the response to student H's *intuitive* claim that vaccines should not be mandated because unvaccinated individuals put only themselves at risk (2). Students G and I provide *counterclaims*, stating that vaccine refusal risks immunocompromised individuals and may lead to widespread infection, thus representing *emotive* (3) and *rationalistic* reasoning (4). Yet, in a later turn, student G *advances* student H's claim that unvaccinated individuals risk only themselves, even though it is not attributable to science knowledge. Only after such an agreement is established does student G provide a *counterclaim* motivated by *emotive reasoning*, repeating the social need to protect immunocompromised individuals (5).

Student J then *acknowledges* the potential societal benefits of mandated vaccinations (6), but quickly shifts the focus and presents a *counterclaim* for mandatory vaccinations that relies on her *personal experiences*. Student K *adds* details that rely on her *personal experience* as well (7). Together, they object to mandatory vaccinations for reasons pertaining to their past experiences (6), their familiarity with people who are afraid of needles (7), and their familiarity with people who have had adverse side effects to vaccines (8). These claims were not backed by an objective body of knowledge, but nonetheless were accepted uncritically by the group.

The groups' positioning on their map was at the extreme end of the "against" side (Figure 3.3). The students' justification for their positioning illustrates that considerations related to their personal experiences and emotions eventually drove their resolution of the dilemma. They stated that "we think that vaccines should not be mandatory because there are traumatized and anxious people [about vaccines]" (personal experience), with the claim that "it's good to get vaccinated so as to not endanger cancer patients and babies" (emotive reasoning) added as a reservation (Figure 3, blue callout).

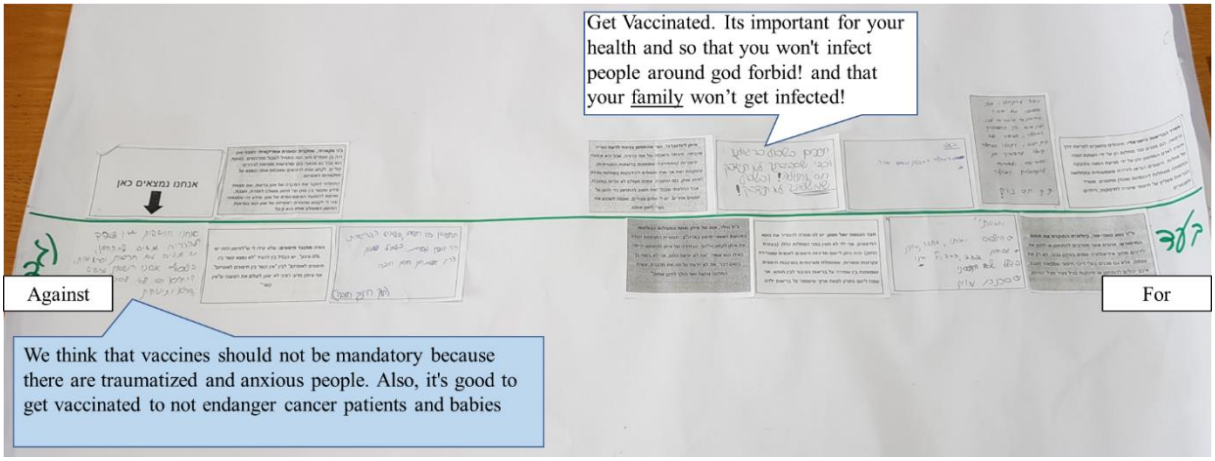


FIGURE 3.3 A photograph of the students' map, group 3. Blue callout is the group's final argument.

5.2.4 Summary of findings from peer-led argumentation

At times, students who participated in peer-led small-group argumentation developed arguments that relied extensively on science content and rationalistic reasoning. Such arguments might have been raised when students wanted to strengthen their position in countering their peers' objections. On such occasions, students developed their arguments across several talk turns and offered more elaborate arguments in comparison to those raised in teacher-led argumentation. However, when the argumentation became heated and confrontational, students sometimes refused to acknowledge their peers' scientifically backed arguments. Conversely, students in arguments who aimed to reach a quick consensus neglected valuable critique of arguments that lacked validity, and which relied more prominently on subjective experiences and intuition. Moreover, though instances in which students relied more on science knowledge were noticeable in the group talk, they were eventually backgrounded in the more visible end product of the argumentation—the controversy map and its presentation.

6 Discussion

To date, progress on the implementation of SSI argumentation has been modest at best, and superficial in many documented cases (Tidemand & Nielsen, 2017). In this regard, the perceived fit of organizational practices with dominant organizational objectives is widely recognized as crucial for substantive adoption (Coburn, 2004). We join this insight and argue that to move toward sustainable and substantive implementation of SSI argumentation as a core instructional practice, this perceived fit needs to be examined. However, the interactional conditions under which SSI argumentation can be more integrative and coherent with dominant schooling norms and objectives are murky.

To navigate this uncertain situation, we first showed that what places SSI argumentation outside the basis for justifiable implementation may be related to two substantial tensions with contemporary schooling objectives: one related to the *content* of learning interactions (Rundgren et al., 2016; Sadler & Zeidler, 2005), and one related to the *form* of learning interactions that emerges in alternative participant structures (Zafrani & Yarden, 2022a). Efforts to implement SSI argumentation as a core instructional practice, we argue, must address and alleviate these tensions. Otherwise, the achievement of schooling objectives may be seen as threatened.

We set forth with such efforts in an extra-organizational free space shielded from organizational conflicts and tensions, in which teachers and students could participate in SSI argumentation in ways that might be disapproved of inside schools. In this testing ground, learning interactions that were effective, and those that required modification to be considered compatible with schools could be identified. Qualitative exploration of the interactional details of enactments of SSI argumentation may shed some light on how practical integration could potentially begin to take place.

We explored how the details of classroom interactions occurring during SSI argumentation might illuminate the conditions under which students rely more prominently on science knowledge and rationalistic patterns of reasoning, but also the conditions under which such reliance is undermined in favor of subjective knowledge claims. Thus, our findings identified some factors that may allow the integration of SSI argumentation as a core instructional practice, but also emphasized the associated challenges. In the following, we discuss these in relation to what is known from previous studies.

6.1 When pedagogical innovation and tradition converge

Previous studies have suggested that it is personal experience, intuition, and emotional considerations—and not scientific understanding—that provide the primary guide for students' negotiations of SSIs (Nielsen, 2012; Venville & Dawson, 2010). Though rich in personal contexts that can encourage students' engagement (Furberg & Silseth, 2021; Zeidler & Sadler, 2007), such reliance on subjective knowledge may also distance SSI argumentation from its potential integration with schooling culture, where the priorities favor objective scientific knowledge and rationalistic reasoning (van Der Zande et al., 2009; Venville & Dawson, 2010).

The literature suggests that the absence of teachers' use of interrogative interactions in classroom discussions may hamper productive reasoning (Lowell et al., 2022; Pimentel & McNeill, 2013). Our observations of teacher-led interactions indeed suggested that when teachers do not employ interrogative talk moves, students' contributions often do not extend past subjective knowledge (Table 3.8, teacher-led non-interrogative talk). However, where interrogative interactional moves were employed more prominently, such as when teachers asked students to elaborate their thinking, students' reliance on rationalistic reasoning seemed more visible (Table 3.8, teacher-led interrogative talk). In our data, this was achieved through the use of moves that went beyond mere elicitation to include requests for clarifications and

justifications over several turns. Thus, teachers' employment of such talk moves may render the products of SSI argumentation more suitable for the culture of contemporary schooling.

In certain talk conditions of peer-led argumentation, students' arguments relied extensively on science knowledge and rationalistic reasoning. As in previous studies (Arvola & Lundegård, 2012; Nielsen, 2012a), our data illustrate that such reliance occurred when students had to defend their argument in the face of opposition. The granular details of the interactions reveal that this was achieved through the employment of moves that added substantiations and strength to arguments in response to opposition that relied on more subjective and less valid knowledge (Table 3.8, peer-led confrontational and productive talk).

It appears, then, that critiquing talk initiated by teachers (e.g., follow-up interrogations) or by students (e.g., expressing opposing arguments) may have given more prominence to arguments that rely on science knowledge and rationalistic reasoning compared to instances where critique was absent.

TABLE 3.8 Structure, organization, and product of SSI argumentation

Participant structure	**Organization of interactions**	**Key talk moves (according to Felton et al., 2019)**	**Product of interactions**
Teacher-led	• Non-interrogative talk: Eliciting students' ideas with no follow-up questioning • No attempt to compare students' differing positions	*Position?* *Interpret*	• Subjective knowledge claims mediate the argumentation • Undeveloped reliance on science knowledge and rationalistic reasoning
	• Interrogative talk: Eliciting students' ideas with responsive follow-up questioning • Minimal attempt to compare students' differing positions	*Clarify?*	• Arguments are developed across several turns • Increased reliance on science knowledge and rationalistic reasoning • Minimal critiquing activity
Peer-led	• Confrontational talk: No attempt to explore differing positions	*Counterclaim,* *Dismiss*	• Reliance on science knowledge and rationalistic reasoning to convince an opponent • Absence of listening and argumentation collapse
	• Productive talk: Attempt to explore differing positions without neglecting critique	*Counterclaim,* *Substantiate,* *Advance,* *Accommodate*	• Reliance on science knowledge to convince an opponent • Listening to and acknowledging differing positions
	• Uncritical talk: No attempt at critiquing differing positions	*Agree, Add*	• Subjective knowledge claims mediate the argumentation

6.2 When pedagogical innovation and tradition collide

While showing the potential for SSI argumentation to converge with schooling culture, our findings also illustrate instances of potential collision. Overall, our findings show that teachers may lack the knowledge and competence needed to intensify students' reliance on science knowledge and support productive argumentation in both teacher-led and peer-led participant structures.

In teacher-led interactions, our observations suggest that teachers may have difficulty managing argumentation in productive ways. This was most notable in the absence of talk moves that required students to critique and expand each other's contributions. Instead, and similar to previous studies (Lowell et al., 2022), teachers in our study often opted to elicit arguments individually (Table 3.8, Teacher-led interrogative and non-interrogative talk). This action may be problematic for the integration of SSI argumentation into schools as it does not elevate student arguments that rely on science knowledge and rationalistic reasoning compared to those that rely on subjective knowledge.

Our findings also suggest that a peer-led organization of talk may impinge on the form of argumentation, as also identified in previous studies where it was related to students' sociability issues (Bathgate et al., 2015). In our data, argumentation tended to be confrontational and marked with disagreement and dismissal of opposing stances (Table 8, peer-led confrontational talk) or conversely, marked with uncritical agreement with arguments that rely on personal experiences and emotions (Table 3.8, peer-led uncritical talk). Though both cases differ in their form of argumentation, the ultimate result, as illustrated in students' artifacts, tended to obscure their prior reliance on science knowledge. Such instances can potentially hinder the acceptability of SSI argumentation as a core instructional practice.

Before becoming non-productive, peer-led argumentation in small groups elicited more scientifically robust arguments than the teacher-led discussions did. However, because the teacher circulated among the peer groups, these arguments were mostly visible to the group members and hidden from the teacher's attention. These findings suggest that the teachers carry some responsibility in the efforts to render argumentation in small groups more productive, and that they may lack knowledge and competence in managing group dialog. Therefore, to reconcile SSI argumentation and schooling tradition, more proactive involvement may be required from the teachers to build capacity for argumentation that is not confrontational or uncritical, as well as to leverage instances where students rely on science knowledge so that such instances will not be confounded within the group talk.

6.3 Implications

This study extends previous work in that it attributes an instrumental significance to teachers' employment of talk moves that have been recognized as productive (Felton et al., 2019; Lowell et al., 2022), but not as an end in and of itself. Given that schools do not prioritize SSI argumentation, such an approach may induce resistance in practice (Kilinc et al., 2017). Rather, we argue, successful implementation may lie in adjusting those aspects of the traditional objectives that directly impede SSI argumentation, while still maintaining the compatibility of SSI argumentation for achieving said objectives. Such leveraging of the customs of work to bolster a pedagogical innovation may allow schools to experiment with pedagogies without having to digress significantly from their existing repertoire of practices (Bingham & Burch, 2019).

The ways in which this aim can be achieved are born out of the instrumental significance of productive argumentation. Our findings draw attention to the particular importance of teacher preparation for the implementation of SSI argumentation in ways that manage its incompatibility with schooling objectives, thereby reducing the risks and costs of this pedagogy. Such preparation might include an emphasis on the use of talk moves that can shift talk away from subjective experience and toward objective contributions that are more valuable within the culture of schooling. Previous studies have shown that increasing teachers' awareness of productive interactions improves classroom talk (Oliveira, 2010). Our findings extend this work and show that without such awareness, enactments of SSI argumentation can easily sway toward more subjective and trivial knowledge claims, which may be less valued in science classrooms (van Der Zande et al., 2009).

It is important to state that we certainly do not endorse the exclusion of students' reliance on personal experiences, intuitions, and emotions. The realm of subjective experience remains a fertile ground for students' equitable engagement (Furberg & Silseth, 2021; Zeidler & Sadler, 2007). However, in a culture that places a premium on objective scientific knowledge, reliance on subjective experiences may prevent the incorporation of SSI argumentation altogether. Rather, we asked how SSI argumentation can be integrative and in service of the norms and goals that schools are currently set to achieve while remaining rigorously directed toward the scientific and dialogic goals of argumentation. Though research remains to be done, our hope is that our findings will contribute to the design of TPD courses that can support larger-scale and permanent adoption of SSI argumentation.

7 Limitations

While we believe our study can contribute to the implementation of SSI argumentation in schools, it also has limitations. The first relates to the data sources. This study focused on the parameters of classroom interactions separated from the attributions of individual teachers and schools. However, successes or failures within this educational intervention may not be exclusively explained by properties inherent to the intervention and can also be attributed to its fit with pre-existing school characteristics, or the pedagogical capacity with which teachers implement the intervention (Coburn, 2004). In this sense, future research could potentially benefit from tracking school- and teacher-level conditions to answer the question of why enactments of SSI argumentation unfold differently across teachers and participant structures. The second limitation relates to generalizability. While the small sample size did enable a detailed view of the mechanisms of enactments, which cannot be observed on a large-scale, generalizations from the findings to larger sets of science teachers and students cannot be made.

CHAPTER 4. Discussion and conclusions

> *"It is difficult to get someone to understand something, when their salary depends upon them not understanding it" (Sinclair, 1935, p. 109)*

1 Integrating theory and methods for the advancement of dialogic argumentation

While the research in this dissertation was conducted in Israel, the puzzle it attends to is global - educational reformers and researchers are trying to advance student-centered pedagogies in a school system geared mainly towards teacher-centered pedagogy (Mehta & Fine, 2019b). Reform mandates advocating for the incoming of dialogic argumentation into schools also belong to this movement. Grounded in constructivist notions of learning, these reform mandates sought to shift the object of science instruction from focusing on a collection of facts and science terminologies to the induction of students to the epistemologies, norms, and dispositions of science (NGSS, 2013). To approximate this objective, proponents of this view argue, committing science knowledge to memory is insufficient. Instead, learning must allow students to collaboratively construct explanations of their own to scientific phenomena and examine those explanations against evidence and against the explanations of their peers (Driver et al., 2000; Kuhn, 2010; Macagno et al., 2015; Ryu & Sandoval, 2012, 2015), just like professional scientists do.

However, we continue to find substantial evidence that reform mandates advocating for the incoming of dialogic argumentation, such as the NGSS (2013) and the NRC (2012), have been unsuccessful in penetrating schools' walls at scale and in influencing how teachers teach and students learn science (Henderson et al., 2018; McNeill & Berland, 2017; Teo, 2019; Wilkinson et al., 2017). Relating to both the constraints and affordances for implementation, this dissertation is focused on why it is so difficult - and what would it take - to dislodge the dominant teacher-centered pedagogy and modes of interaction for the incoming of dialogic pedagogy. I, therefore, began this dissertation by raising the overarching question:

> *Why don't more schools, and the teachers who work in them, seek to incorporate dialogic argumentation more prominently into their science classrooms, and what can be done to help them to do so?*

Relating to this two-part question, a recurring argument encountered throughout both studies that compose this dissertation was that organizational actors might implement innovative practices to the extent that these practices are considered legitimate inside their

organizations (Bingham & Burch, 2019; Bridwell-Mitchell, 2013; Heinze & Weber, 2016; Malhotra et al., 2021; Sonenshein, 2016).

Lending impetus and validity to this argument are previous studies that illustrate how this process of implementation might occur in varying organizations. For example, in healthcare organizations, medical professionals were more successful in integrating practices that diverge from western medicine, and that belong to integrative medicine, after they learned what approaches were most effective in limiting the resistance that might arise when introducing these practices to their organization (Heinze & Weber, 2016). In university-industry collaborations, university researchers working in an environment who values open publishing and academic freedom, were more willing to embrace industry-oriented practices that adhere to a commercial value to the extent such practices did not jeopardize high-quality academic research (Perkmann et al., 2019). In law firms, actors who advocate for work-family balance in work-intensive environments, strategically responded to anticipated resistance by discursively minimizing the threat of new practices to the legitimate conduct of their organizations (Malhotra et al., 2021). Jointly, these studies seek to understand how the implementation of a new organizational practice can be pursued and attained in an environment highly constrained by formal structures and routines that might make the new practice appear illegitimate.

I extend this line of research in the two studies that comprise this dissertation by exploring how the process of implementation of dialogic argumentation, a practice that may not be accepted as legitimate, unfolds in the educational field, and in school organizations. Both studies squarely position verbal interactions between teachers and students, and between students and their peers, at the heart of both constraints and affordances to efforts to implement dialogic argumentation in science classrooms. However, they differ in their focus and explore the process of implementation from complementary theoretical lenses.

The study outlined in Chapter 2 is focused on how the practice of dialog argumentation may be excluded from the interests and missions of contemporary school organizations and, therefore, perceived as illegitimate. In other words, it explores in granularity how instructional practices can become *separate* from schools' organizational conduct, thereby answering the first part of the overarching question that deals with constraints to implementation. Conversely, by focusing on opportunities to better align dialogic argumentation with the interests and missions of contemporary schooling, the study in Chapter 3 explores how instructional practices can become *reconciled* with organizational conduct. As such reconciliation depends on the perceived legitimacy of the new practice by the target audience (Sonenshein, 2016), this

exploration proposes an initial important step towards resolving the second part of the overarching question that deals with affordances for implementation.

In this discussion, I seek accumulativeness and dialog among this diversity of perspectives to develop analytical and thematic connections between the two studies. Below I discuss the contributions from both studies to theory and to practice and formalize the findings into propositions.

2 Contributions to theory

2.1 The conditions that entails for practice separation

In Chapter 2, I present an analysis of the relationship between how teachers are accustomed to do their work and the development of new teaching practices aimed at enhancing dialogic argumentation. This analysis is built around a view of organizations as institutionalized, which means that they operate according to taken-for-granted, master principles, termed institutional logics, that define and shape legitimate organizational behavior and provide motives for organizational actions (Reay & Jones, 2016; Thornton & Ocasio, 2008; Zilber, 2016). Focusing on school organizations, this means that teachers' definitions of what it means to teach in legitimate ways are embedded within and shaped by the organizational culture of their schools, which are themselves embedded within and shaped by wider institutional logics (Bridwell-Mitchell, 2015).

Institutional logics not only prescribe what constitutes taken-for-granted organizational missions, but also provide legitimate means to achieve these missions (Thornton & Ocasio, 2008). In this sense of embeddedness, macro-level institutional understandings are embedded in teachers' work and, thus, in micro-level classroom learning interactions (Heritage, 2005; Sarangi & Roberts, 2008; Seedhouse, 2004). That is, classroom interactions can be positively related to institutional mandates, and therefore legitimate, if they are structured in such a way that advances the attainment of organizational missions. To the contrary, classroom interactions can be negatively related to institutional mandates and illegitimate if they undermine the attainment of such missions,

I, therefore, propose in this study that these two levels of social structuring, the institutional and the interactional, shape instructional practices inside schools. The data from this study revealed two important insights; the existence of a shared teacher understanding about the appropriate missions of schools, and the existence of clear interactional structures

used in classrooms to fulfill these missions – both of which misaligned with the mission of recent reform documents in general, and of this study in particular, to implement dialogic argumentation.

The analysis grounds three central institutional logics that provide teachers guidance to how to teach in appropriate ways, the logics of: *accountability*, *tracking*, and *the profession*. Of course, not all teachers invoked these logics with the same intensity, but they all expressed the notion of being constrained by the same aggregate of institutional mandates that imbue their work with sources of legitimacy.

All these logics intertwine with each other in how they inform appropriate instruction and undermine dialogic argumentation. Invoking the logic of *accountability*, teachers took their cues for what is worth teaching exclusively towards the material that will appear in standardized tests. In this form of classroom conduct, the accurate acquisition of science vocabularies and facts, and not the collaborative construction of knowledge, appears to compose the objectives of learning. Institutionalized *tracking* meant to teachers that accessibility to high status science knowledge should be stratified across tracks. Thus, instead of committing to provide equal opportunities for students to engage in demanding learning practices, acting by this logic may have deprived low track students of engagement with dialogic argumentation. Invoking the logic of the *profession*, teachers saw themselves as the ones who were primarily responsible for students' learning, not the students themselves, or a collaboration between teachers and students. Learning, by this logic, was made possible by directly providing students with science knowledge and facts.

I then proposed, by connecting classroom talk to its institutional context (Heritage, 2005; Seedhouse, 2005), that schooling objectives justified by the macro-level logics of accountability, tracking, and the profession were all made achievable through micro-level classroom interactions, thereby suggesting that the institutionalization of schools may rest on an interactional bedrock. Grounded in in-depth analysis of verbal classroom interactions, I suggested that teachers may design classroom conduct and orient learning interactions by reference to the goals and missions of the school institution, as they understand them. These institutionally sensitive interactions typically follow the IRE pattern of talk. I connected the structure of classroom interactions to their institutional contexts by exhibiting features of actions and teacher-student relations that are characteristic to the school institution. I then argued that the institutional context may be positively related to the maintenance of interactions

that engender teacher-centered instruction, and negatively related to dialogic interactions in the sense that such interactions are avoided.

Specifically, I showed that by orienting to the logic of accountability, interactional sequences were designed to resemble testing, in which teacher questions and evaluations directed students towards accuracy. Such interactions undermined the exploration of students-generated understandings, which is needed for productive argumentation (Lowell et al., 2022; Pimentel & McNeill, 2013). Orienting to the logic of tracking, teacher questions invited students' reliance on mere common sense. This contrasts with the conception that all students should be afforded access to high-status and demanding learning opportunities (Hodge, 2019; NGSS, 2013). Finally, it was clear that an important principle of dialogic argumentation - that teachers, and students should assume symmetrical responsibilities in knowledge construction (Berland et al., 2020; McNeill & Berland, 2017; Miller et al., 2018) - is not a feature of institutionalized classroom talk. Instead, and orienting to the logic of the profession, interactional asymmetry arose from the predominant IRE pattern, where teachers were not only the ones asking the questions, but also the ones doing most of the intellectual work to answer them.

Examining the IRE pattern as a form of institutional talk explicate the ways in which institutional missions are carried in classrooms through the management of interactions (Arminen, 2017). The findings from Chapter 2, therefore, can explain how the institutional order binds and regulates the interactional order in such a way that excludes the employment of dialogic argumentation from being considered as a legitimate instructional practice. They suggest that IRE became the incumbent mode of classroom interaction because it is consistent with teachers’ perceptions about which interactions work effectively to achieve their school's missions, which renders IRE legitimate.

Conversely, the findings show that dialogic interactions are not consistent with institutional logics that bind and regulate schools' conduct, which may lead teachers to see such interactions as illegitimate and, consequently, be resistant to their incoming into their classrooms. By understanding how interactions that follow the IRE pattern are positively related to institutional mandates we can understand how interactions conducive to dialogic argumentation can be negatively related to the same mandates. Learning by means of dialogic interactions departs from institutional talk in that it requires uncertainty-driven and open questioning, more symmetrical interactional relationships between teachers and students, and is required to be deployed equitably across tracks.

The findings also solidify our knowledge about how learning interactions actively reify and maintain the institutional order within which they are recognized to occur. I show how the very act of teaching and learning by means of IRE directs teachers and students towards reinforcing an assemblage of institutional understandings. Specifically, when the IRE pattern is employed in the classroom it reaffirms the logic of accountability by placing premium on closed and fact-driven questioning, the logic of tracking by reducing the difficulty of questioning to match the perceived abilities of low track students, and the logic of the profession by maintaining interactional asymmetry. In this way, we can begin to understand how the constraints to dialogic argumentation which operate in the institutional level take on tangible realization in the interactional level.

When combined, conclusions derived from macro- and micro-level data shows that the socially constructed conduct of schools is both shaped by institutional logics and a collection of institutionally-specific interactional practices. These conclusions may thus provide insights into mechanisms enacted to keep the practice of dialogic argumentation separate from the habitual conduct of schools. Formalized as a proposition, I offer the following:

> *PROPOSITION 1: The request to implement dialogic argumentation, with its underlying principles and epistemologies, not only strips teachers from their existing interactional routines but may also symbolizes to them the displacement of expectations, norms, and values that they relied upon to make sense of their work. Therefore, implementing dialogic argumentation may mean to teachers, and to the schools in which they work, that legitimacy will no longer be taken-for-granted, but at risk of erosion.*

To put it differently, teachers may experience great difficulty reconciling the institutional understandings they rely upon to define their work with dialogic argumentation which is perceived by them as far removed from those definitions. Therefore, when insights gathered from the macro- and micro-level data are taken together, the documented absence of dialogic argumentation from classroom practice (Duschl & Osborne, 2002; Henderson, McNeill, González-Howard, Close, & Evans, 2017; Katsh-Singer et al., 2016) becomes understood as part of the process of the institutionalization of schools.

2.2 The conditions that entails for practice reconciliation

Legitimacy, then, may entail the separation or the reconciliation of a practice from the habitual conduct of organizations. As corollary of the first proposition, I assert that finding ways to carry out the practice of dialogic argumentation in ways that are broadly consistent, and not conflicting, with the elements deemed legitimate inside schools can potentially improve the

chances of practice acceptability and implementation. The study in Chapter 3 frames this strategic response to implementation resistance as an action of reconciliation between what dialogic argumentation can achieve in terms of learning and the schooling version of quality learning. The study in Chapter 3 provides insights into how teachers can begin to overcome the tensions associated with changing instruction in ways that can be perceived as undermining the functioning of their schools. This study can, therefore, be viewed as an initial step towards actualizing the action of practice reconciliation as a strategic response to implementation resistance.

The study in Chapter 3 is based in the context of SSI argumentation. This form of argumentation is focused on controversial social issues that encompass an intricate relationship between science concepts and phenomena and ethical and moral considerations (Sadler & Donnelly, 2006). By engaging with SSI argumentation, it is argued, students can become not only more scientifically literate (Nielsen, 2012b), but can also, through arguing on urging social concerns, undergo a process through learning by which they can enact responsible democratic tendencies (Bencze et al., 2012).

In this chapter I argue that a better resemblance of these processes of learning by argumentation to the typical learning in contemporary schools, might improve its uptake by teachers. Based on current literature, I suggest that conjoining the goal of learning by means of SSI argumentation with the goals and practices of contemporary schooling may surface two major tensions, which can shift the balance between the two. Primarily, I argue, science learning in schools opposes learning by SSI argumentation by its detentions to valued and desired content and form of learning interactions. Pertaining to the varied definitions of valued content of interactions, school science tend to place premium on the use of objective science content and understandings in students' contributions (Dawson & Venville, 2009; Nielsen, 2012a; van Der Zande et al., 2009; Venville & Dawson, 2010), while SSI argumentation may engender interactions that rely on subjective forms of knowledge and prior experiences (Christenson et al., 2012; Sadler & Zeidler, 2005; Zeidler & Sadler, 2007).

Further complicating this impediment, and pertaining to the varied definitions of valued forms of interactions, students' participation in argumentative talk may produce counterproductive argumentation in that it may be confrontational (Bathgate et al., 2015), or uncritical (Albe, 2008), and may further distance students from reliance on objective science knowledge (Venville & Dawson, 2010). To preserve what they perceive as appropriate means

and ends of science instruction, then, teachers adhering to traditional instructional practices and goals of schooling may oppose implementing SSI argumentation (Kilinc et al., 2017).

To extend our understanding of how SSI argumentation can better resonate with the conduct of contemporary schools, I examine tensions pertaining to the content and form of learning interactions unfold through a moment-by-moment analysis of classroom talk. This exploration, I contend, could allow us to identify the conditions that lead to productive argumentation so that they could be further capitalized to achieve resonance with schooling objectives. Observations of teachers' enactments of SSI argumentation in a specially designed free space, shielded from the pressures of day-to-day schooling, termed here as *climax days*, were conducted for this purpose.

Through the analysis of learning interactions, I suggest that content- and form-related tensions, that can be harmful to implementation of SSI argumentation, can be either alleviated or intensified by the ways in which teachers manage the argumentative activity. Though previous studies show that science tends to disappear from students' negotiation of SSI (Ottander & Simon, 2021; Venville & Dawson, 2010), the data from Chapter 3 shows that when teachers were employing interactional moves that are critiquing and interrogative in their function, increased students' reliance on science knowledge is observed. When this occurs, argumentation appears more compatible with the traditionally understood meaning of quality learning, thus potentially moving towards being better embraced inside schools.

However, in other instances of argumentation, teachers appeared to abstain from deploying interactional moves that encourage critique and, consequently, shifting the talk towards subjectivity and away from science and, thereby, away from being accepted inside schools. The use of interrogation and critique also showed a potential in swaying peer-led argumentation towards resembling the schooled version of quality science learning. However, teachers appeared constrained in their capacity to leverage such inter-group instances to benefit the rest of the classroom, therefore curtailing the reach of such productive forms of argumentation.

Such instances of unproductive argumentation, or constrained capitalization of productive forms of argumentation, occurred despite TPD efforts that aimed to provide those teachers with wide array access to knowledge and skills necessary to the endeavor of SSI argumentation. It is, therefore, imperative to acknowledge the data that suggest that the knowledge and skills required to sustainably transform teaching towards dialogic argumentation may not be easily acquired. These findings resonate with previous studies that

illustrate the constrained capacity of TPD to support teachers in handling the pedagogical challenges that may arise during enactments argumentation-supporting activities. Similar to previous studies, the data shows that TPD may not be successful in helping teachers to acquire and exploit knowledge about productive ways to manage dialogic learning interactions (Lowell et al., 2022; McNeill, González-Howard, et al., 2016; Pimentel & McNeill, 2013).

To sum, overcoming some of the constraints of day-to-day schooling by the establishment of a space that may have liberated these teachers from these barriers may also have created the occasion for engagement with dialogic argumentation. However, due to the teachers' constrained capacities to manage dialogic interactions, the products of this engagement mostly focused on students' subjective knowledge and were, thus, far removed from those valued within the contemporary schooling culture. This could potentially constrain the future transfer of dialogic argumentation from the extra-curricular free space into the rest of the school organization. Thus, the successful delivery of dialogic argumentation may require from teachers the effective acquisition and utilization of interactional practices through which "closer to schooling" content and form of learning interactions could be extracted. Formalized as a proposition I offer the following:

> *PROPOSITION 2: Teaching by means of dialogic argumentation can produce outputs valued by the standards of contemporary schooling, thus potentially producing practice legitimacy and increasing chances of implementation. However, this achievement is profoundly sensitive to the knowledge and competence of the teachers who bring it about. If teachers are constrained in their capacities to manage argumentative interactions, learning outputs can steer away from what is deemed as valuable learning inside their schools, potentially making this practice appear as illegitimate.*

This proposition, thereby, positions teachers as capable at either mitigating or aggravating practice illegitimacy. Assuming the low returns yielded from unproductive forms of argumentation, pursuing broader organizational change beyond the low-stake experimental zone of the free space may invite resistance and scrutiny from teachers who adhere to traditional pedagogies who can be potentially affected in their day-to-day missions. The second proposition, then, extends the first one by suggesting that in the ability of teachers to generate legitimacy for their schools by means of dialogic argumentation, the acquisition and deployment of new knowledge in teaching is imperative. Thus, successful implementation may require not only overcoming institutional constraints, but also the effective adoption of knowledge-related aspects of argumentation, through which legitimacy can be generated.

3 Contributions to practice

Combined, the two propositions encompass both teachers' *willingness* (the perceived legitimacy of a practice) and *ability* (the knowledge and competence needed to carry dialogic activities) to respond to reform mandates that advocate for the advancement of dialogic argumentation. The propositions also account for the interactional mechanisms that explain how these two factors may mediate instruction in science classrooms away from dialogic argumentation and towards teacher-centered pedagogy. Where do teacher educators come into this process of supporting teachers' knowledge and legitimating a new instructional practice? I argue that this more informed theoretical understanding about the institutional conditions of teaching could also help teacher educators to design and disseminate TPD courses that address more directly challenges that pertain to issues of teachers' willingness and ability to implement dialogic argumentation. For this reason, these propositions also matter for practical reasons, with which the remainder of this discussion is concerned.

3.1 An institutionally informed professional development

It is tempting to suggest practical conclusions for the advancement of dialogic argumentation that may affect the level of teaching practice by means of fundamental systemic changes, such as de-centralizing school systems to be less bounded by state accountability standards, or de-tracking entire schools. However, such fundamental changes may not only involve substantial financial investments and intense reaction from those who identify with the current structuring of schools, but may also be profoundly ineffective in sustaining instructional change. Previous studies showed that when efforts to restructure school systems in these manners were not explicitly coupled to the instructional practice the sought to change, they were mostly unsuccessful in leading teachers to teach differently (D. K. Cohen & Mehta, 2017; Cuban, 2013; Elmore, Peterson, & McCarthey, 1996; Oakes, Quartz, Ryan, & Lipton, 2000). Indeed, the findings presented in Chapter 3 suggest that overcoming certain structural barriers of schools may not work as a straightforward road leading to sustainable and large-scale implementation of dialogic argumentation.

If *fundamental* paths towards *extensive* instructional changes, such as structural changes (Elmore et al., 1996; Oakes et al., 2000) and reform mandated changes (Henderson et al., 2017) have been largely ineffective in sustainably changing instruction from being teacher- to student-centered, what would an alternative look like? As top-down change can be viewed by teachers

as something done *to* them and not *with* them (Ball, 1989), I attempt to relax the assumption that fundamental restructuring of schools can lead to instructional change. Instead, and in line with the propositions suggested above, I offer practical conclusions which follow an *incremental* path towards *piecemeal* instructional change.

Recognizing that TPD courses can serve as an instrument that better aligns reform mandates and classroom instruction (Wilkinson et al., 2017), in the remaining paragraphs I suggest, subject to future empirical work, institutionally informed design principles for TPD courses. These design principles specify the factors that can contribute to the advancement of a new practice that may be perceived as illegitimate by teachers in potentially sustainable and substantive ways. Primarily, a TPD designed by these principles aims to gain acceptance and approval by teachers and schools by fitting the new practice to reflect, and not contrast, their underlying values and beliefs about appropriate instruction. This means that the success of its implementation is likely to be determined by the alignment between the pedagogical values implied by the practice and the values underlying the school organization. Unlike the process in which teachers focus on similarities between surface-level features of a new practice and their existing practices (McNeill, González-Howard, et al., 2016), these design principles aspire to hone in on the deeper-level conceptual attributes of a new practice to and to see how they can achieve appropriate organizational conduct. These design principles also recognize that it may be difficult for teachers to achieve such alignment without opportunities to learn and develop interactional know-hows in terms of productive argumentation. Therefore, these design principles regard the success of implementation of dialogic argumentation as dependent on both teachers' *willingness* and *ability* to be responsive to implementation demands.

3.2 Accounting for teachers' willingness and ability to implement dialogic argumentation: an institutionally informed approach

A practice becomes infused with legitimacy when organizational actors see the value of using it to achieve taken-for-granted missions and goals of their organization (Heinze & Weber, 2016). For teachers, if a practice prevents them from pursuing certain goals important to the reaffirming of the conduct of their schools, it will be perceived as illegitimate (Bridwell-Mitchell, 2015). In schools, this means that successful implementation of an illegitimate practice may depend on its ability to be converted into the more familiar and less threatening discourse of day-to-day conduct of schools. In this sense, TPD courses can attempt to influence teachers by imbuing the practice of dialogic argumentation with meanings that correspond with

institutional mandates imposed on teachers and schools.

One way that this could be accomplished is by purposefully highlighting the attributes of a practice that can satisfy the institutional demands that organizations conform to (Perkmann et al., 2019; Sonenshein, 2016; Wright & Nyberg, 2017). Such an approach was previously termed as the advancement of organizational ambidexterity (Bingham & Burch, 2019), organizational pluralism (Heinze & Weber, 2016), or as the formation of hybrid organizations (Perkmann et al., 2019). By this approach, practices that prove difficult for implementation because of their perceived illegitimacy inside schools can be reshaped by teacher educators in ways that increase their fit with the goals of schools, thereby potentially increasing the probability of teachers' willingness to use them. As a dissonance may exist between the framing of dialogic argumentation and more traditional instructional practices, teacher educators aiming to advance dialogic pedagogy may need to define and communicate this instructional practice in ways that can gain the support of teachers. This can include ruling in particular understandings about dialogic pedagogy that link it to preferred missions in schools and the tangible practices that could be used for the attainment of such missions.

For example, the data from Chapter 2 shows that teachers who adhere to the logic of accountability may frame dialogic argumentation as a threat to the mission of content coverage and, therefore, as illegitimate. A TPD course that accounts for accountability-related teachers' willingness for implementation can aim to associate students' reliance on science knowledge and language with school missions that emphasize the acquisition of science content and terminologies. In terms of teachers' ability for implantation, an accountability-sensitive TPD design can include a focus on the interactional means that can emphasize students' reliance on rationalistic forms of reasoning during argumentation. The data from Chapter 3 show that such interaction-motivated alignment with school institutional understandings can include the deployment of interrogative talk moves, which can push students away from reliance on out-of-school knowledge and language and towards reliance on school-appropriate science knowledge.

Knowledge about the deployment of interrogative talk moves could also assist teachers who adhere to the logic of tracking, who may see low track students as incapable of argumentation. The data from Chapter 2 show that these teachers may accept students' replies that rely solely on subjective, out-of-school knowledge. A TPD course that aim to account to the willingness of teachers to implement dialogic argumentation in low track classrooms could, therefore, explicitly address students' tendency to rely on such trivial forms of knowledge, but

also jointly seek with teachers the interactional means that can build on subjective forms of knowledge in order to extend from it to reliance on more concrete science knowledge.

Teachers can also adhere to the logic of the profession and fear for professional implications that are tied to the implementation of dialogic pedagogy, such as losing their central position in the classroom. A translation of dialogic argumentation to the professional realities of classroom conduct could potentially benefit from the framing of the role of science teachers as critical for the productive conduct of argumentation, thus accounting for the perceived jeopardy for their central position in classroom interactions. Such framing could attend to the differences in the quality of argumentation that are related to the presence, or absence, of teacher scaffolding and management of talk.

In table 4.1 I outline suggested stages for the design of an institutionally informed TPD. The stages are sequential and summarize the core findings discussed above. They are designed to take into consideration the social structuring of schools and of teachers' work and to explain it from macro- and micro-level perspectives. The first three of these stages are logically derived from the findings I present in Chapter 2 and relate to pervasive institutional constraints that may undermine the implementation of a new practice. The subsequent two stages relate to the findings I present in Chapter 3 and to opportunities to integrate the new practice into teachers' work in a way that mitigates the conflict between what the new practice is set to achieve and teachers' view of appropriate organizational conduct.

To be sure, I am not arguing that attention to institutional mandates should supersede other TPD design considerations. Rather, I argue that an institutionally informed approach to TPD design can help teachers balance the competing demands imposed on them by their schools and by reform mandates. Therefore, institutionally informed design considerations should be viewed as supplemental, and employed when the need arises to minimize conflicts between research on learning, policy that aims to advance new pedagogies, and teachers' practices "on the ground".

Adopting an institutionally informed approach may carry consequences not only for TPD design, but also motivate and direct educational researchers to expand the focus of their analyses of schools. This broadened scope can include the idea that implementation success is reliant, in part, on schools' ability to maintain their organizational legitimacy while, at the same time, avoiding obsolescence by experimenting with pedagogical innovations (Bingham & Burch, 2019). By framing research on implementation efforts in this way, researchers can develop research questions that focus on the conditions and practices that support an

institutionally informed approach, the practices that undermine it, the identification of teachers that are most suitable to initiate organizational change in this direction, and how can they be best supported to effectively manage and sustain this complex mission.

TABLE 4.1 A suggested framework for an institutionally informed TPD design

TPD design stage	Goal	Suggested means	Desired Product
1. Conceptualizing teachers' work in an institutionalized context: adopting a macro-level perspective	To understand how teachers perceive the task of maintaining appropriate organizational conduct	Preliminary discussion with participating teachers about their daily work, focusing on: their goals for teaching, the pressures that they endure, their instructional beliefs and approaches to teaching	A record of macro-level institutional logics that underpin teachers' work and which determine which goals and practices are deemed as legitimate at work
2. Conceptualizing teachers' work in an institutionalized context: adopting a micro-level perspective	To identify the dominant instructional practices that are perceived by teachers as suitable for the achievement of appropriate organizational conduct	Preliminary discussion with participating teachers about their instructional practices (if possible, coupled with classroom observations), focusing on: how they teach to achieve the goals that they set for themselves, how external pressures regulate their teaching	A set of micro-level practices that teachers use to achieve legitimate goals set by macro-level logics
3. Positioning the new practice in the institutional context	To understand how the new practice can disrupt appropriate organizational conduct from both macro and micro-level perspectives in ways that can encourage teachers' resistance to implementation	A comparison between the current goals and practices of teachers with the underlying assumptions of the new practice and the goals that it is set to achieve	A set of identified tensions and conflicts between traditional practices and the new practice that can make the new practice appear illegitimate inside schools
4. Cohering the new practice with the institutional context	To understand how, without diluting its underlying assumptions, the new practice can be effective at achieving appropriate organizational conduct, or how frictions between the new practice and current missions can be mitigated	A joint discussion with teachers focusing on where conflicts between current practices and the new practice can be mitigated that can engender the possibility of portraying the practice as being valuable and appropriate for the conduct of schools	A set of practical tools that can help in avoiding conflicts between practices and that can bolster instances of practice reconciliation
5. Safely incorporating the new practice into the daily work of teachers	To frame the new practice as less at odds with appropriate organizational conduct, thereby allowing the integration of the new practice into teachers' arsenal of legitimate practices	Asking teachers to implement the new practice in a regular lesson	Piecemeal advancement towards practice legitimacy and incremental organizational change
* These design principles are not meant to be prescriptive for all TPD courses, but are formulated to guide teacher educators how to introduce teachers to a new instructional practice that is advocated in reform documents, but that might be perceived as illegitimate inside schools (e.g., dialogic argumentation)			

References

Adger, C. T. (2001). Discourse in Educational Settings *The handbook of discourse analysis* (pp. 503).

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*: Teachers College Press.

Albe, V. (2008). When scientific knowledge, daily life experience, epistemological and social considerations intersect: Students' argumentation in group discussions on a socio-scientific issue. *Research in Science Education, 38*(1), 67-90.

Alexander, R. (2008). Culture, dialogue and learning: Notes on an emerging pedagogy. *Exploring talk in school*, 91-114.

Anyon, J. (2017). Social class and the hidden curriculum of work *Childhood socialization* (pp. 369-394): Routledge.

Armanios, D. E., & Eesley, C. E. (2021). How do institutional carriers alleviate normative and cognitive barriers to regulatory change? *Organization Science, 32*(6), 1415-1438.

Arminen, I. (2017). *Institutional interaction: Studies of talk at work*: Routledge.

Arvola, A. O., & Lundegård, I. (2012). 'It's Her Body'. When Students' Argumentation Shows Displacement of Content in a Science Classroom. *Research in Science Education, 42*(6), 1121-1145.

Asterhan, C. S. (2018). Exploring enablers and inhibitors of productive peer argumentation: The role of individual achievement goals and of gender. *Contemporary Educational Psychology, 54*, 66-78.

Attewell, P. (2001). The winner-take-all high school: Organizational adaptations to educational stratification. *Sociology of education*, 267-295.

Avidov-Ungar, O. (2016). A model of professional development: Teachers' perceptions of their professional development. *Teachers and Teaching, 22*(6), 653-669.

Balgopal, M. M., Wallace, A. M., & Dahlberg, S. (2017). Writing from different cultural contexts: How college students frame an environmental SSI through written arguments. *Journal of Research in Science Teaching, 54*(2), 195-218.

Ball, S. J. (1989). Micro-politics versus management: Towards a sociology of school organization. *Politics and the Processes of Schooling*.

Bathgate, M., Crowell, A., Schunn, C., Cannady, M., & Dorph, R. (2015). The learning benefits of being willing and able to engage in scientific argumentation. *International Journal of Science Education, 37*(10), 1590-1612.

Bencze, L., El Halwany, S., & Zouda, M. (2020). Critical and active public engagement in addressing Socioscientific problems through science teacher education *Science teacher education for responsible citizenship* (pp. 63-83): Springer.

Bencze, L., Pouliot, C., Pedretti, E., Simonneaux, L., Simonneaux, J., & Zeidler, D. (2020). SAQ, SSI and STSE education: defending and extending "science-in-context". *Cultural Studies of Science Education, 15*(3), 825-851.

Bencze, L., Sperling, E., & Carter, L. (2012). Students' research-informed socio-scientific activism: Re/visions for a sustainable future. *Research in Science Education, 42*(1), 129-148.

Berger, P. L., & Luckmann, T. (1966). *The social construction of reality: A treatise in the sociology of knowledge*: Anchor.

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching, 49*(1), 68-94.

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education, 94*(5), 765-793.

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education, 93*(1), 26-55.
Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education, 95*(2), 191-216.
Berland, L. K., Russ, R. S., & West, C. P. (2020). Supporting the scientific practices through epistemologically responsive science teaching. *Journal of Science Teacher Education, 31*(3), 264-290.
Binder, A. (2007). For love and money: Organizations' creative responses to multiple environmental logics. *Theory and society, 36*(6), 547-571.
Bingham, A. J., & Burch, P. (2019). Reimagining complexity: Exploring organizational ambidexterity as a lens for policy research. *Policy Futures in Education, 17*(3), 402-420.
Blatchford, P., Kutnick, P., Baines, E., & Galton, M. (2003). Toward a social pedagogy of classroom group work. *International Journal of Educational Research, 39*(1-2), 153-172.
Bricker, L. A., & Bell, P. (2008). Conceptualizations of argumentation from science studies and the learning sciences and their implications for the practices of science education. *Science Education, 92*(3), 473-498.
Bridwell-Mitchell, E. N. (2013). The rationalizing logics of public school reform: How cultural institutions matter for classroom instruction. *Journal of Mixed Methods Research, 7*(2), 173-196.
Bridwell-Mitchell, E. N. (2015). Theorizing teacher agency and reform: How institutionalized instructional practices change and persist. *Sociology of education, 88*(2), 140-159.
Bridwell-Mitchell, E. N., & Fried, S. A. (2020). Learning one's place: Status perceptions and social capital in teacher communities. *Educational Policy, 34*(7), 955-991.
Brooks, C. F. (2016). Role, power, ritual, and resistance: A critical discourse analysis of college classroom talk. *Western Journal of Communication, 80*(3), 348-369.
Burch, P. (2007). Educational policy and practice from the perspective of institutional theory: Crafting a wider lens. *Educational Researcher, 36*(2), 84-95.
Carspecken, F. P. (2013). *Critical ethnography in educational research: A theoretical and practical guide*: Routledge.
Cazden, C. B., & Beck, S. W. (2003). Classroom discourse. *Handbook of discourse processes*, 165-197.
Centers for Disease Control and Prevention. (2018). *Comparison of 20th Century Annual Morbidity and Current Morbidity: Vaccine-Preventable Diseases*. Retrieved from https://stacks.cdc.gov/view/cdc/58586/cdc_58586_DS1
Chen, Y. C., Benus, M. J., & Hernandez, J. (2019). Managing uncertainty in scientific argumentation. *Science Education, 103*(5), 1235-1276.
Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students' responses. *International Journal of Science Education, 28*(11), 1315-1346.
Christenson, N., Rundgren, S.-N. C., & Höglund, H.-O. (2012). Using the SEE-SEP model to analyze upper secondary students' use of supporting reasons in arguing socioscientific issues. *Journal of Science Education and Technology, 21*(3), 342-352.
Christodoulou, A., Levinson, R., Davies, P., Grace, M., Nicholl, J., & Rietdijk, W. (2021). The use of Cartography of Controversy within socioscientific issues-based education: students' mapping of the badger-cattle controversy in England. *International Journal of Science Education, 43*(15), 2479-2500.
Coburn, C. E. (2004). Beyond decoupling: Rethinking the relationship between the institutional environment and the classroom. *Sociology of education, 77*(3), 211-244.

Cohen, D. K., & Mehta, J. (2017). Why reform sometimes succeeds: Understanding the conditions that produce reforms that last. *American Educational Research Journal, 54*(4), 644-690.
Cohen, R., Zafrani, E., & Yarden, A. (2020). Science teachers as proponents of socio-scientific inquiry-based learning: From professional development to classroom enactment. *Science teacher education for responsible citizenship*, 117-132.
Colaner, A. C. (2016). Education versus family: institutional logics in the early care and education field. *American Educational Research Journal, 53*(3), 673-707.
Cornelissen, J. P., Durand, R., Fiss, P. C., Lammers, J. C., & Vaara, E. (2015). Putting communication front and center in institutional theory and analysis. *40*(1), 10-27.
Cuban, L. (2013). Why so many structural changes in schools and so little reform in teaching practice? *Journal of Educational Administration, 51*(2), 109-125.
Dawson, V., & Venville, G. (2013). Introducing high school biology students to argumentation about socioscientific issues. *Canadian Journal of Science, Mathematics and Technology Education, 13*(4), 356-372.
Dawson, V., & Venville, G. J. (2009). High-school Students' Informal Reasoning and Argumentation about Biotechnology: An indicator of scientific literacy? *International Journal of Science Education, 31*(11), 1421-1445.
Diamond, J. B. (2012). Accountability policy, school organization, and classroom practice: Partial recoupling and educational opportunity. *Education and Urban Society, 44*(2), 151-182.
DiMaggio, P., & Powell, W. W. (1983). The iron cage revisited: Collective rationality and institutional isomorphism in organizational fields. *American sociological review, 48*(2), 147-160.
Drew, P., & Heritage, J. (1992). *Talk at work: Interaction in institutional settings*: Cambridge Univ Pr.
Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312.
Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*(1), 39-72.
Edelson, D. C., Reiser, B. J., McNeill, K. L., Mohan, A., Novak, M., Mohan, L., . . . Deutch Noll, J. (2021). Developing research-based instructional materials to support large-scale transformation of science teaching and learning: The approach of the OpenSciEd middle school program. *Journal of Science Teacher Education, 32*(7), 780-804.
Edwards, A. D., & Westgate, D. P. (1994). *Investigating classroom talk* (Vol. 13): Psychology Press.
Elmore, R. F., Peterson, P. L., & McCarthey, S. J. (1996). *Restructuring in the classroom: Teaching, learning, and school organization*: ERIC.
Erduran, S., & Jiménez-Aleixandre, M. P. (2008). Argumentation in science education. *Perspectives from classroom-Based Research. Dordre-cht: Springer*.
Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88*(6), 915-933.
Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics, 5*(1), 1-4.
Evagorou, M., Jimenez-Aleixandre, M. P., & Osborne, J. (2012). 'Should we kill the grey squirrels?'A study exploring students' justifications and decision-making. *International Journal of Science Education, 34*(3), 401-428.

Evagorou, M., Nielsen, J. A., & Dillon, J. (2020). *Science Teacher Education for Responsible Citizenship: Towards a Pedagogy for Relevance Through Socioscientific Issues* (Vol. 52): Springer Nature.

Evagorou, M., & Osborne, J. (2013). Exploring young students' collaborative argumentation within a socioscientific issue. *Journal of Research in Science Teaching, 50*(2), 209-237.

Everitt, J. G. (2017). *Lesson plans: The institutional demands of becoming a teacher*: Rutgers University Press.

Felton, M., Crowell, A., Garcia-Mila, M., & Villarroel, C. (2019). Capturing deliberative argument: an analytic coding scheme for studying argumentative dialogue and its benefits for learning. *Learning, Culture and Social Interaction*, [Epub ahead of print].

Frederiksen, N., Gottlieb, S. C., & Leiringer, R. (2021). Organising for infrastructure development programmes: Governing internal logic multiplicity across organisational spaces. *International Journal of Project Management, 39*(3), 223-235.

Furberg, A., & Silseth, K. (2021). Invoking student resources in whole-class conversations in science education: A sociocultural perspective. *Journal of the Learning Sciences*, 1-39.

Garton, S. (2012). Speaking out of turn? Taking the initiative in teacher-fronted classroom interaction. *Classroom Discourse, 3*(1), 29-45.

Gee, J. P. (2014). *An introduction to discourse analysis: Theory and method*: Routledge.

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of grounded theory: Strategies for qualitative research*: Routledge.

González-Howard, M., McNeill, K. L., Marco-Bujosa, L. M., & Proctor, C. P. (2017). 'Does it answer the question or is it French fries?': an exploration of language supports for scientific argumentation. *International Journal of Science Education, 39*(5), 528-547.

González-Howard, M., & McNeill, K. L. (2019). Teachers' framing of argumentation goals: Working together to develop individual versus communal understanding. *Journal of Research in Science Teaching, 56*(6), 821-844.

González-Howard, M., & McNeill, K. L. (2020). Acting with epistemic agency: Characterizing student critique during argumentation discussions. *Science Education, 104*(6), 953-982.

Grace, M. M., & Ratcliffe, M. (2002). The science and values that young people draw upon to make decisions about biological conservation issues. *International Journal of Science Education, 24*(11), 1157-1169.

Grimes, P., McDonald, S., & van Kampen, P. (2019). "We're getting somewhere": Development and implementation of a framework for the analysis of productive science discourse. *Science Education, 103*(1), 5-36.

Haedicke, M. A., & Hallett, T. (2015). Research Strategies for Inhabited Institutionalism *Handbook of Qualitative Organizational Research: Innovative Pathways and Methods*: Routledge.

Heinze, K. L., & Weber, K. (2016). Toward organizational pluralism: Institutional intrapreneurship in integrative medicine. *Organization Science, 27*(1), 157-172.

Henderson, J. B., McNeill, K. L., González-Howard, M., Close, K., & Evans, M. (2017). Key challenges and future directions for educational research on scientific argumentation. *Journal of Research in Science Teaching*.

Henderson, J. B., McNeill, K. L., González-Howard, M., Close, K., & Evans, M. (2018). Key challenges and future directions for educational research on scientific argumentation. *Journal of Research in Science Teaching, 55*(1), 5-18.

Heritage, J. (2005). Conversation analysis and institutional talk. *Handbook of language and social interaction, 103*, 47.

Hodge, E. M. (2019). “Common” Instruction? Logics of Ability and Teacher Decision Making Across Tracks in the Era of Common Standards. *American Educational Research Journal, 56*(3), 638-675.
Iordanou, K. (2016). Developing epistemological understanding in scientific and social domains through argumentation. *Zeitschrift für Pädagogische Psychologie, 30*(2-3), 109-119.
Israeli Ministry of Education. (1992). *Tomorrow 98: Report of the Superior Committee on Science Mathematics and Technology Education in Israel*. Jerusalem: State of Israel Ministry of Education Curriculum Center.
Israeli Ministry of Education. (2009). *High Order Thinking Strategies*. Jerusalem. Retrieved from http://meyda.education.gov.il/files/Tochniyot_Limudim/Portal/EstrategyotChashiva.pdf (in Hebrew).
Israeli Ministry of Education. (2010). The Importance of Breakfast Worksheets. Retrieved from http://cms.education.gov.il/EducationCMS/Units/Tochniyot_Limudim/Portal/Haashara/MadaTech/MBoker.htm
Israeli Ministry of Education. (2017). *Transparency in Education*. Israeli Ministry of Education, Retrieved from https://shkifut.education.gov.il/national.
Israeli Ministry of Education. (2018). *The Lower Secondary Science Curriculum*. Jerusalem, Israel.
Jimenez-Aleixandre, M. P., Rodriguez, A. B., & Duschl, R. A. (2000). " Doing the lesson" or" doing science": Argument in high school genetics. *Science Education, 84*(6), 757-792.
Johnson, B. L., & Owens, M. (2005). Building new bridges. Linking organization theory with other educational literatures. *Journal of Educational Administration, 43*(1), 41-59.
Johnson, M., & Mercer, N. (2019). Using sociocultural discourse analysis to analyse professional discourse. *Learning, Culture and Social Interaction, 21*, 267-277.
Jungwirth, H. (1991). Interaction and gender—findings of a microethnographical approach to classroom discourse. *Educational Studies in Mathematics, 22*(3), 263-284.
Katsh-Singer, R., McNeill, K. L., & Loper, S. (2016). Scientific Argumentation for All? Comparing Teacher Beliefs About Argumentation in High, Mid, and Low Socioeconomic Status Schools. *Science Education, 100*(3), 410-436.
Kilinc, A., Demiral, U., & Kartal, T. (2017). Resistance to dialogic discourse in SSI teaching: The effects of an argumentation-based workshop, teaching practicum, and induction on a preservice science teacher. *Journal of Research in Science Teaching, 54*(6), 764-789.
Kim, M., & Roth, W.-M. (2018). Dialogical argumentation in elementary science classrooms. *Cultural Studies of Science Education, 13*(4), 1061-1085.
Klopfer, L. E., & Aikenhead, G. S. (2022). Humanistic science education: The history of science and other relevant contexts. *Science Education, 106*(3), 490-504.
Knight-Bradsley, A., & McNeill, K. L. (2016). Teachers’ pedagogical design capacity for scientific argumentation. *Science Education, 100*(4), 645-672.
Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85*(3), 291-310.
Kovalainen, M., & Kumpulainen, K. (2005). The discursive practice of participation in an elementary classroom community. *Instructional Science, 33*(3), 213-250.
Kuhn, D. (2010). Teaching and learning science as argument. *Science Education, 94*(5), 810-824.
Lemke, J. L. (1990). *Talking science: Language, learning, and values*: Ablex Publishing Corporation.

Lewis, A. E., & Diamond, J. B. (2015). *Despite the best intentions: How racial inequality thrives in good schools*: Oxford University Press.
Lortie, D. C. (1977). Schoolteacher: A Sociological Study: University of Chicago Press.
Lowell, B. R., Cherbow, K., & McNeill, K. L. (2022). Considering discussion types to support collective sensemaking during a storyline unit. *Journal of Research in Science Teaching, 59*(2), 195-222.
Macagno, F., Mayweg-Paus, E., & Kuhn, D. (2015). Argumentation theory in education studies: Coding and improving students' argumentative strategies. *Topoi, 34*(2), 523-537.
Macpherson, A. C. (2016). A comparison of scientists' arguments and school argumentation tasks. *Science Education, 100*(6), 1062-1091.
Malhotra, N., Zietsma, C., Morris, T., & Smets, M. (2021). Handling resistance to change when societal and workplace logics conflict. *Administrative science quarterly, 66*(2), 475-520.
Marsh, J. A., Allbright, T. N., Bulkley, K. E., Kennedy, K. E., & Dhaliwal, T. K. (2020). Institutional Logics in Los Angeles Schools: Do Multiple Models Disrupt the Grammar of Schooling? *American Journal of Education, 126*(4), 603-651.
Mayweg-Paus, E., Macagno, F., & Kuhn, D. (2016). Developing argumentation strategies in electronic dialogs: Is modeling effective? *Discourse Processes, 53*(4), 280-297.
McNeill, K. L., & Berland, L. K. (2017). What is (or should be) scientific evidence use in k-12 classrooms? *Journal of Research in Science Teaching, 54*(5), 672-689.
McNeill, K. L., González-Howard, M., Katsh-Singer, R., & Loper, S. (2017). Moving beyond Pseudoargumentation: Teachers' Enactments of an Educative Science Curriculum Focused on Argumentation. *Science Education, 101*(3), 426-457.
McNeill, K. L., González-Howard, M., Katsh-Singer, R., & Loper, S. (2016). Pedagogical content knowledge of argumentation: Using classroom contexts to assess high-quality PCK rather than pseudoargumentation. *Journal of Research in Science Teaching, 53*(2), 261-290.
McNeill, K. L., Katsh-Singer, R., González-Howard, M., & Loper, S. (2016). Factors impacting teachers' argumentation instruction in their science classrooms. *International Journal of Science Education, 38*(12), 2026-2046.
McNeill, K. L., Lowenhaupt, R. J., & Katsh-Singer, R. (2018). Instructional leadership in the era of the NGSS: Principals' understandings of science practices. *Science Education, 102*(3), 452-473.
McNeill, K. L., Marco-Bujosa, L. M., González-Howard, M., & Loper, S. (2018). Teachers' enactments of curriculum: Fidelity to Procedure versus Fidelity to Goal for scientific argumentation. *International Journal of Science Education,* 1-21.
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.
McPherson, C. M., & Sauder, M. (2013). Logics in action: Managing institutional complexity in a drug court. *Administrative science quarterly, 58*(2), 165-196.
Mehan, H. (1979). *Learning lessons: Social organization in the classroom*: Harvard University Press.
Mehta, J., & Fine, S. (2019a). *In search of deeper learning: Inside the Effort to Remake the American High School*: Harvard University Press.
Mehta, J., & Fine, S. (2019b). In Search of Deeper Learning: The Quest to Remake the American High School *In Search of Deeper Learning*: Harvard University Press.
Mercer, N., & Wegerif, R. (1999). Is 'exploratory talk'productive talk. *Learning with computers: Analyzing productive interaction*, 79-101.

Merleau-Ponty, M. (1962). *Phenomenology of Perception*: Psychology Press.
Meyer, H.-D., & Rowan, B. (2012). *The new institutionalism in education*: SUNY Press.
Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American journal of sociology, 83*(2), 340-363.
Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in philosophy and education, 27*(4), 283-297.
Miller, E., Manz, E., Russ, R., Stroupe, D., & Berland, L. K. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. *Journal of Research in Science Teaching, 55*(7), 1053-1075.
Namdar, B., & Shen, J. (2016). Intersection of argumentation and the use of multiple representations in the context of socioscientific issues. *International Journal of Science Education, 38*(7), 1100-1132.
Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 21*(5), 553-576.
NGSS. (2013). Next generation science standards: For states, by states (Vol 1) Washington.
Nielsen, J. A. (2012a). Co-opting Science: A preliminary study of how students invoke science in value-laden discussions. *International Journal of Science Education, 34*(2), 275-299.
Nielsen, J. A. (2012b). Science in discussions: An analysis of the use of science content in socioscientific discussions. *Science Education, 96*(3), 428-456.
NRC. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas: National Academies Press.
Nussbaum, E. M. (2020). Critical integrative argumentation: Toward complexity in students' thinking. *Educational Psychologist, 56*(1), 1-17.
Oakes, J. (2005). *Keeping track*: Yale University Press.
Oakes, J., Quartz, K. H., Ryan, S., & Lipton, M. (2000). Becoming good American schools: The struggle for civic virtue in education reform. *The Phi Delta Kappan, 81*(8), 568-575.
Oliveira, A. W. (2010). Improving teacher questioning in science inquiry discussions through professional development. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 47*(4), 422-453.
Osborne, J. (2013). The 21st century challenge for science education: Assessing scientific reasoning. *Thinking Skills and Creativity, 10*, 265-279.
Osborne, J., Borko, H., Fishman, E., Gomez Zaccarelli, F., Berson, E., Busch, K., . . . Tseng, A. (2019). Impacts of a practice-based professional development program on elementary teachers' facilitation of and student engagement with scientific argumentation. *American Educational Research Journal, 56*(4), 1067-1112.
Osborne, J., Simon, S., Christodoulou, A., Howell-Richardson, C., & Richardson, K. (2013). Learning to argue: A study of four schools and their attempt to develop the use of argumentation as a common instructional practice and its impact on students. *Journal of Research in Science Teaching, 50*(3), 315-347.
Ottander, K., & Simon, S. (2021). Learning democratic participation? Meaning-making in discussion of socioscientific issues in science education. *International Journal of Science Education, 43*(12), 1895-1925.
Owens, D. C., Sadler, T. D., Petitt, D. N., & Forbes, C. T. (2021). Exploring undergraduates' breadth of socio-scientific reasoning through domains of knowledge. *Research in Science Education*, 1-16.

Perkmann, M., McKelvey, M., & Phillips, N. (2019). Protecting scientists from Gordon Gekko: How organizations use hybrid spaces to engage with multiple institutional logics. *Organization Science, 30*(2), 298-318.
Peurach, D. J., Cohen, D. K., Yurkofsky, M. M., & Spillane, J. P. (2019). From mass schooling to education systems: Changing patterns in the organization and management of instruction. *Review of Research in Education, 43*(1), 32-67.
Pimentel, D. S., & McNeill, K. L. (2013). Conducting talk in secondary science classrooms: Investigating instructional moves and teachers' beliefs. *Science Education, 97*(3), 367-394.
Poole, D. (1992). Language socialization in the second language classroom. *Language learning, 42*(4), 593-616.
Reay, T., & Hinings, C. R. (2009). Managing the rivalry of competing institutional logics. *Organization studies, 30*(6), 629-652.
Reay, T., & Jones, C. (2016). Qualitatively capturing institutional logics. *Strategic Organization, 14*(4), 441-454.
Roberts, R., & Gott, R. (2010). Questioning the evidence for a claim in a socio-scientific issue: an aspect of scientific literacy. *Research in Science & Technological Education, 28*(3), 203-226.
Rudsberg, K., & Öhman, J. (2015). The role of knowledge in participatory and pluralistic approaches to ESE. *Environmental Education Research, 21*(7), 955-974.
Rundgren, C.-J., Eriksson, M., & Rundgren, S.-N. C. (2016). Investigating the intertwinement of knowledge, value, and experience of upper secondary students' argumentation concerning socioscientific issues. *Science & Education, 25*(9-10), 1049-1071.
Russ, R. S., & Berland, L. K. (2018). Invented Science: A Framework for Discussing a Persistent Problem of Practice. *Journal of the Learning Sciences, 28*(3), 279-301.
Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education, 96*(3), 488-526.
Ryu, S., & Sandoval, W. A. (2015). The influence of group dynamics on collaborative scientific argumentation. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(3), 335-351.
Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education, 28*(12), 1463-1488.
Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 42*(1), 112-138.
Sandoval, W. A., Enyedy, N., Redman, E. H., & Xiao, S. (2019). Organising a culture of argumentation in elementary science. *International Journal of Science Education, 41*(13), 1848-1869.
Sandoval, W. A., Kawasaki, J., & Clark, H. F. (2021). Characterizing science classroom discourse across scales. *Research in Science Education, 51*(1), 35-49.
Sarangi, S., & Roberts, C. (2008). *Talk, work and institutional order: Discourse in medical, mediation and management settings* (Vol. 1): Walter de Gruyter.
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.
Scott, R. (2013). *Institutions and organizations: Ideas, interests, and identities*: Sage Publications.

Seedhouse, P. (1996). Classroom interaction: possibilities and impossibilities. *ELT journal, 50*(1), 16-24.
Seedhouse, P. (2004). The interactional architecture of the language classroom: A conversation analysis perspective. *Language learning*.
Seedhouse, P. (2005). Conversation analysis and language learning. *Language teaching, 38*(4), 165.
Segal, A., Snell, J., & Lefstein, A. (2017). Dialogic teaching to the high-stakes standardised test? *Research Papers in Education, 32*(5), 596-610.
Sengul, O., Enderle, P. J., & Schwartz, R. S. (2020). Science teachers' use of argumentation instructional model: linking PCK of argumentation, epistemological beliefs, and practice. *International Journal of Science Education, 42*(7), 1068-1086.
Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*(2-3), 235-260.
Sinclair, U. (1935). *I, Candidate for Governor*: University of California Press.
Snell, J., & Lefstein, A. (2018). "Low Ability," Participation, and Identity in Dialogic Pedagogy. *American Educational Research Journal, 55*(1), 40-78.
Sonenshein, S. (2016). How corporations overcome issue illegitimacy and issue equivocality to address social welfare: The role of the social change agent. *Academy of management review, 41*(2), 349-366.
Spillane, J. P. (2009). *Standards deviation: How schools misunderstand education policy*: Harvard University Press.
Stake, R. E. (1995). *The art of case study research*: Sage.
Stewart, O. G., & Jordan, M. E. (2017). "Some explanation here": a case study of learning opportunities and tensions in an informal science learning environment. *Instructional Science, 45*(2), 137-156.
Stroupe, D. (2014). Examining classroom science practice communities: How teachers and students negotiate epistemic agency and learn science-as-practice. *Science Education, 98*(3), 487-516.
Ten Have, P. (1991). Talk and institution: A reconsideration of the 'asymmetry'of doctor-patient interaction. *Talk and social structure: Studies in ethnomethodology and conversation analysis*, 138-163.
Teo, P. (2019). Teaching for the 21st century: A case for dialogic pedagogy. *Learning, Culture and Social Interaction, 21*, 170-178.
Thornton, P. H., & Ocasio, W. (2008). Institutional logics. *The Sage handbook of organizational institutionalism, 840*(2008), 99-128.
Tidemand, S., & Nielsen, J. A. (2017). The role of socioscientific issues in biology teaching: From the perspective of teachers. *International Journal of Science Education, 39*(1), 44-61.
Topçu, M. S., Yılmaz-Tüzün, Ö., & Sadler, T. D. (2011). Turkish preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning. *Journal of Science Teacher Education, 22*(4), 313-332.
Toulmin, S. E. (2003). *The uses of argument*: Cambridge university press.
Tracy, K., & Robles, J. (2009). Questions, questioning, and institutional practices: an introduction. *Discourse Studies, 11*(2), 131-152.
van Der Zande, P., Brekelmans, M., Vermunt, J. D., & Waarlo, A. J. (2009). Moral reasoning in genetics education: Educational research. *Journal of Biological Education, 44*(1), 31-36.

Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching, 47*(8), 952-977.
Weber, M. (1947). *The theory of social and economic organization*: Simon and Schuster.
Wilkinson, I. A., Reznitskaya, A., Bourdage, K., Oyler, J., Glina, M., Drewry, R., . . . Nelson, K. (2017). Toward a more dialogic pedagogy: Changing teachers' beliefs and practices through professional development in language arts classrooms. *Language and education, 31*(1), 65-82.
Wood, T. (1998). Alternative patterns of communication in mathematics classes: Funneling or focusing. *Language and communication in the mathematics classroom*, 167-178.
Wortham, S. (2008). Linguistic anthropology of education. *Annual review of anthropology, 37*, 37-51.
Wright, C., & Nyberg, D. (2017). An inconvenient truth: How organizations translate climate change into business as usual. *Academy of management journal, 60*(5), 1633-1661.
Wu, Y.-T. (2013). University students' knowledge structures and informal reasoning on the use of genetically modified foods: Multidimensional analyses. *Research in Science Education, 43*(5), 1873-1890.
Yarden, A. (2009). Reading scientific texts: Adapting primary literature for promoting scientific literacy. *Research in Science Education, 39*(3), 307-311.
Yerrick, R., & Ridgeway, M. (2017). Culturally responsive pedagogy, science literacy, and urban underrepresented science students *Inclusive principles and practices in literacy education*: Emerald Publishing Limited.
Yurkofsky, M. (2021). From Compliance to Improvement: How School Leaders Make Sense of Institutional and Technical Demands When Implementing a Continuous Improvement Process. *Educational Administration Quarterly, 58*(5), 300-346.
Zafrani, E., & Yarden, A. (2017). Becoming a Science Activist: A Case Study of Students' Engagement in a Socioscientific Project. *Sisyphus-Journal of Education, 5*(3), 44-67.
Zafrani, E., & Yarden, A. (2022a). Dialog-constraining institutional logics and their interactional manifestation in the science classroom *Science Education, 106*(1), 142-171. doi:https://doi.org/10.1002/sce.21687
Zafrani, E., & Yarden, A. (2022b). The potential for reconciling pedagogical tradition and innovation: the case of socioscientific argumentation. [Under review]. *Instructional Science*.
Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of elementary science education, 21*(2), 49.
Zeidler, D. L., & Sadler, T. D. (2007). The role of moral reasoning in argumentation: Conscience, character, and care *Argumentation in science education* (pp. 201-216): Springer.
Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education, 89*(3), 357-377.
Zilber, T. B. (2007). Stories and the discursive dynamics of institutional entrepreneurship: The case of Israeli high-tech after the bubble. *Organization studies, 28*(7), 1035-1054.
Zilber, T. B. (2016). How institutional logics matter: A bottom-up exploration *How Institutions Matter!* (pp. 137-155): Emerald Group Publishing Limited.
Zohar, A. (2013). Challenges in wide scale implementation efforts to foster higher order thinking (HOT) in science education across a whole school system. *Thinking Skills and Creativity, 10*, 233-249.
Zohar, A., & Alboher Agmon, V. (2017). Raising test scores vs. teaching higher order thinking (HOT): senior science teachers' views on how several concurrent policies

affect classroom practices. *Research in Science & Technological Education, 36*(2), 243-260.
Zohar, A., & Cohen, A. (2016). Large scale implementation of higher order thinking (HOT) in civic education: The interplay of policy, politics, pedagogical leadership and detailed pedagogical planning. *Thinking Skills and Creativity, 21*, 85-96.
Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 39*(1), 35-62.

Appendices

Appendix A: Supporting Information for Chapter 2 - additional examples of institutional talk

The following tables presents data not included in the main text, which provides additional examples of how institutional talk in classrooms may reflect institutional logics in detriment of dialogic argumentation. Table S1 presents classroom interactions argued to reflect and be motivated by the logic of accountability. Table S2 presents classroom interactions argued to reflect and be motivated by the logic of tracking. Table S3 presents classroom interactions argued to reflect and be motivated by the logic of the profession. Below each table we provide a brief analysis of the interaction to argue how it reflects corresponding institutional logics and how such interaction can undermine dialogic argumentation.

TABLE S1 An additional example for a terminology-oriented classroom interactions as reflective of the logic of accountability

1	GanimTeacher4	Let's try to understand what a growth hormone is. Yes?
2	Student A	(reading verbatim from the text) It is a hormone secreted from the pituitary gland.
3	GanimTeacher4	So, we understand that in the brain we have a gland called (waiting for students to complete the sentence)
4	Students	(in chorus) Pituitary gland.
5	GanimTeacher4	Pituitary gland. It secretes some substance. This substance is (waiting for students to complete the sentence)
6	Students	(in chorus) Growth hormone.
7	GanimTeacher4	Growth hormone. And the function of the growth hormone is to (waiting for students to complete the sentence)
8	Student A	Elongate the bones.
9	GanimTeacher4	Elongate the bones, which eventually cause (waiting for students to complete the sentence)
10	Student A	Growth.
11	GanimTeacher4	Growing in height. Good.

Analysis: Though the opening question can invite a plurality of answers (1), the following turns mostly focused on more shallow dimensions of the opening question and clarify that what GanimTeacher4 is looking for is for students to recite scientific terminology. Instead of discussing the scientific phenomena, GanimTeacher4 guided the students towards the desirable answer by reverting to the precise terminology needed for the answer to be considered correct (3, 5, 7, 9). Thus, desirable answers were more terminology related and demanded recitation of scientific terms presented in the text handed to students. Heavily restricted, this form of talk reflects teachers' notions of what knowledge is valuable to increase students' test scores, as it was observed in the macro-level. That is, a knowledge that is structured on basic, fact-like, definitions, but that is also considered accurate. Dialogic argumentation demands that students negotiate their understanding of science with their teachers and other students, as well as construct explanations and communicate their understanding with others. However, through this sequence of interactions, students may be socialized to the idea that their participation should be composed entirely of accurate terminologies, and which are assessed for their accuracy by the teacher.

TABLE S2 An additional example for a common-sense oriented classroom interaction as reflective of the logic of tracking

1	RamotTeacher1	What happens when I climb up a high mountain? What will I be lacking?
2	Students	(in chorus) Oxygen.
3	RamotTeacher1	So, how are mountain climbers climb up if they have no oxygen?
4	Student A	They carry an oxygen container.
5	Student B	They have these things.
6	RamotTeacher1	What do they do if they don't have an oxygen container?
7	Student C	Die.
8	Student D	They exercise.
9	Student E	They drink water.
10	Student D	They work out a lot.
11	Student F	They put this mask on their faces before they go up and it has oxygen in it.
12	Student B	No way they go up the mountain without equipment.
13	RamotTeacher1	Do they climb in one attempt, or do they rest along the way?
14	Students	(in chorus) They rest.
15	RamotTeacher1	What happens when climbers rest?
16	Student G	They accumulate something.
17	RamotTeacher1	What happens in their body? What is created?
18	Student I	Red blood cells.
19	RamotTeacher1	More red blood cells.

Analysis: Though the discussion was lively, and many students participated, their contribution relied mostly on knowledge that had little to do with the subject of the lesson, which dealt with cellular respiration. To make the content relatable, RamotTeacher1 grounded the subject in less abstract phenomena which pertains to acclimatization to environments with low levels of oxygen (1). This question invited replies that relied more on common sense than on disciplinary body of knowledge (4, 5, 8-12). When the teacher picked up that the students are struggling with the answer, she re-phrased her question in a way that reduces its cognitive demand to the use of common-sense (13), which then led to a question that demanded recall of information presented realier in the lesson (18). As this type of questions took more volume of classroom interactions in low track classrooms, we see this structure of interaction as reflecting the logic of tracking. For low-track students, preconceived low expectation on the teachers' side may push towards non-productive classroom interactions, as shown in this example. As teachers tend to believe that students should first master the basic content before turning to higher-order tasks (such as argumentation), a process of marginalization of low track students from engagment with dialogic arfumentation may be put into motion. Moreover, this structure of classroom interactions, with its emphasis on day-to-day knowledge, does not challenge students with academic content beyond their current abilities, thus enhancing the proposed marginalization process.

TABLE S3 Additional example for funneled classroom discourse as reflective of the logic of the profession

1	RamotTeacher2	(Presenting a textbook question that showed a figure with three balloons positioned at different heights. The student needed to identify which balloons are filled with hydrogen, carbon dioxide, and air)
2	Student A	I think that C is air.
3	Student B	(Balloon C is filled with) hydrogen. Hydrogen is the lightest gas in the world.
4	RamotTeacher2	(To student A) You say that the red balloon is filled with air?
5	Students	(together) No. No.
6	RamotTeacher2	We were asked to tell by the height of the balloon what gas is filled inside. You're saying that balloon C, the red balloon, is air. What the other students are saying, and you can hear them, is that your answer is probably not correct. Why? Because if this balloon is positioned higher than the other balloons, what does it probably contain?
7	Student B	Hydrogen which is the lightest gas in the world.
8	RamotTeacher2	(To student A) The highest balloon is lighter or heavier than the others?
9	Students	(In chorus) Lighter.
10	RamotTeacher2	Lighter. Out of all gasses that we know, which is the lightest? Hydrogen, right? So, the red balloon probably contains what?
11	Students	(In chorus) Hydrogen.
12	RamotTeacher2	Hydrogen. Good, we corrected the answer because we understood that hydrogen is lighter than air.

Analysis: In this example, funneling occurred even when correct answers were likely to appear in the conversation. As RamotTeacher2 mentioned, most the students in the classroom knew the correct answer to the question (6), and some were clearly able to provide a detailed explanation which justify their replies (3). Yet, through a series of questioning, RamotTeacher2 simplifies the information in the question with herself doing most of the thinking (6-12) and changing the type of knowledge required to answer it. In doing so, students' contributions are reduced to one word replies and they are prevented from clarifying their ideas for themselves (9,11). Teachers, then, may assume powerful roles and maintain asymmetry in the classroom through increasing scaffolding and accommodation of inexperienced students to the discourse of the classroom, a process in which the thinking becomes more and more simple. Such asymmetry ensure that the classroom talk will not be conducted among equals, but that one side, the teacher, will hold more power in directing the conversation with students having little opportunity to influence its direction. This structure of interaction maintains deeply held notions about the teaching profession, which hold teachers as the primary catalysts of classroom learning and the sole pedagogical authority in the classroom. Thus, it may undermine teachers' willingness to create oppurtunities for more symmetricall collaborative interactions with traditional, teacher-led, interactions.

Appendix B: Science activities developed for Climax days in 2019/20 (in Hebrew)

B.1 Science activity for climax day 1: genetic passports and encryption

<u>הצופן הגנטי ואיך הוא משפיע על התכונות שלנו</u>

ב-DNA של כל אחד מאתנו נמצא המידע התורשתי המשפיע על התכונות שלנו. אבל כיצד המידע אשר נמצא בחומר התורשתי יכול ללמד אותנו משהו על תכונות האדם?

בתרגיל זה תלמדו מעט על הצופן הגנטי ובעזרתו תנסו לבדוק האם חומר תורשתי של תינוק מסוים מעיד על כך שהוא חולה במחלה תורשתית מסוימת.

"שפת" ה-DNA

כל מולקולת DNA מורכבת מארבע אבני בניין המסומנות: **A**, **T**, **C** ו-**G**. בכל מולקולת DNA מספר והרכב שונה של אבני בניין אלו ברצף שונה.

לפניכם לדוגמה, רצף של 33 אבני בניין שהם חלק ממקטע של DNA שמשפיע על תכונה מסוימת.

GGCATTGTGGAACAATGCTGTACCAGCATCTGC

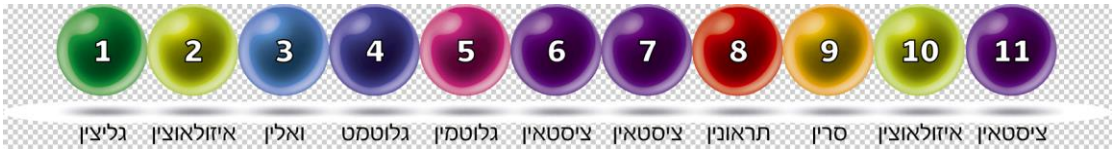
לפי רצף אבני הבניין ב-DNA נוצרים חלבונים. החלבונים הם אלו שיוצרים את התכונות השונות. בשביל להבין את הצופן אתם צריכים קודם להבין את "שפת" החלבונים.

"שפת" החלבונים

אבני הבניין של חלבון הן 20 סוגים של חומצות אמיניות. כל מולקולת חלבון מורכבת מרצף שונה ומספר שונה של חומצות אמיניות אלו.

לפניכם, לדוגמה, רצף של 11 חומצות אמיניות של חלבון כלשהו (כל כדור צבעוני באיור מסמל חומצה אמינית מסוג מסוים):

:

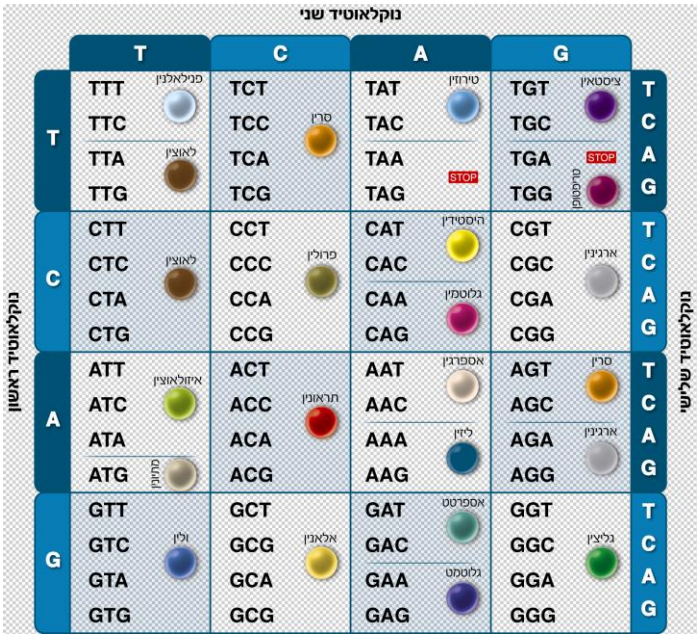


כיצד מתורגם המידע מ"שפת" ה-DNA ל"שפת" החלבונים?

אפשר לדמות את אבני הבניין של הDNA לארבע אותיות המרכיבות שפה דמיונית. מכל שלוש אותיות ברצף DNA אפשר להרכיב מילה שהיא צופן לחומצה אמינית מסוימת. כך למשל, הרצף GGC הוא צופן לחומצה האמינית גליצין ואילו ATT הוא צופן לחומצה האמינית איזולאוצין.

הצופן הגנטי

הקשר בין השלשות של אבני הבניין של ה- DNA לבין החומצות האמיניות מכונה הצופן הגנטי. בעזרת פענוח הצופן הגנטי יודעים היום לקשר רצף של DNA לכל חומצה אמינית. הצופן הגנטי מוצג בטבלה שלפניכם.



כדי להכיר את הצופן הגנטי נסו לענות על השאלות הבאות:

1. מהם הקודונים לחומצה האמינית היסטידין?
2. מהם הקודונים לחומצה האמינית פנילאלנין?
3. ציינו חומצה אמינית אחת שמקודדת על–ידי ארבעה קודונים שונים.
4. ציינו חומצה אמינית אחת המקודדת על ידי קודון אחד בלבד.
5. לפניכם רצף של אבני בניין ב.DNA בעזרת טבלת הצופן הגנטי רשמו משמאל לימין את רצף החומצות האמיניות בחלבון.

GCAAAAAGGGCTCAA

זכרו: השלשה הראשונה קובעת את החומצה האמינית הראשונה בחלבון. השלשה השנייה קובעת את החומצה האמינית השנייה בחלבון, וכך הלאה.

הקשר בין המידע שב **DNA** לתכונה:

מחלת הדממת (המופיליה) כדוגמה

מחלת הדממת (המופיליה) היא מחלה שבה נפגע תהליך הקרישה של הדם. החולים בדממת סובלים מדימום בלתי פוסק במקרה של פציעה. אם הפציעה חמורה, הדימום עלול לגרום למוות. בעבר לא היה טיפול יעיל למחלה והחולים נפטרו לרוב בגיל צעיר. היום ניתן לטפל בחולים אך בשביל שהטיפול יהיה יעיל ובזמן, חשוב מאוד לאבחן מוקדם ככל האפשר את התינוקות החולים.

ב-DNA של החולים בדממת יש שינוי (מוטציה) במקטע שבו קיים המידע ליצור אחד מהחלבונים שמשתתפים בתהליך הקרישה, שנקרא 9F. המוטציה יכולה לגרום לייצור של חלבון 9F לא תקין. כשהחלבון 9F אינו תקין, תהליך הקרישה של הדם נפגע. במקרה של פציעה, הפצע ממשיך לדמם ללא הפסק.

לפניכם רצף של DNA שהוא חלק מהמקטע שבו המידע ליצירת חלבון הקרישה 9F בקרב אנשים בריאים:

GCAATGAAATATGGAATATATACC

קבלו מהמורה רצף של DNA של תינוק שנולד לא מזמן שיש לבדוק האם הוא חולה בהמופיליה.
אתם חלק מהצוות הרפואי העובד בבית חולים. בעזרת הצופן הגנטי והשאלות הבאות עליכם להחליט אם התינוק שנבדק חולה בהמופיליה או לא.

I. לכמה חומצות אמיניות מקודד הרצף שניתן לכם?

II. בעזרת טבלת הצופן הגנטי רשמו משמאל לימין את רצף חומצות אמיניות של מקטע זה של החלבון 9F בקרב אנשים בריאים.

3. האם יש הבדל בין רצף ה-DNA של התינוק שנבדק (הרצף שקיבלתם מהמורה) לזה של אנשים בריאים? אם כן, מהו ההבדל.

4. בעזרת טבלת הצופן הגנטי רשמו משמאל לימין את רצף החומצות האמיניות של מקטע זה של החלבון 9F של התינוק שנבדק.

5. מה ההבדל בין רצף החומצות האמיניות בחלבון שנוצר בגופם של אנשים בריאים לבין הרצף בחלבון שנוצר בגופו של התינוק שנבדק?

6. האם אתם חושבים שהתינוק שנבדק הוא חולה או בריא?

בדיקות **DNA** אישיות: מה דעתי?

המשיכו לצפות בכתבה. שימו לב אילו בעיות מעלים המרואיינים.

למדתם על הצופן הגנטי והבנתם איך המידע שמתקבל מבדיקות הDNA יכול לתת מידע על תכונה אחת של הנבדק.

העליתם תכונות שהייתם רוצים לחשוף ב-DNA של עצמכם ותכונות שאינכם מעוניינים לחשוף.

אילו תכונות נוספות של האדם יכולות להיחשף מבדיקה של החומר התורשתי שלו ואילו בעיות יכולות לעלות מחשיפה כזו? תוכלו להיעזר בכתבה שראיתם.

היעזרו בכל אלה כדי לקבוע את עמדתכם:

האם הייתם מוכנים למסור דגימה לחברות המספקות שירותי אבחון גנטי?

היעזרו בתבנית בעמוד הבא כדי לחשוב ולנסח תשובה. בתבנית:

1. כתבו את דעתכם האישית. הסבירו ונמקו מדוע זוהי דעתכם (אם הייתם מוכנים, או לא מוכנים, למסור דגימה – רשמו את כל הסיבות המצדיקות את ההחלטה הזו. אם קשה לכם להחליט, רשמו את הסיבות שמעוררות בכם התלבטות).
2. בזוגות, ספרו את דעתכם לשותף שלכם והקשיבו לדעתו.

3. נסחו תשובה משותפת של עמדתכם על סמך ההבנות המשותפות של שניכם אותה תחלקו עם שאר המשתתפים. אינכם חייבים להגיע להסכמה מוחלטת. במידה ואינכם מסכימים – רשמו גם את הנקודות שבהן לא הסכמתם.
4. בדיון כיתתי - שתפו את שאר המשתתפים בתשובה שלכם.
5. קחו אתכם את תשובתכם לפעילות המסכמת של היום

עבודה אישית :מהן המחשבות שלי בנושא	**בזוגות :**מה הבנתי מהדברים שהשותף/ה שלי סיפר/ה לי
שיתוף ידע עם כל הכיתה :מהן ההבנות המשתפות שלנו ,מה כדאי לחלוק עם אחרים ,מהן הנקודות החשובות שעלו בשיחה בינינו	

B.2 Science activity for climax day 2: urbanization and ecological conservation

פעילות מדעים בנושא שימור מול פיתוח עירוני

פעילות 1:

לפניכם שני טיעונים של תלמידים, סידני ותום, המתווכחים ביניהם על מידת ההשפעה של התרחבות העיר על מגוון מיני הציפורים:

1. לדעתכם, מי מהם צודק? מדוע?

פעילות 2: תצפית ציפורים עירונית

1. צאו לרחבת הדשא שלפני מרכז הפיס. זהו מינים של ציפורים בעזרת הקישור:

2. נסו לספור כמה ציפורים ראיתם מכל מין.
3. רשמו את תוצאות התצפית שלכם באמצעות הטבלה. לדוגמה:

מין הציפור	מספר הציפורים שראינו	היכן נראתה הציפור	מה עשתה הציפור
נחליאלי	2	על הדשא	קיפצה. מנקרת משהו בין העשבים.

1. באילו רכיבים בנוף (דשא, עצים גבוהים, שיחים, אדמה חולית, בניינים, מדרכות) ראיתם ציפורים?

_____

_____

_____

_____

2. אילו רכיבים בנוף שבו צפיתם בציפורים (דשא, עצים גבוהים, שיחים, אדמה חולית, בניינים, מדרכות) נפוצים בעיר ואילו נדירים יותר?

_____

_____

_____

_____

3. אילו מהרכיבים האלה אתם מזהים באזור המגורים שלכם ואילו בפרק השכונתי שלכם?

_____

_____

_____

_____

4. נסו לשער, אילו ציפורים יהיו נפוצות יותר בפארק השכונתי שלכם ואילו ברחוב בו אתם גרים? הסתמכו על התצפית שלכם כדי להסביר את השערתכם.

_____

_____

_____

_____

כעת, סכמו את הממצאים שלכם בכיתה ביצירת טבלה משותפת של סוגי הציפורים שנצפו, מספר פרטים והמיקום שבו הן נצפו.

פעילות 2: הבדלים בין שטחים עירוניים לשטחים פתוחים

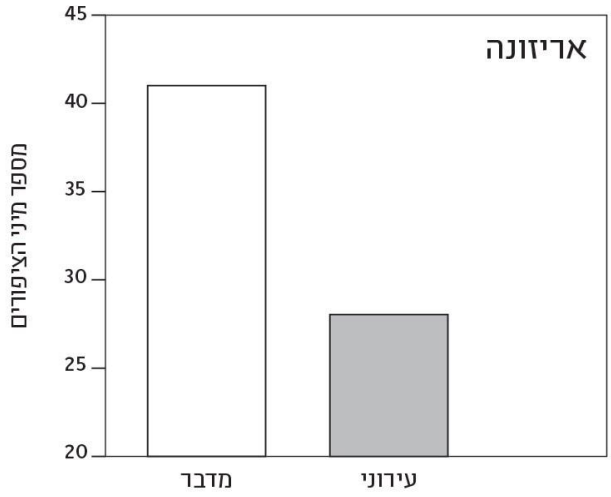
יותר ממחצית אוכלוסיית האנשים בעולם חיה כיום בערים, והמספר הולך ועולה. בשל הגידול בשטחן ובמספרן יש להבין כיצד בני אדם ויצורים חיים יכולים לחיות בערים אלה לצד אלה. העיר כמערכת אקולוגית, שנתפסה בעבר כסביבה אבודה מראש ליצורים חיים, הפכה להיות אתגר עולמי בשמירת טבע.

בשל יכולת התעופה שלהם ויכולתם להסתגל לסביבות מאתגרות, עופות הצליחו היטב לכבוש את העיר. כמו כן, בני אדם סובלניים למרבית מיני העופות, בעוד מכרסמים, זוחלים, פרוקי רגליים שונים וצמחי בר חשופים להדברה והרחקה.

במחקר שבו נבדק מספר מיני הציפורים באזור מדברי טבעי או באזור עירוני באריזונה שבארצות הברית, התקבלו התוצאות הבאות:

שטח עירוני: כל שטח בתוך עיר, הכולל שכונות מגורים, מבני תעשייה, פארקים.

שטח פתוח: שטח טבעי, ללא התערבות האדם. לדוגמה: יער, מדבר, אוקיינוס, ערבה, ג'ונגל.



תמונה מס' 1: מגוון מיני הציפורים באזורים שונים באריזונה. תוצאות מתוך:
https://www.birds.org.il/he/article-page.aspx?articleId=1193

על פי תוצאות המחקר שמוצגות בגרפים ענו על השאלות הבאות:

1. הסתכלו בגרף:

א. כמה מיני ציפורים נמצאו באזור המדבר הטבעי?

ב. כמה מיני ציפורים נמצאו באזור העירוני?

ג. מה ניתן להסיק מכך על מספר מיני הציפורים באזור הטבעי לעומת האזור העירוני באריזונה?

_____

_____

_____

2. נסו לשער מדוע יש הבדלים במספר מיני הציפורים בין אזורים פתוחים/טבעיים לאזורים עירוניים?

_____

_____

_____

3. בתוך המרחב העירוני באילו אזורים אתם מצפים למצוא מגוון מינים גדול יותר: אזורי תעשיה, אזורי קניות, אזורי מגורים, פארקים עירוניים? הסבירו את בחירתכם.

_____

_____

_____

פעילות 3:

בטבלה נראות תוצאות של מחקר נוסף שנעשה בעיר פניקס שבמדינת אריזונה בארצות הברית. בדומה לתצפית שעשיתם, החוקרים ערכו תצפיות בציפורים בשכונות שונות בעיר, ובפארקים שנמצאים באותן שכונות.

טבלה מס' 2: מספר מיני הציפורים בשכונות שונות ובפארקים שכונתיים בעיר פניקס. הנתונים נלקחו מתוך:

שם השכונה	מספר מיני הציפורים שנצפו בשכונה	מספר מיני הציפורים בפארק השכונתי
קשמן	21	33
ווסטרן סטאר	21	28
סונריסה	19	28
צולה קוב	25	23
קאונטרי גייבלס	17	28
נואב	15	18

Kinzig, A. P., P. Warren, C. Martin, D. Hope, and M. Katti. 2005. The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. *Ecology and Society* **10**(1): 23. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art23/

בזוגות: על פי הנתונים שמוצגים בטבלה ענו על השאלות הבאות:

1. א. מה אפשר להסיק מהטבלה על מספר מיני הציפורים בשכונה לעומת מספר מיני הציפורים בפארק של אותה שכונה?

_____

_____

_____

2. מהו ההסבר לתופעה זו, לדעתכם? קשרו את הממצאים שלכם מהתצפית בחצר בית הספר להסבר שלכם.

<u>עבודה בקבוצות:</u>

בחלקים הקודמים של הפעילות ערכתם תצפית שבה בחנתם אילו מינים של ציפורים נמצאים בסביבת המגורים שלכם, וכיצד מינים אלו משתלבים במאפייני הסביבה. בנוסף, נחשפתם לטקסטים שבוחנים איך מגוון מיני הציפורים משתנה לפי סוגי שטח שונים (עירוני, מדברי, עירוני-שכונה, עירוני-פארק).

כעת, חזרו שוב אל הטיעונים של סידני ותום. היעזרו בתצפית שערכתם ובטקסטים שקראתם כדי למלא את הטבלה בעמוד הבא. בעזרת הטבלה תוכלו לעזור לסידני ותום להגיע להכרעה. הכריעו כקבוצה אילו עדויות תומכות בטיעונים השונים. הוסיפו טיעונים שלכם כקבוצה התומכים בכל אחד מן הטיעונים.

עדויות מהתצפיות וציטוטים מהטקסט	במי העדות תומכת			כיצד תומכת בהם העדות?
	סידני	תום	באף אחד\בשניהם	
בתצפית שלנו ראינו סוגים שונים של ציפורים על עמודי חשמל, עמודי תאורה, ועל הכביש או המדרכה.				אלו רכיבים בנוף שנפוצים בשטח העירוני ולכן גם נצפה לראות הרבה ציפורים בעיר
באריזונה, מספר מיני הציפורים במדבר גבוה ממספר המינים בתוך הערים.				על פי נתוני המחקר, לשטח העירוני יש השפעה שלילית על מגוון מיני הציפורים בעיר אולי יש הרבה ציפורים אבל המגוון שלהם מצומצם
לציפורים יכולת הסתגלות לסביבות מאתגרות ובני אדם מגלים סובלנות כלפיהן				הסביבה העירונית לא דוחה את כל הציפורים. יש מיני ציפורים שמצליחים להסתגל לחיים בעיר
לפי תצפית שנערכה בעיר פניקס שבמדינת אריזונה, ברוב הפארקים השכונתיים ניתן לצפות במספר מינים רב יותר של ציפורים מאשר בשכונות המגורים				מינים רבים יותר של ציפורים מעדיפים צמחיה על שטח בנוי.
בתצפית שלנו ראינו ציפורים מסתתרות בתוך עצים ושיחים.				בשטחים פתוחים יש בדרך כלל יותר עצים ושיחים מאשר בתוך העיר
בנייה של פארקים שכונתיים רבים יותר עשויה להפחית את הפגיעה במגוון מיני הציפורים				
עדות נוספת מהתצפית שלנו				
עדות נוספת מהטקסטים				

כעת כשבחנתם את הראיות:

1. בתחילת הפעילות נדרשתם לשער מי מבין סידני ותום צודק. האם דעתכם השתנתה?
2. איזה טיעון, של סידני או של תום, יותר משכנע לדעתכם? הסבירו מה הופך את הטיעון שבו בחרתם למשכנע יותר.
3. הרחיבו את הטיעון שבו בחרתם (של סידני או של תום) כך שהוא יהיה משכנע אף יותר. היעזרו בנתונים שאספתם מהתצפית ובטקסטים לשם כך.

פעילות 4: איך אנחנו יכולים להשפיע?

הסרטים שלפניכם מציגים שתי גישות לשימור הטבע.

מהם לדעתכם ההבדלים בין שתי גישות השימור?

1. מתי לדעתכם כדאי לנקוט בכל גישה?
2. כיצד אתם חושבים שאזרחים יכולים להשפיע על החלטות שמתקבלות לגבי עתיד שטחים פתוחים או שטחים עירוניים?

_____

_____

מה אנחנו יכולים לעשות כדי להשפיע על שמירת מגוון הציפורים בנס ציונה? (בקבוצות)

<u>שימור מיני ציפורים ייחודיים בנס ציונה</u>

במסגרת סקר תשתיות טבע עירוני בנס ציונה שנערך בשנת 2016 נמצא כי ישנה פגיעה במערכות הטבע הייחודיות אשר מתקיימות מסביב לעיר. פגיעה זו הובילה לנטישת המרחב על ידי מיני עופות ייחודיים ולהחלפתם על ידי מינים אחרים שמסתגלים לסביבה המשתנה.

מינים רבים שנמצאו בעבר בשטחים פתוחים ובשטחי הכורכר לא נמצאו במהלך הסקר, לדוגמה: כחל מצוי, חטפית אפורה, סבכי קוצים, חמריה חלודת זנב ועוד.

כדי לאפשר המשך קיום ושגשוג של מגוון מיני עופות מקננים בעיר נס ציונה ובסביבתה נדרש תכנון ששם דגש על שמירה ושיקום של בתי הגידול הייחודיים שסביב העיר.

לפניכם תיאור של אחד המינים שנמצאו בסקר באזור נס ציונה. (לתת לכל קבוצת תלמידים מין אחר של ציפור לקטע זה, להכין כדפי מידע עם תמונה שנותנים לכל קבוצה)

1. קראו את התיאור וכתבו מה ניתן לדעתכם לעשות כדי לשמור על הציפורים ממין זה באזור נס ציונה.
2. הציגו לשאר הקבוצות את הצעותיכם.
3. רשמו הצעה משותפת לעיריית נס ציונה שתכלול את ההצעות שנראות לכם מתאימות. מטרות ההצעה: א. לעודד בקרב תושבי העיר הרגלים התומכים במשיכת הציפור לעיר. ב. ליצור בעיר שטחים ציבוריים ופרטיים המעודדים את הציפור להתגורר בה. הסבירו לעירייה על סמך מה אתם מעלים את המלצותיכם.

שרקרק מצוי

מין בסכנת הכחדה. מבעלי הכנף הססגוניים בארצנו. השרקרק חופר מחילה בקרקעות רכות ומקנן בה. מזונו העיקרי הוא חרקים ממשפחת הדבוראים דבר היוצר קונפליקט עם מגדלי הדבורים. השרקרקים תלויים בקירות עפר לקינון ובשטחים פתוחים לצייד, והללו הולכים ומתמעטים. השרקרק המצוי כמעט ונעלם מאזורים מסוימים בארץ בשנות החמישים, עקב הרעלות מחומרי הדברה. משנות השמונים החלה התאוששות של מין זה וכיום ניתן לראותו שוב באזורים אלו. אזור נס ציונה הוא אחד המוקדים הגדולים של השרקרק המצוי בשפלה.

.

בזבוז אירופי

ציפור שיר קטנה אשר מקננת כמעט רק על ברושים בצידי פרדסים ומטעים. ציפור זאת נפגעה מצייד ואיבוד שטחי מחייה. באזור נס ציונה נמצא הריכוז הגדול ביותר בארץ של מין זה המקנן בעיקר בשדרות ברושים בפרדסים, אך גם מקנן בסביבה הבנויה, בגינות ציבוריות ופארקים.

שיחנית קטנה

השיחנית הקטנה היא ציפור חיונית וזריזה, שמקפצת לה מענף לענף בחוסר מנוחה תמידי. היא מחבבת במיוחד נופים של שיחים ועצים דלילים, ערוצים של נחלי אכזב, עצי אשל, יערות, פארקים ואפילו גינות עירוניות. מזונה: כנימות, זבובונים וחרקים זעירים אחרים. נכחדה כמעט לחלוטין מאזור מישור החוף והשרון עקב העלמות בית גידולה. במהלך הסקר בנס ציונה נמצאה אוכלוסייה קטנה של שיחניות בפרדסים נטושים ובשדות.

חוחית

ציפור יפיפייה של שולי החורש ושדות בור המצויה גם באזורים מיושבים. אוכלת בעיקר זרעי צמחי בר קוצניים ומכאן שמה (חוח עקוד הוא שם של צמח בר קוצני נפוץ(. בחורף ובראשית האביב החוחית עשויה לאכול גם זרעים של אורנים אותם היא שולפת מתוך האצטרובלים,בחמישים השנים האחרונות נפגעה קשות עקב הרס בתי גידול וציד נרחב. בנס ציונה נמצאת אוכלוסייה מסוימת בעיקר בשדות בור ופרטים מקננים על שדרות ברושים ומחטניים (כמו אורנים) מסביב לעיר.

כוס חורבות

דורס לילה קטן הפעיל חלקית אף ביום. דורס לילי זה הוא טריטוריאלי מאוד החי לרוב בזוגות קבועים, החיים בנחלה במשך כל חודשי השנה. הכוס נפוץ בעיקר בשטחים פתוחים, אך גם בישובים כפריים ובנופים חקלאיים. הוא שכיח ברוב אזורי הארץ, חובב במיוחד תלי חורבות, וכן אזורים טרשיים או סלעיים עם מצוקים קטנים וגלי אבנים שבהם הוא מוצא חורים מתאימים למסתור ולקינון. הקן ממוקם בכוכים במצוקים או בטרסות אבן, חללים בעצים ובעליות גג, ובאזורים חוליים גם במחילות שנחפרו באדמה על ידי מכרסמים גדולים או שועלים. הכוס מקנן גם במחילות וסדקים בסלעים אותם הוא מוצא בחורבות מחצבות נטושות. בנס ציונה נמצא זוג אחד המקנן במחצבה נטושה.

B.3 Science activity for climax day 3: mandatory vaccination

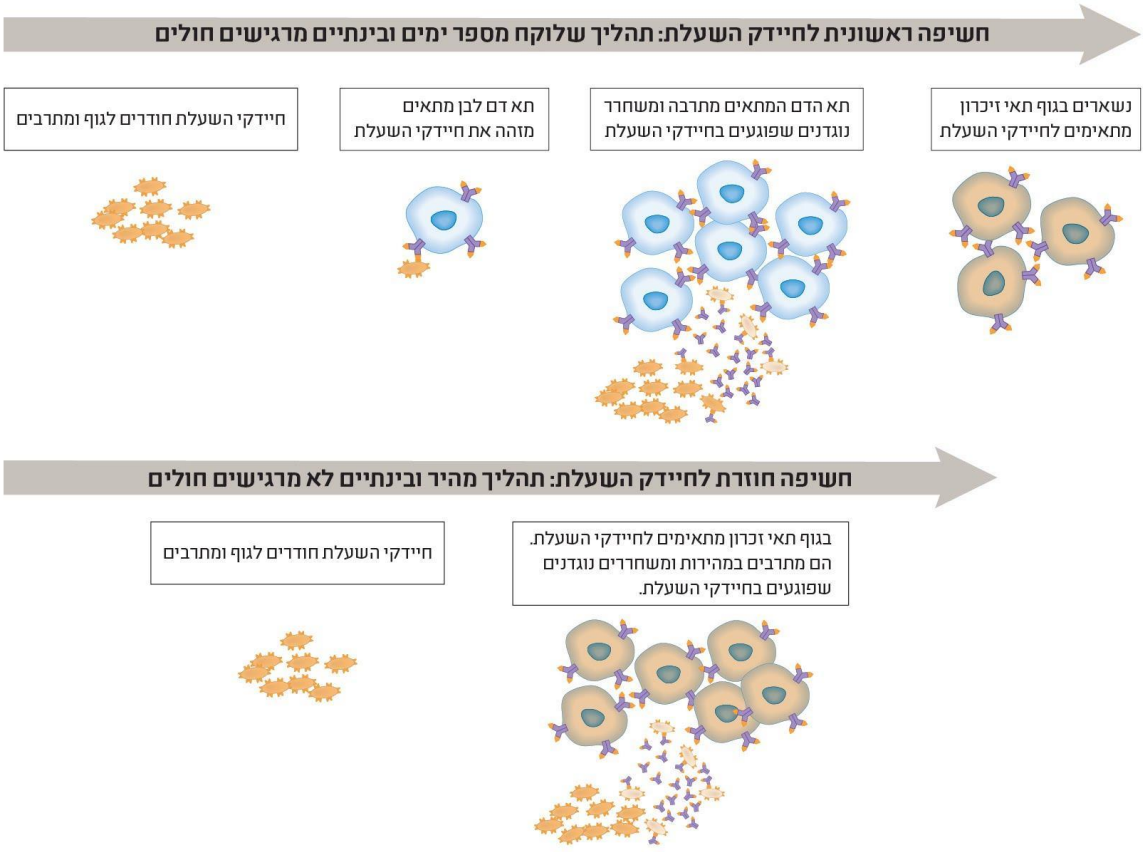
<u>חיסונים והשפעתם על החברה</u>

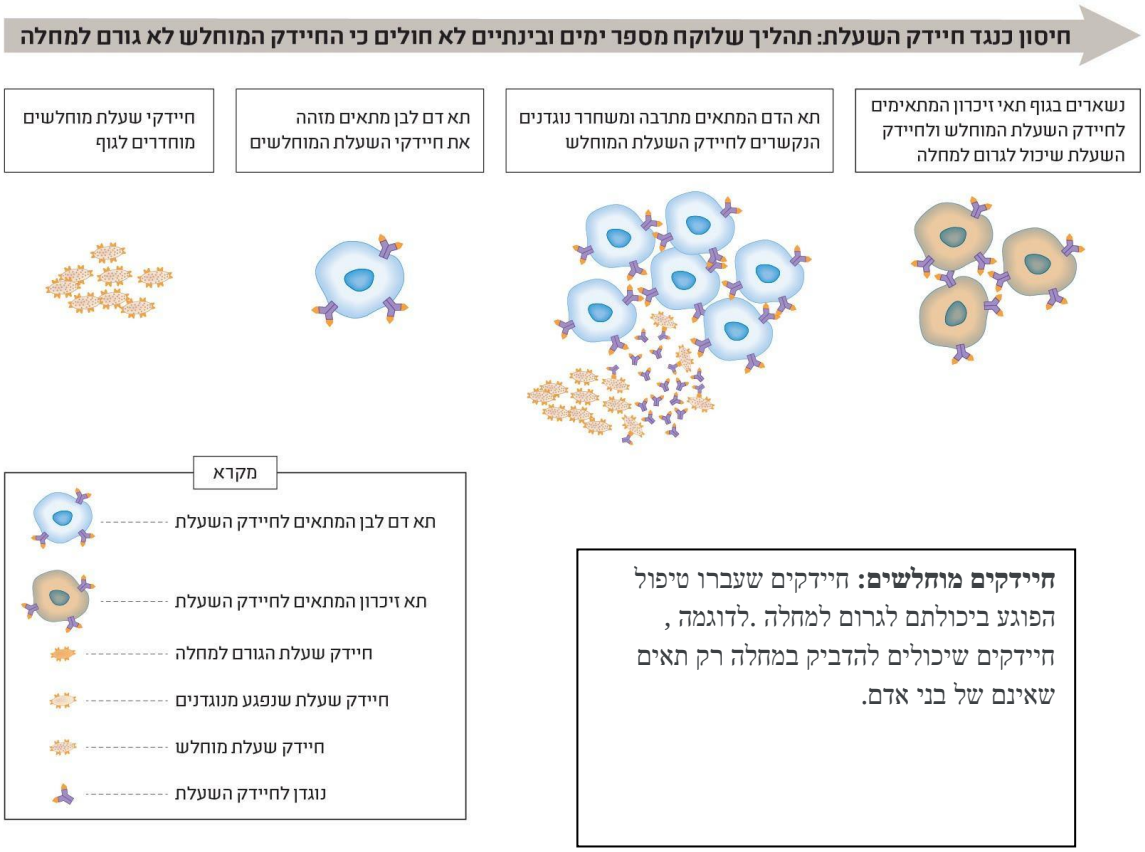
מעטים הם הפיתוחים המדעיים שהשפעתם על בריאות החברה גדולה מאלו של החיסונים. השימוש בחיסונים הוביל לצמצום תפוצתן העולמית של מחלות מסוימות, שחלקן יכולות לגרום לנכות או למוות. לכן, גורמי בריאות בארצות הברית וגם בישראל ממליצים לחסן ילדים מפני 16 מחלות שונות.

<u>**?**פעילות מס' 1: מה זה חיסון / כיצד פועל חיסון</u>

1. עד כמה אתם מכירים את דרך הפעולה של חיסונים? העלו שאלות שיש לכם לגבי חיסונים ורשמו אותן.

2. התבוננו באיורים. בעזרת המידע שקיבלתם מהאיורים הבאים ענו על השאלות שבסוף.





איור 1. מנגנון הפעילות של חיסונים

א. השלימו את הטבלה הבאה:

	איזה חיידק שעלת חדר לגוף (חי/ מוחלש)	האם כבר יש בגוף תאי זיכרון לחיידק השעלת (כן/לא)	משך הזמן שלוקח עד שמערכת החיסון פוגעת בחיידק השעלת (ארוך / קצר)	האם מרגישים חולים (כן/לא)
חשיפה ראשונית לחיידק השעלת	<u>חיידק חי</u>	<u>לא</u>	<u>ארוך</u>	<u>כן</u>
חשיפה חוזרת לחיידק השעלת		<u>כן</u>		<u>לא</u>
חיסון כנגד חיידק השעלת על ידי הזרקת חיידק מוחלש	<u>חיידק מוחלש</u>		<u>ארוך</u>	
חשיפה לחיידק שעלת לאחר חיסון על ידי הזרקת חיידק מוחלש		<u>כן</u>		

ב. הסבירו, כיצד חיסון יכול למנוע התפתחות מחלה כאשר נחשפים לגורם מחלה?

ג. האם קיבלתם תשובות לשאלות שהעליתם בתחילת הפעילות?

<u>פעילות מס' 2: השפעת החיסונים</u>

בארצות הברית נערכה השוואה בין מספר מקרי התחלואה בשנת 2018 ממחלות שונות אשר להן קיים חיסון, למספר מקרי התחלואה לשנה מאותן מחלות במאה ה-20. התוצאות מוצגות בטבלה מס' 1.

טבלה 1. שיעור תחלואה בארצות הברית ממחלות שונות בשנת 2018 אל מול תחלואה שנתית במאה ה-20

(המידע נלקח מהמרכז לבקרת מחלות ומניעתן, ארצות הברית, 2018)

מחלה	תחלואה שנתית במאה ה-20 (1901-1999)	תחלואה ב-2018	ירידה (באחוזים)
אבעבועות שחורות	29,005	0	100%
דיפתריה	21,053	1	99%<
חצבת	530,2017	273	99%<
חזרת	162,344	2251	99%
שעלת	200,752	13,439	93%
אדמת	47,745	5	99%<
פוליו	16,316	0	100%

1. הביאו דוגמה למחלות שהתחלואה מהן הופחתה בערך ביותר מ95%.

2. הביאו דוגמה למחלה שכבר לא חולים בה בכלל בשנת 2018 בארצות הברית.

מהנתונים שבטבלה ניתן לראות שחלה ירידה משמעותית בתחלואה ממחלות אלו ויש אף שנעלמו מהעולם. מחלת אבעבועות שחורות נעלמה מהעולם ומחלת הפוליו קרובה להיעלמות בזכות החיסונים נגדן.

פעילות מס' 3: משחק: "תופסת חיסונים"

שלב ראשון:

כדי להבין טוב יותר את השפעת החיסונים על בריאות הציבור נשחק תופסת.

1) מתנדב אחד נדרש להיות התופס. עליו לצאת החוצה מהכיתה בזמן ששאר התלמידים מתארגנים
2) שאר השחקנים מקבלים מהמורה קלף. הקלף הזה הוא שלכם בלבד ורק אתם יודעים את תוכנו.

אם קיבלתם קלף ריק: אתם מצטרפים אל התופס לאחר שהוא תופס אתכם. כעת גם אתם יכולים לנסות לתפוס שחקנים אחרים

אם קיבלתם קלף "עצור": התופס לא יכול לתפוס אתכם ואתם לא יכולים להצטרף אליו ולתפוס שחקנים אחרים

שימו לב! יש להסתיר את הקלפים מהשחקן התופס

המשחק מסתיים לאחר שכל התלמידים חשפו את הקלפים שלהם

שלב שני:

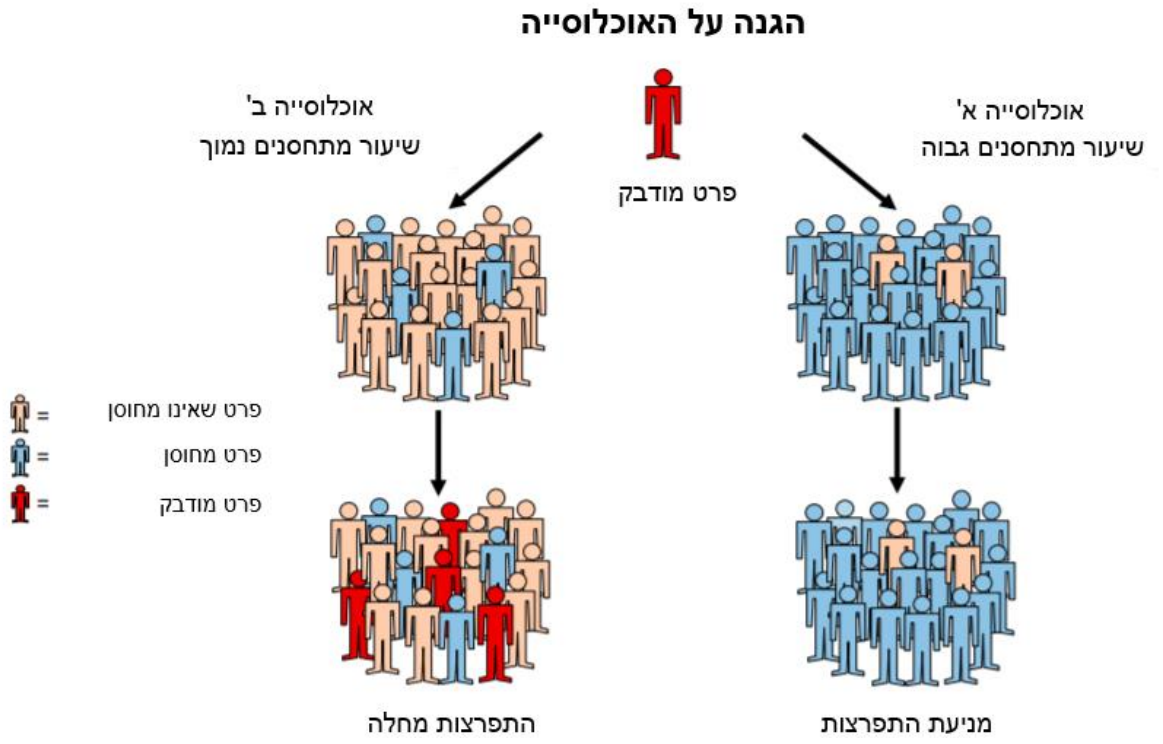
אותם חוקים, רק עם חלוקה מחודשת של הקלפים

שאלה לתלמידים בסיום המשחק:

באיזה מהשלבים (הראשון או השני) היה לתופס קל יותר לנצח ומדוע?

<u>פעילות מס' 4: חסינות העדר</u>

בנוסף להגנה האישית על האדם שקיבל את החיסון, חיסונים מאפשרים גם הגנה רחבה ברמת החברה ומונעים הפצת מחלות. לדוגמה, אדם חולה באדמת, עלול להדביק במחלה אדם שלא חוסן וטרם חלה במחלה. לעומת זאת, אדם החולה באדמת לא ידביק במחלה אדם שחוסן לאדמת וטרם חלה במחלה (איור 1). תופעה זו של הגנה רחבה על האוכלוסייה על ידי חיסונים אישיים נקראת חסינות העדר.



איור 2. חסינות העדר: הגנה על אוכלוסיות עם שיעור מתחסנים גבוה ונמוך. נלקח מ:

Orenstein, W. A., & Ahmed, R. (2017). Simply put: vaccination saves lives.

היעזרו במשחק ששיחקנו ובאיור מס' 1 וענו על השאלות הבאות:

1. במה דומה משחק התופסת לנראה באיור? במה הם שונים?

1. מה יקרה למספר החולים במחלה אם תחול ירידה באחוז האנשים המתחסנים?

2. מה יקרה לתינוקות שלא חוסנו עדיין אם תחול ירידה באחוז האנשים המתחסנים?

3. האם אדם שלא מתחסן משפיע רק על הבריאות האישית שלו?

חסינות העדר חשובה במיוחד עבור תינוקות שעדיין לא התחסנו, אנשים מבוגרים שמערכת החיסון שלהם נחלשת ואנשים שלא יכולים להתחסן מסיבות בריאותיות שונות, כמו חולי סרטן. אם כך, שיעור גבוה של מתחסנים חשוב כדי להגן על פרטים מסוימים באוכלוסייה ולמנוע התפרצות של מחלות.

היות וחסינות העדר תלויה במוכנות של אנשים להתחסן, ירידה בשיעור המתחסנים עלולה לפגוע בחסינות העדר ולחשוף אנשים מסוימים למחלות.

למרות ההגנה האישית והחברתית שחיסונים מעניקים, נשמעים בשנים האחרונות יותר ויותר קולות של אנשים החוששים מחיסונים. חלק מהאנשים מתנגדים לחיסונים באופן מוחלט מסיבות פוליטיות או דתיות, וחלקם מתנגדים כי שלהם חששות מהשפעות שליליות של החיסון עצמו. דוגמה לחשש מהשפעות שליליות של חיסונים אפשר למצוא בדעה הציבורית הקושרת בין רכיבים מסוימים של חיסונים לבין בעיות התפתחותיות בילדים, כמו אוטיזם. זאת למרות שמחקרים מדעיים נרחבים לא מצאו קשר בין חיסונים להופעת אוטיזם בילדים. לפעמים חששות אלו מקבלים הד תקשורתי שמסייע להפיץ אותם. למשל, השחקנית והסופרת ג'ני מקארת'י שהבן שלה, אוון, אובחן כאוטיסט בגיל שנתיים וחצי קושרת בין האבחון לחיסונים קודמים שאוון קיבל. מקארת'י מרבה להביע את דעתה כנגד חיסונים בראיונות בכלי התקשורת, ברשתות חברתיות, ואפילו כתבה ספר בנושא. נוסף על כך, מקארת'י פעילה בארגוני הורים המודאגים מהקשר בין חיסונים לאוטיזם ומובילה הפגנות כנגד חיסונים.

<u>פעילות מס' 5: מחלת החצבת</u>

מחלת החצבת נגרמת על ידי נגיף (וירוס) והיא מחלה מדבקת ביותר. בחלק מהמקרים, סיבוכי המחלה עלולים להיות קשים ואף לסכן חיים.
חצבת מועברת מאדם לאדם על ידי פיזור הנגיף לסביבה בעת שיעול, עיטוש או מגע עם הפרשות מהאף וליחה. לאדם שאינו מחוסן הנחשף לחולה חצבת, יש סיכון של יותר מ-90% להידבק במחלה.

בשנים האחרונות חלה עליה במספר חולי החצבת באירופה ובארצות הברית במדינות שהיו כמעט חופשיות מהמחלה. גם בישראל עלה מספר החולים במחלה בשנים האחרונות.

צפו בסרטו הבא המתאר מקרה של התפרצות מחלת החצבת בקהילות בארצות הברית:

https://www.youtube.com/watch?v=n9k3kNfz8VE

1) מהי הבעיה המוצגת בסרטון?

_____

_____

_____

2) בזוגות, מה הייתם אומרים לאדם אשר מתנגד להתחסן כדי לשכנע אותו להתחסן? כדי לנסח את תשובתכם, סכמו בכרטיסיות המצורפות את הרעיונות המרכזיים שלמדתם בפעילות. תוכלו להיעזר בנתונים שמובאים בדפי העבודה ובמונחים חסינות העדר, תאי זיכרון, נוגדנים, התפרצות המחלה, יעילות החיסונים.

B.4 Science activity for climax day 4: human genetic modifications

<u>פעילות מדעים בקבוצות</u>

מוניתם להיות חברי וועדה ממשלתית שסוקרת האם ההכנסה של ריפוי גנטי לסל התרופות היא כדאית וראויה. לפניכם קטעי מידע המתארים תכונות שונות של בני אדם. לפי קטעי המידע האלו והשאלות שבסופם תצטרכו לקבוע האם ראוי וכדאי ששינוי גנטי לתכונות אלו יהיה חלק מסל הבריאות. בקבוצות, קראו את קטעי המידע וענו על השאלות שבסופם כדי לקבוע את החלטתכם הקבוצתית.

תכונה 1: מהי פנילקטונוריה?

פנילקטונוריה היא מחלה תורשתית נדירה שבה אחד מרכיבי המזון אינו מפורק כראוי. רכיב זה רעיל לתאי הגוף, ומכיוון שאינו מפורק הוא מצטבר בדם וגורם נזק. תסמיני המחלה קשים: פיגור שכלי עמוק, הפרעות התנהגות קשות ועוד.

המחלה נגרמת משינוי בDNA שעובר בתורשה וגורם ליצירת חלבון לא תקין ולפגיעה בפירוק תקין של הרכיב המסוים במזון.

כל תינוק שנולד בבית חולים במדינת ישראל עובר בדיקה לאבחון המחלה עם לידתו. אם בבדיקה נמצא שהתינוק חולה, ניתן להתחיל בטיפול מוקדם מאוד ולמנוע את הופעת התסמינים של המחלה.

הטיפול במחלה מתבסס על הימנעות מוחלטת ממזונות המכילים את הרכיב המסוכן עבור החולים: החולים צריכים להימנע ממזונות עשירים בחלבון, כמו מוצרי בשר, קטניות ומוצרי חלב. כמו כן, על החולים להימנע לחלוטין מצריכת משקאות דיאטטיים. כתחליף למזונות אלה מקבלים החולים באופן קבוע אבקת חלבון שממנה הוציאו את הרכיב הרעיל עבורם. הם צריכים לעקוב כל חייהם אחר רמות הרכיב הרעיל בדם, ואם יש חריגה לרעה עליהם לקבל מייד הנחיות איך להוריד את רמתו בתזונה שלהם. יש חולים המעידים כי הם מרגישים כשרמות הרכיב עולות בדמם.

נכון להיום, אין תרופה למחלה הנדירה הזו, אך כל עוד החולים מקפידים לאכול רק לפי הדיאטה המיוחדת המתאימה להם, באפשרותם לנהל אורח חיים רגיל.

חוקרים בוחנים אפשרות לרפא פנילקטונוריה על ידי החלפת מקטע ה-DNA הפגום שבחולים במקטע תקין. תהליך זה נקרא ריפוי גני.

1. מהי התכונה שמדובר עליה בקטע המידע?
2. מה גורם לכך שאדם יהיה חולה בפנילקטונוריה?
3. האם ניתן לטפל במחלה בדרך שאינה על ידי ריפוי גני?
4. האם אתם חושבים שצריך לטפל במחלה על ידי ריפוי גני?
5. היעזרו בתיאורי התכונות שלפניכם. האם התכונה שעליה קראתם היא חד גנית, מספר גנית או רב גנית? מדוע?

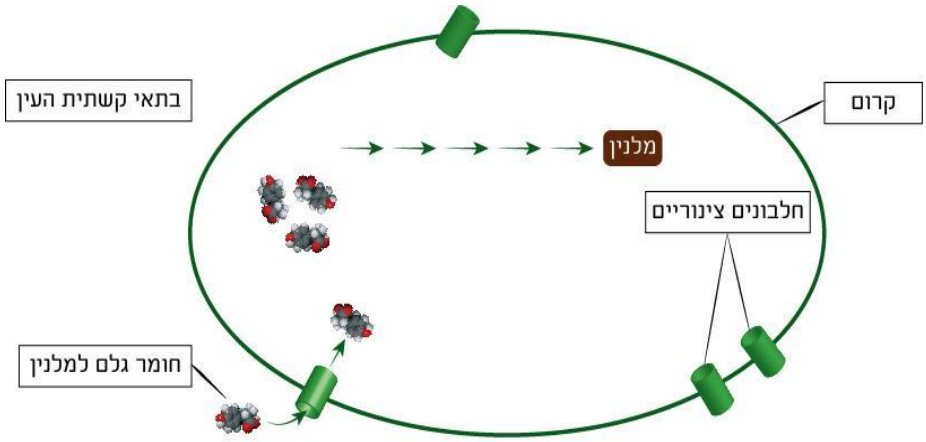
עליכם להציג את התכונה שעליה קראתם והמאפיינים שלה בפני הכיתה. השאלות שבסיום קטעי המידע והטבלה הבאה יעזרו לכם להעלות את המאפיינים המשמעותיים של כל תכונה.

התכונה	הגורם לתכונה (גן יחיד, מספר גנים, גנים רבים מאוד)	ביטוי לתכונה	האם החלפת גן יחיד תצליח בוודאות לשנות את התכונה?	האם קיימת דרך נוספת להשפיע על התכונה (דרך שאינה הנדסה גנטית)?	האם ראוי להתערב בעזרת הנדסה גנטית כדי לשנות את התכונה?

תכונה 2: מה קובע את צבע העיניים?

החומר היוצר את צבע העור של גופנו, צבע השיער וצבע העיניים נקרא מלנין. בעיניים הוא נוצר בתאים ייחודיים הנמצאים בקשתית, החלק הצבעוני של העין.

חומר הגלם שממנו נוצר מלנין עובר בזרם הדם ונכנס לתוך התאים הייחודיים בקשתית המייצרים מלנין. חומר גלם זה נכנס לתאים באמצעות חלבון צינורי, הנושא אותו לתוך התאים. כמו כל חלבון, יש אצל כל אחד מאיתנו מקטע ב-DNA (גן) המקודד לחלבון זה.



אצל אנשים עם עיניים חומות הDNA יוצר חלבון הצינורי אשר עובד ביעילות, ומכניס יחסית הרבה חומר גלם לתוך התאים. כתוצאה מכך התאים מייצרים הרבה מלנין, ונוצר צבע חום. לעומת זאת, בקרב אנשים עם עיניים כחולות, החלבון הצינורי הנוצר מה-DNA אינו עובד ביעילות, ומכניס יחסית מעט חומר גלם לתוך התאים. כתוצאה מכך התאים מייצרים מעט מאוד מלנין, וכמעט שלא נראה צבע חום בקשתית.

אז למה רואים צבע כחול בעיניים חסרות מלנין? הצבע הכחול של עיניים נקרא צבע פיזיקלי: האור הפוגע בקשתית העין נשבר בדרך מסוימת היוצרת אורך גל כחול. תופעה זו דומה לצבע הכחול של נוצות הטווס, ולצבע הכחול של השמיים.

יש אנשים עם עיניים ירוקות, בצבעי ענבר (חום-אדום) ועם טבעות של צבעים שונים בקשתית העין. יצירת מלנין היא תהליך מורכב, והמקטע ב-DNA (הגן) המקודד לחלבון המעביר את חומר הגלם למלנין מסביר רק את ההבדל בין עין שיש בה צבע (כל הגוונים) לעין שאין בה צבע (כחולה). שאר המופעים המגוונים של העיניים נקבעים על ידי עשרות גנים אחרים ב-DNA.

1. מהי התכונה שמדובר עליה בקטע המידע?
2. מה גורם למופעים השונים של התכונה?
3. אפשר לשנות את הגן המקודד לחלבון המעביר את חומר הגלם למלנין באמצעות הנדסה גנטית.
4. האם שינוי בחלבון זה יגרום לשינוי צבע העיניים?
5. האם בעזרת שינוי גנטי שישנה חלבון זה נוכל לבחור צבע עיניים מדויק?
6. האם אתם חושבים שראוי לשנות את התכונה הזאת על ידי הנדסה גנטית?

עליכם להציג את התכונה שעליה קראתם והמאפיינים שלה בפני הכיתה. השאלות שבסיום קטעי המידע והטבלה הבאה יעזרו לכם להעלות את המאפיינים המשמעותיים של כל תכונה.

התכונה	הגורם לתכונה (גן יחיד, מספר גנים, גנים רבים מאוד)	ביטוי לתכונה	האם החלפת גן יחיד תצליח בוודאות לשנות את התכונה?	האם קיימת דרך נוספת להשפיע על התכונה (דרך שאינה הנדסה גנטית)?	האם ראוי להתערב בעזרת הנדסה גנטית כדי לשנות את התכונה?

תכונה 3:

התרופה היקרה בעולם

מריה בת השנה ועשרה חודשים מרהט, סובלת מ-SMA, מחלת ניוון שרירים תורשתית ונדירה. אחיה נפטר מהמחלה לפני כ-5 שנים. בינואר 2020 ניתנה למריה התרופה זולג'נסמה הנחשבת לתרופה היקרה בעולם. מריה תחגוג בעוד כחודשיים את יום הולדתה השני ולכן הייתה חשיבות רבה לזרז את מתן הטיפול מכיוון שהתרופה ניתנת עד גיל שנתיים וההמלצה היא לתת אותה מוקדם ככל הניתן.

מחלת ה SMA - נובעת משינוי גנטי יחיד בDNA שמוביל למוות של תאי עצב שמעבירים אותות מהמוח וגורמים לשרירי השלד להתכווץ ולהניע את הגוף. הפגיעה בתאי העצב גורמת לחולשה ודלדול שרירים המחמירים עם הגיל ובסופו של דבר מאבדים הילדים את היכולת ללכת, לדבר, לבלוע ולנשום. עד לאחרונה הייתה המחלה חשוכת מרפא.

התרופה זולג'נסמה נחשבת תרופה פורצת דרך בריפוי גני: היא מכניסה DNA תקין לתאים של החולים דבר שגורם לריפוי של המחלה אצל התינוק. יתרונה הוא בכך שמדובר בטיפול חד פעמי – זריקה אחת והתינוק מחלים. המחקר שפורסם על הצלחת הטיפול כלל מעקב של שנתיים עד עכשיו. זהו זמן קצר יחסית, ויעילותו לאורך זמן מחייבת מעקב ממושך יותר.

זולג'נסמה נחשבת לתרופה היקרה בעולם: עלות הטיפול החד פעמי היא כ־7.6 מיליון שקל. בישראל הטיפול נכנס השנה לסל התרופות, כך שקופות החולים יממנו את הטיפול לילדים החולים במחלה. עבור מריה זהו סיכוי אמיתי לחיים בריאים יותר.

1. מהי התכונה שמדובר עליה בקטע המידע?
2. מה גורם לכך שאדם יהיה חולה ב SMA?
3. מדוע חשבו לרפא מחלה זו על ידי ריפוי גני?
4. האם ניתן לטפל במחלה בדרך אחרת?
5. האם אתם חושבים שצריך לטפל במחלה על ידי ריפוי גני? הביאו נימוקים בעד ונגד.

עליכם להציג את התכונה שעליה קראתם והמאפיינים שלה בפני הכיתה. השאלות שבסיום קטעי המידע והטבלה הבאה יעזרו לכם להעלות את המאפיינים המשמעותיים של כל תכונה.

התכונה	הגורם לתכונה (גן יחיד, מספר גנים, גנים רבים מאוד)	ביטוי לתכונה	האם החלפת גן יחיד תצליח בוודאות לשנות את התכונה?	האם קיימת דרך נוספת להשפיע על התכונה (דרך שאינה הנדסה גנטית)?	האם ראוי להתערב בעזרת הנדסה גנטית כדי לשנות את התכונה?

תכונה 4:

האם גובהם של בני האדם הולך ועולה?

אם נתבונן בשריון אבירים מימי הביניים, או נמדוד את אורך המיטות או את גובה המשקופים של הדלתות שנבנו במאות הקודמות, ניווכח שכל אלה היו נמוכים יחסית לגובהם של אנשים כיום. כך למשל, בשנת 1860הגובה הממוצע של הגברים הבוגרים בהולנד היה 165 ס"מ בלבד ואילו כיום הוא 184 ס"מ.

דוגמה נוספת של שינוי בגובה נצפתה בילדים שהיגרו עם הוריהם מגואטמלה לארצות הברית. בטבלה שלפניכם מובאים נתוני הגובה של ילדים בני 7–9 שהיגרו לארצות הברית, לעומת נתוני הגובה של ילדים בני אותם גילים שנותרו עם הוריהם בגואטמלה*.

*המחקר נערך על ילדים מפני שהם בתקופת גדילה :קיים חלון זמן שבו מתרחשת צמיחת העצמות .תכונת הגובה אצל אנשים בוגרים שסיימו לצמוח כבר קבועה ואינה נתונה לשינויים.

גובה ממוצע של ילדים בגואטמלה ושל ילדים שהיגרו מגואטמלה

גיל הילדים (בשנים)	גובה ממוצע (בס"מ) של ילדים שנותרו בגואטמלה	גובה ממוצע (בס"מ) של ילדים שהיגרו לארצות הברית
7	109.3	119.7
8	116.1	126.5
9	120.6	133.1

1. מהי המסקנה מן הנתונים בטבלה?

הסבר אפשרי לעלייה בגובה הממוצע של ילדים אלה הוא השיפור המשמעותי בתזונה ובשירותי הבריאות. הסבר דומה אפשר לייחס לעלייה בגובהם של הגברים בהולנד: התזונה ושירותי הבריאות במאה העשרים ואחת נמצאים ברמה גבוהה יותר מרמתם באלה שאפיינו את המאה התשע-עשרה.

עלייה בנתוני הגובה הממוצע קיימת באוכלוסיות נוספות ברחבי העולם, כנראה מפני שבאזורים מסוימים חל שיפור מתמיד בתזונה ובמניעת מחלות. לכן גובהם הממוצע של אנשים באוכלוסיות שונות משמש כיום אחד המדדים לתנאי המחיה של מקום מגוריהם.

2. מהי התכונה שמדובר עליה בקטע המידע?
3. מה גורם לכך שאדם יהיה גבוה או נמוך בנוסף למידע התורשתי ב-DNA?
4. לאור תשובתכם לשאלה 3:
   א. האם תמיד להורים נמוכים יהיו ילדים שיגדלו לבוגרים גבוהים? הסבירו.
   ב. האם החלפת הגנים ב-DNA של ילדים לגנים המשפיעים לטובה על גובה תגרום להם להיות בוגרים גבוהים?

עליכם להציג את התכונה שעליה קראתם והמאפיינים שלה בפני הכיתה. השאלות שבסיום קטעי המידע והטבלה הבאה יעזרו לכם להעלות את המאפיינים המשמעותיים של כל תכונה.

התכונה	הגורם לתכונה (גן יחיד, מספר גנים, גנים רבים מאוד)	ביטוי לתכונה	האם החלפת גן יחיד תצליח בוודאות לשנות את התכונה?	האם קיימת דרך נוספת להשפיע על התכונה (דרך שאינה הנדסה גנטית)?	האם ראוי להתערב בעזרת הנדסה גנטית כדי לשנות את התכונה?

תכונה 5:

תינוקות מהונדסים גנטית

בנובמבר 2018 העלה חוקר גנטיקה סיני, סרטון לאתר יוטיוב שבו הוא חשף תאומות בשם ננה ולולו, שעברו שינוי גנטי כאשר עוד היו עוברים בשלב הראשוני ביותר. השינוי הגנטי נעשה כדי למנוע מהתאומות לחלות באיידס. לאחר השינוי הגנטי העוברים הושתלו ברחם של אימם, וכשנולדו נבדקו שוב ונמצא שהן בריאות.

הסיבה שהחוקר עשה שינויי גנטיים בתינוקות היא שהאב שלהן הוא נשא של הנגיף (וירוס) שגורם למחלת האיידס ועלול להדביק את בנותיו. אלא שיש היום דרכים פשוטות בהרבה עבור נשאים להביא ילדים בריאים לעולם. בעזרת שיטות אלו נולדים תינוקות בריאים ברחבי העולם כל הזמן.

המערכת בה השתמש החוקר לשינוי גנטי בעוברים אינה מושלמת והיא עלולה להביא לשינויים גנטיים נוספים בעוברים כפי שנמצא במחקרים קודמים. לא ניתו עכשיו לדעת מה יהיו השפעות של השינויים הגנטיים על ננה ולולו : האם יתפתחו ויגדלו באופן תקין? האם יוכלו להוליד ילדים? האם האזורים ב-DNA שעברו שינוי יעברו בצורה תקינה לצאצאים שלהן? האם על ידי עריכה שמטרתה "תיקון" תכונה אחת, יצרנו בעיה בתכונה אחרת? כך שלשינויים גנטיים כאלו יש סיכונים.

סין היא אחת המדינות הבודדות בהן אין פיקוח על ביצוע שינויים גנטיים בבני אדם. אך מחקר זה חצה את הגבולות אפילו בסין. בעקבות המחקר והשערורייה שהתעוררה בעולם אחריו, המדען הסיני נשפט על "עיסוק ברפואה באופן לא חוקי", ונידון לשלוש שנות מאסר. במהלך המשפט נחשף שהתאומות לא היו התינוקות המהונדסות היחידות: תינוק שלישי שעבר הנדסה גנטית נולד במהלך 2019.

1. מהי התכונה ששינה החוקר הסיני בעזרת שינוי גנטי?
2. מה רצה החוקר למנוע?
3. האם ניתן למנוע את המחלה בדרך אחרת?
4. האם אתם חושבים שצריך למנוע את המחלה על ידי טיפול גנטי? הביאו נימוקים בעד ונגד.

עליכם להציג את התכונה שעליה קראתם והמאפיינים שלה בפני הכיתה. השאלות שבסיום קטעי המידע והטבלה הבאה יעזרו לכם להעלות את המאפיינים המשמעותיים של כל תכונה.

התכונה	הגורם לתכונה (גן יחיד, מספר גנים, גנים רבים מאוד)	ביטוי לתכונה	האם החלפת גן יחיד תצליח בוודאות לשנות את התכונה?	האם קיימת דרך נוספת להשפיע על התכונה (דרך שאינה הנדסה גנטית)?	האם ראוי להתערב בעזרת הנדסה גנטית כדי לשנות את התכונה?

פעילות 3: במליאת כיתה

הציגו את התכונה שעליה קראתם והמאפיינים שלה בפני הכיתה. השאלות שבסיום קטעי המידע והטבלה יעזרו לכם להעלות את המאפיינים המשמעותיים של כל תכונה.

התכונה	הגורם לתכונה (גן יחיד, מספר גנים, גנים רבים מאוד)	ביטוי לתכונה	האם החלפת גן יחיד תצליח בוודאות לשנות את התכונה?	האם קיימת דרך נוספת להשפיע על התכונה (דרך שאינה הנדסה גנטית)?	האם ראוי להתערב בעזרת הנדסה גנטית כדי לשנות את התכונה?

פעילות 4: סיכום

איזו מחמש התכונות שעליהן קראתם הייתם בוחרים להכניס לשינוי גנטי בסל התרופות של המדינה? מדוע? היעזרו בידע ונתונים מקטעי הקריאה כדי להסביר את החלטתכם.

_____

_____

_____

_____

_____

B.5 Science activity for climax day 5: fake news

"פייק ניוז" בראי השיטה המדעית

חלק 1: עיון בכתבות הנשלחות לעיתון

שלום עורכים יקרים. לפניכם שתי כתבות שנשלחו אל העיתון שלנו. קראו אותן ורשמו לעצמכם:

א) איזו מהן נראית לכם "פייק ניוז" ומדוע?

ב) איזו מהן משכנעת אתכם יותר ומדוע?

כתבה ראשונה: אוסילו

מתוך הודעה לעיתונות של חברת בוארון, משווקת "אוסילו":

נלקח מאתר:

http://www.scooper.co.il/pr/1001584/

מתכוננים לעונת השפעת כבר עכשיו. אחד הגורמים לנדידת מחלת השפעת הוא המטיילים. בעידן בו המרחק הגיאוגרפי מתקצר בשל יכולת הניידות הגבוהה, אנשים עוברים ממדינה למדינה ונושאים עמם מחלות מהמדינה מהם הם מגיעים ומדביקים בה במדינה אליה הגיעו.

בנוסף, אדם חולה, השוהה במחצית בני אדם בריאים במהלך טיסה ארוכה, וחלוקים אותו אויר, שכן מע' האוויר במטוס סגורה, כמעט ללא תחלופת אויר, יכול לגרום לתחלואה של עד 70% מן הנוסעים (על פי נתוני המרכז לבקרת מחלות ומניעתן).

אוסילו מבית Boiron (בוארון), חברת ההומיאופתיה הגדולה בעולם, הינו תכשיר הומיאופתי המסייע במניעה וטיפול בשפעת ובסימפטומים דמויי שפעת, לרבות חום, צמרמורות, רעד, כאבי גוף, כאבי שרירים, חולשה כללית ושיעול.

אוסילו פועל במהירות וביעילות מרבית לעצירת השפעת כאשר נלקח ב-48 שעות הראשונות מעת הופעת תסמיני המחלה: חום, הרגשה כללית רעה, חולשה, צמרמורות, כאבי שרירים.

שימוש באוסילו מעבר ל-48 שעות הראשונות מקל ומקצר את משך המחלה. ניתן להשתמש באוסילו גם למניעת הידבקות בשפעת במהלך עונת החורף או לאחר מגע עם אדם החולה במחלה. אוסילו הוכח כיעיל במחקר קליני.

עובדות חשובות על אוסילו:

- אוסילו הינו התכשיר הנמכר ביותר בצרפת מבין כל התרופות ללא מרשם לטיפול בשפעת, והתרופה ההומיאופתית המובילה לטיפול במחלה בארה"ב!
- באוסילו משתמשים מיליוני אנשים ביותר מ-50 מדינות ברחבי העולם
- אוסילו נמכר למעלה מ-65 שנה
- מחקרים רפואיים הוכיחו כי אוסילו מסייע בהקלה ובטיפול בתסמיני השפעת.
- אוסילו בטוח לשימוש לכל המשפחה, ללא תופעות לוואי וניתן לשילוב עם כל טיפול תרופתי
- מומלץ לקחת אוסילו לפני טיסה, למניעת הידבקות

כתבה שנייה: סיפורה של שרלוט*

מתוך "שמורת טבע" עלון למורי הביולוגיה ומורי מדעי הסביבה, גיליון 195, ינואר 2018

שרלוט היא ילדה חולת אפילפסיה מקולורדו שבארצות הברית. היא נולדה ב-2010, ועוד בהיותה תינוקת אובחנה עם אפילפסיה מסוג קשה ביותר, שלא הגיבה לתרופות. ככל שגדלה הפכו התקפי האפילפסיה לתכופים ומתמשכים יותר, עד כדי 300 התקפים בשבוע. היא החלה ליטול מיצוי קנביס, ושלושה חודשים לאחר מכן חלה ירידה של למעלה מתשעים אחוזים בהתקפים האפילפטיים של שרלוט. זן הקנביס שקיבלה שרלוט כונה "הרשת של שרלוט".(Maa and Figi, 2014) "

אפילפסיה היא מחלה שבה חלה עוררות יתר של קבוצות תאי עצב במוח בו-זמנית. עוררות יתר זו גורמת לחולים להתקפים של פרכוסים ואובדן הכרה. למעלה משישים מיליון אנשים ברחבי העולם סובלים מאפילפסיה (Rektor, 2015). נכון להיום, התרופות הקיימות אינן מרפאות את המחלה, אלא מקלות את התסמינים בקרב 70% מהחולים. יתר 30% החולים זקוקים לניתוח מוח, או שאין טיפול מתאים עבורם. מכיוון שתרופות אינן מסייעות לחולים אלה, מכונה מחלתם אפילפסיה עמידה.

הניסיון למצוא תרופה לאפילפסיה עמידה הוביל, בין השאר, לקנביס, לאחר מאות שנים שבהן דווח על אנקדוטות חיוביות בטיפול בפרכוסים באמצעות הצמח. הצלחת הטיפול בשרלוט הוא אנקדוטה נוספת. לא כל הילדים עם אפילפסיה עמידה מגיבים לזן שעזר לשרלוט או לקנביס בכלל. לאחרונה נערכים ניסויים הבודקים את אופן פעולתו של קנביס בחיות מעבדה ובניסויים קליניים (Blair, 2015). חשוב לדעת כיצד פועל הקנביס על הורדת הפרכוסים, מדוע ילדים מגיבים באופן שונה לטיפול בקנביס, אילו שינויים עלולים להתרחש עם גדילתה של שרלוט, והאם אין נזק לכבד בטווח ארוך.

מקורות

Blair, R.E., Deshpande, L.S. and DeLorenzo, R.J. (2015). “Cannabinoids: is there a potential treatment role in epilepsy?” *Expert Opin Pharmacother 16*: 1911–1914.

Maa, E. and Figi, P. (2014). “The case for medical marijuana in epilepsy”. *Epilepsia 55*: 783–786.

Rektor, I., Schachter, S.C., Arya, R., Arzy, S., Braakman, H., Brodie, M.J., Brugger, P., Chang, B.S., Guekht, A. and Hermann, B. (2015). “Third international congress on epilepsy, brain, and mind: Part 2”. *Epilepsy Behavior 50*: 138–159.

חלק 2: היכרות עם השיטה המדעית

כיצד מדענים בודקים השערות?

בימינו יש מוסכמות מדעיות שנראות לנו כמובנות מאליהן. לדוגמה, אנחנו יודעים שמחלות מדבקות הן תוצאה של מעבר חיידקים או וירוסים מאדם לאדם ולכן שמירה על ניקיון והיגיינה עוזרת להקטין את הסיכוי לחלות. נוסף על כך, אנחנו יודעים שכל יצור חי נוצר מיצור חי שקדם לו על ידי חלוקה של תאים או על ידי הפריה של תאי המין. אבל איך הגיעו למסקנות הללו? מה עשו מדענים כדי לבדוק אם השערה היא נכונה או מוטעית?

איגנץ זמלווייס ומחקרו על קדחת הלידה

איגנץ זמלווייס (1818-1865) היה רופא נשים שעבד בבית חולים בווינה שבאוסטריה. בתקופה שבה הוא עסק ברפואה היו נשים יולדות רבות שמתו כמה ימים לאחר הלידה ממחלה שנקראה קדחת היולדות. לפני שנמשיך הלאה, זכרו: באותה עת, המדע עוד לא הכיר את קיומם של מיקרואורגניזמים גורמי מחלות.

זמלווייס ניסה להבין מה גורם למחלה כדי לנסות להקטין את התמותה. בבית החולים שבו עבד היו שתי מחלקות ליולדות. במחלקה הראשונה עבדו סטודנטים לרפואה ובמחלקה השנייה עבדו אחיות מיילדות. זמלווייס בחן את שיעורי התמותה בין שתי המחלקות והוא שם לב לנתונים מעניינים:

	מחלקת סטודנטים לרפואה			מחלקת אחיות מיילדות		
שנה	לידות	מקרי מוות מקדחת יולדות	שיעור התמותה	לידות	מקרי מוות מקדחת יולדות	שיעור התמותה
1844	3157	260	8.2%	2956	68	2.3%
1845	3492	241	6.9%	3241	66	2.04%
1846	4010	459	11.5%	3754	105	2.8%

זמלווייס ניסה למצוא הסבר להבדלים המשמעותיים בין שתי המחלקות. הוא העלה מספר השערות:

השערה 1 – גורם באוויר: ההשערה הרווחת באותה עת הייתה שקדחת יולדות נגרמת בגלל ריח רע הנמצא באוויר של בתי חולים שמקורו בחומר נרקב. השערה זו הייתה כל כך פופולרית שנשים רבות העדיפו ללדת בבתיהן וברחוב ורק לא להגיע לבית החולים. שתי מחלקות היולדות נמצאות מתחת לקורת הגג של אותו בית חולים. לכן, לו השערה זו הייתה נכונה היינו מצפים לראות שיעורי תמותה דומים בין המחלקות.

השערה 2 – צפיפות מיטות: השערה נוספת הייתה שצפיפות יתר בבתי חולים גורמת לקדחת יולדות. למחלקת הסטודנטים לרפואה יצא שם רע בווינה כ"מחלקת המוות". לכן, יולדות רבות ביקשו לא להגיע אליה וצפיפות המטופלות הייתה למעשה גבוהה יותר במחלקת האחיות-מיילדות. בית החולים הפחית את מספר השוהים במחלקות היולדות, ולמרות זאת שיעור התמותה נותר כשהיה.

השערה 3 – נוכחות מאיימת של כומר: כומר נוצרי בא להעניק מחילה לנשים יולדות שלקו בקדחת היולדות לפני מותן. הכומר נהג ללבוש חלוק שחור ולצלצל בפעמון כשהוא הלך במסדרונות בית החולים. השערה אחת טענה שטקס המחילה והנוכחות של הכומר הלחיצו יולדות וגרמו להופעת קדחת היולדות אצלן. זמלווייס התייחס גם להשערה זו ברצינות וערך ניסוי כדי לבחון אותה. הוא שכנע את הכומר להיכנס אל המחלקה דרך דלת אחורית ואסר עליו להשתמש בפעמון. שיעורי התמותה בין המחלקות לא השתנו.

השערה 4 – גורם שמועבר אל היולדות ממחלקות אחרות: סטודנטים לרפואה שעבדו במחלקת היולדות עבדו גם במחלקות נוספות, ואילו האחיות-מיילדות עבדו רק במחלקת היולדות. באותה עת לא נהגו רופאים לשטוף את הידיים במעבר בין המחלקות. זה הוביל את זמלווייס לשער שחומר כלשהו ממחלקות אחרות מועבר דרך הסטודנטים לרפואה ליולדות וגורם לקדחת. כדי לבחון השערה זו זמלווייס חייב את הסטודנטים ואת המיילדות לשטוף ידיים לפני בדיקת יולדות. שיעור התמותה במחלקת הסטודנטים לרפואה ירד ל - 1.27% ובמחלקת היולדות ל - 1.30%.

גישה מקובלת במדעים היא לבצע ניסוי שבו יוצרים השוואה בין מצבים או בין קבוצות, שבה בכל פעם משנים רק גורם יחיד, וכל שאר הגורמים בניסוי נותרים זהים. הגורם המשתנה בניסוי הוא הגורם שבהשערה שמעלים החוקרים.

זמלווייס שינה בכל פעם גורם יחיד על פי השערותיו, ובדק את שיעור התמותה לאחר השינוי.

סיכום תוצאות המחקרים של זמלוויס

השערה	בדיקה	תוצאה	מסקנה
1. גורם באוויר	אותה קורת גג	שתי המחלקות נמצאות בסמיכות אחת לשנייה וחולקות את אותו האוויר	גורם באוויר איננו הגורם לקדחת היולדות
2. צפיפות מיטות	בית החולים דאג להפחית את מספר היולדות בשתי המחלקות	לא חל שינוי בשיעור התמותה מקדחת היולדות בשתי המחלקות	צפיפות המיטות איננה הגורם לקדחת היולדות
3. כומר מפחיד	זמלווייס שכנע את הכומר להיכנס למחלקות בדלת האחורית ולא להשתמש בפעמון	לא חל שינוי בשיעור התמותה מקדחת היולדות בשתי המחלקות	הכומר איננו הגורם לקדחת היולדות
4. גורם ממחלקות אחרות	זמלווייס חייב את הסטודנטים והמיילדות לשטוף ידיים בתמיסת מי כלוריד לפני בדיקת היולדות	שיעור התמותה במחלקת הסטודנטים ירד ל-1.27% ובמחלקת המיילדות ל-1.30%	גורם ממחלקות אחרות הוא הסיבה לקדחת היולדות

זבובים, רימות ובריאה ספונטנית

עוד מימי היוונים הייתה קיימת תיאוריה שלפיה יצורים חיים נוצרים באופן ספונטני, מחומרים כמו אדמה או מים, או מיצורים אחרים. התיאוריה נולדה מתצפיות שבהן נראו יצורים חיים במקומות שלא נראו בהם קודם לכן. לדוגמה, בבשר שהושאר סתם כך על השולחן יתפתחו עם הזמן רימות ומהן ייווצרו זבובים.

הרופא האיטלקי פרנצ'סקו רדי (1626-1697) ניסה לבדוק האם תיאוריה זאת נכונה. הוא הכניס נתחי בשר לשלוש צנצנות. את האחת סגר היטב בפקק; את השנייה כיסה בבד דק ומחורר; ואת השלישית השאיר פתוחה.

לאחר זמן קיבל רדי את התוצאות האלה:

חלק 3: השיטה המדעית ככלי לזיהוי "פייק ניוז" (עבודה בקבוצות)

בקבוצות, ענו על השאלות הבאות:

1. מה עזר לזמלווייס להגיע למסקנה מהמחקר שביצע בנושא קדחת היולדות?
2. מה עזר לרדי להגיע למסקנה מהמחקר שביצע בנושא הבריאה הספונטנית?
3. השוו בין הניסוי של זמלווייס והניסוי של רדי: מה המשותף לדרך שבה המדענים בדקו את השערותיהם בכל דוגמה?
4. עורכים יקרים, לאור ההיכרות שלכם עם המחקרים של זמלוויס ורדי וכעת שאתם מכירים את הקריטריונים למחקר מדעי - קבעו: איזו כתבה ("אוסילו", "הסיפור של שרלוט") משכנעת אתכם ואיזו נראית כמו "פייק ניוז"? מדוע בחרתם כך?
5. איזה מידע הייתם מעוניינים שייכנס לכתבות כדי לשפר אותן?

קחו אתכם את התשובות לשאלות אלו אל המבנית הבין-תחומית. הן יעזרו לכם בתפקידכם כעורכים הבאים להחליט אלו כתבות מתקבלות לעיתון שלכם ואלו לא.

Appendix C: Science activities developed for Climax days in 2020/21 and 2021/22 (in Hebrew)

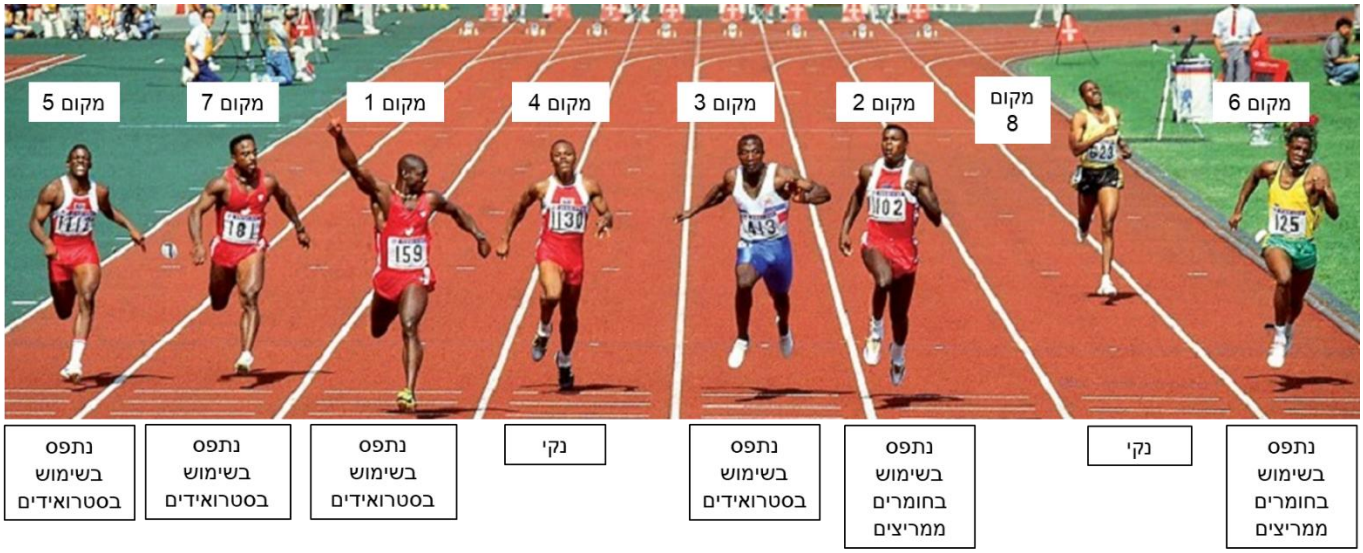
C.1 Science activity for climax day 6: ethics in sports

המדע של השימוש בחומרים אסורים בספורט

חלק א (במליאה):

על ההיסטוריה של השימוש בחומרים משפרי ביצועים בספורט

במקצה 100 מטרים גברים באולימפיאדת סאול 1988 זכה בן ג'ונסון הקנדי במדליית זהב. הוא שיפר את השיא העולמי בריצה בעשירית השנייה, הישג שנחשב לחסר תקדים. יומיים לאחר מכן נשללה ממנו המדליה משום שהתגלה שהוא צרך סטרואידים. בדיקה מקיפה גילתה שרבים מהמשתתפים במקצה הזה השתמשו בחומרים אסורים (איור 1).



איור 1. תמונה מתוך מקצה 100 מטרים באולימפיאדת סאול 1988 מתוך הספר Run, Swim, Throw, Cheat: The Science Behind Drugs in Sport

עבור ספורטאים, המטרה המרכזית בספורט היא לנצח. כדי לשפר ביצועים הם כמובן עוברים משטר קשוח של אימונים – אבל קיימים אמצעים אחרים, כמו השימוש בתוספים משפרי ביצועים, שנפוצים מאוד בקרב ספורטאים. חלקם אינם חוקיים, והשימוש בהם עלול להוביל לענישה ופסילה של הספורטאי או הספורטאית שצרכו אותם.

מבט מהיר אל ההיסטוריה מגלה לנו שהשימוש בחומרים משפרי ביצועים אינו רק בעיה מודרנית, אלא למעשה הוא קיים בערך מהעת שבה הומצא הספורט. כך למשל הרמיס איש ספרטה טען בתוקף שאכילה של תאנים מיובשות עזרה לו לזכות במדליית זהב באולימפיאדה שנערכה בשנת 668 לפני הספירה. קלאודיוס גלנוס, רופא יווני בן המאה השנייה לספירה, רקח עבור גלדיאטורים משקה העשוי מחומץ ואפר שהוא האמין שיכול לספק להם אנרגיה (הרדבול הראשון בהיסטוריה?).

השימוש בחומרים משפרי ביצועים הקצין עם הכניסה לעת המודרנית. ב-1904 תומאס היקס זכה במרתון האולימפי באמצעות שימוש בזריקות סטריכנין (חומר רעיל שבכמויות קטנות מעניק תחושת עוררות לגוף). הוא לא הסתיר זאת מכיוון שבאותה תקופה לא היה איסור על שימוש בחומרים כאלה. כך גם שחקני כדורגל בקבוצת ארסנל צרכו בגלוי כדורים ממריצים לפני משחק גביע חשוב שהתרחש ב-1925.

החל משנות השלושים של המאה הקודמת ועד ימינו חל מפנה ביחס של ארגוני ספורט כלפי חומרים משפרי ביצועים. למשל, באולימפיאדת 1938 נאסר בחוק השימוש ב"סמים וחומרים ממריצים מכל סוג". כיום קיימים ארגונים רשמיים שתפקידם לאתר שימוש בחומרים אסורים בספורט, אך עדיין השימוש בהם הוא מאד נפוץ.

חלק ב (בקבוצות): נא להכיר: אמצעים לשיפור הישגים בספורט

לפניכם אמצעים נפוצים שבעזרתם משפרים ספורטאים את הישגיהם.

1. השוו בין האמצעים השונים: מה דומה ביניהם, מה שונה?
2. האם מפתיע אתכם שספורטאים משתמשים באמצעים כאלו? מדוע?
3. שיתוף במליאה של הדברים המפתיעים והמוכרים מהכרטיסיות

הזרקת סטרואידים

סטרואידים הם חומרים דמויי הורמונים. ספורטאים משתמשים לרוב בסטרואידים המחקים את פעולת ההורמונים הגבריים, שמעודדים את עליית מסת השריר.

הזרקת סטרואידים עלולה לגרום נזק לגוף, לדוגמה עקרות בגברים.

משקאות אנרגטיים ומשקאות איזוטוניים

בעת פעילות גופנית מאומצת במיוחד, כמו ריצת מרתון, דואגים המארגנים להציב שולחנות עם משקאות עבור הספורטאים. המשקאות מכילים גלוקוז המספק אנרגיה לשרירים וכן מינרלים. שונים.

אימון בגבהים

בגובה רב מעל פני הים אחוז החמצן נמוך יחסית. בגופו של אדם העובר מאזור גובה נמוך לאזור בגובה רב מתגבר תהליך ייצור תאי דם אדומים שהם הנשאים של חמצן בדם. לאחר כמה שבועות נמצאים בדם של אדם זה הרבה יותר תאי דם אדומים.

המעבר לגובה רב דורש מעבר בהדרגה, ועלול לגרום לחולשה וסחרחורת.

נעליים משפרות ריצה

נעליים מיוחדות שהסוליה שלהם מכילה רכיבים אלסטיים במיוחד, המוסיפים לקלות התנועה של הרגל תוך כדי ריצה.

תזונה לפני ואחרי אימון או תחרות

לפני תחרות או אימון דואגים ספורטאים להתאים את הארוחות למאמץ הנדרש מהגוף: לפני התחרות נוהגים ספורטאים לאכול מנה עתירת פחמימות, כמו פסטה, המתפרקת לגלוקוז בגוף ומעניקה אנרגיה לגוף. לאחר אימון, דואגים הספורטאים לאכול מנה עתירת חלבונים, כמו דגים כדי לאפשר בנייה מחודשת של השרירים.

בגדי שחייה

שחיינים נוהגים ללבוש בגדי שחייה מיוחדים וכובע שחייה כדי להפחית חיכוך עם המים. הקטנת החיכוך מאפשרת תנועה מהירה יותר, ומשפרת זמני שחייה.

חלק ג (בקבוצות):

העמסת דם: דרכי פעולה וחוקיות

רוכבי אופניים מקצועיים המשתתפים בתחרויות רכיבה בינלאומיות אינם יכולים להיות רק בכושר טוב. הם צריכים להיות בכושר שיא, במיוחד לאור העובדה שגם המשתתפים הנוספים בתחרות נמצאים בכושר מצוין.

האנרגיה הדרושה לפעילות תאי שריר מופקת בתהליך הנשימה התאית: תחילתו בפרוק מולקולות גלוקוז, והמשכו בשחרור אנרגיה באמצעות חמצן במיטוכונדריה. תאי השריר של רוכבי אופניים מקצועיים מכילים כמות גבוהה במיוחד של מיטוכונדריה. כלומר, תאי השריר של רוכבים מקצועיים מפיקים יותר אנרגיה מתאי השריר של רוב האנשים.

רוכבים נושמים בקצב מהיר – עד 75 נשימות בדקה וכך נכנס יותר חמצן לגוף. הם צורכים כמויות גדולות של פחמימות לפני אימון, ואף שותים תוך כדי רכיבה ג'ל מיוחד עשיר בגלוקוז. כך הם יוצרים אספקה שוטפת של גלוקוז לתאי השריר. קצב הדופק הגבוה שלהם, שיכול להגיע עד ל-200 פעימות בדקה, מאפשר שינוע מהיר של חמצן וגלוקוז לתאי השריר.

אבל מה קורה כשרוכבים מאמינים שגם שיפור כל המערכות האלו אינו מספיק? ספורטאים אלה מניחים שכל הרוכבים בתחרויות נמצאים בכושר שיא וכולם רוצים לשפר את הביצועים שלהם כדי לנצח. מחשבות אלה מניעות אותם לחפש אמצעים נוספים לשיפור ההישגים. חלק מרוכבי האופניים מנסים לשפר את הביצועים שלהם באמצעות פעולה שנקראת העמסת דם – עירוי עצמי של דם הנועד להעלות את כמות תאי הדם האדומים בגוף.

לשם העמסת דם, רוכבים שואבים דם מהגוף שלהם ואז מאחסנים אותו בצינון למשל כמה שבועות עד חודשים. לאחר שאיבת הדם, דם חדש מיוצר בגוף כדי להשלים את הדם שהוצא – ממש כמו אחרי תרומת דם. ואז, זמן קצר לפני תחרות, רוכבים מזריקים את הדם שאוחסן בחזרה אל תוך הגוף שלהם. פעולה זו של עירוי דם מעלה את מספר כדוריות הדם האדומות בגוף של רוכבים.

מה קורה בגוף לאחר העמסת דם? (בקבוצות)

1. בקטע הקריאה מצוין שרוכבים מזריקים לעצמם דם כדי להעלות את מספר כדוריות הדם האדומות. הציעו מודל המסביר את הדרך שבה פעולה זו יכולה לשפר את הביצועים של הרוכבים. במחברת שלכם, איירו מה קורה בגוף במצב רגיל (ללא עירוי דם) ומה קורה לאחר העירוי. הסבירו את האיור שלכם.

במצב רגיל:	**לאחר עירוי דם:**
הסבר:	

2. שתפו את המודל שלכם עם שאר הקבוצות

3. (עבודה יחידנית) האם תמליצו לוועדת האתיקה בספורט לאשר לספורטאים לבצע עירוי דם כהכנה לתחרויות או לאסור על כך? היעזרו בקטעי הקריאה, בפדלט (?) ובמודל של תופעת עירוי הדם בספורט כדי להצדיק את ההחלטה שלכם.

_____

_____

_____

_____

4. (דיון במליאה) שתפו את הכיתה בהמלצה שלכם

חלק ג' (עבודת המשך): מה חושבים אחרים?

בצעו ראיון עם אחד מאנשי המקצוע הבאים:

רופא, תזונאי קליני, ספורטאי או מאמן, עורך דין, אוהד ספורט, מורה לספורט

מטרת הריאיון היא:

1. לספר לאדם המתראיין\ת על פעולת העמסת הדם והדרך שבה היא משפרת ביצועים. ספרו לו\ה מה החלטתם לגבי החוקיות של פעולה זו
2. להבין אילו אמצעים מותרים לשימוש, אילו אסורים בעולם הספורט ומדוע

נסחו שאלות לפני הריאיון ושילחו אותן למרואיין כדי שיוכל להתכונן לשיחה איתכם.

רשמו את התשובות של המרואיינים לשאלותיכם בקובץ שיתופי. הקפידו לספר את מי ראיינתם ומה מקצועו.

C.2 Science activity for climax day 7: equitable distribution of resources

הכלכלה של משאבי הטבע: הפרטה, בעלות ציבורית והמחירים של כל גישה

בפעילות זו נציג שתי גישות שבהן חברות ואנשים יכולים לנקוט לשם שמירה על משאבי טבע החיוניים להם. הגישה הראשונה תראה כיצד בעלות פרטית על משאבי טבע יכולה להגן עליהם. הגישה השנייה, לעומתה, תראה שדווקא בעלות ציבורית יכולה להיטיב עם משאבי הטבע.

א. מדוע אנשים מנצלים עד הרס משאבים שהם מעריכים?

דמיינו אחו רחב ופתוח שאליו חקלאים שונים הנמצאים בסביבה מובילים את הפרות שלהם כדי לרעות (איור 1). ככל שעדר הפרות גדול יותר ההכנסה של החקלאי גדולה יותר. לכן, כל חקלאי הרוצה להגדיל את ההכנסה שלו מהעדר ישאף שהעדר יכלול כמה שיותר פרות. אולם, המרעה הפתוח מכיל רק כמות מסוימת של עשב וצמחים אחרים שהפרות ניזונות מהם. אם כל חקלאי יגדיל את מספר הפרות במשק שלו - כמות המזון במרעה תפחת, עד שהמרעה כבר לא יהיה ראוי לגידול פרות. בשלב הזה החקלאים יינטשו אותו ויחפשו מרעה אחר.

איור 1. פרות במרעה פתוח

האקולוג גארט הארדין כינה ב-1968 את הבעיה הזו בשם "הטרגדיה של נחלת הכלל". הארדין טען שבחברות המאמינות בחופש אישי כערך עליון, כל אדם יעדיף לקדם את הרווח האישי שלי בטווח הקצר במחיר של הגנה סביבתית ארוכת טווח. לכן, טוען הארדין, כל משאב שמשותף לכלל הציבור בסופו של דבר ייהרס.

ואכן, הטרגדיה של נחלת הכלל באה לידי ביטוי ברמות שונות במציאות. הדוגמה הבולטת ביותר היא האוויר ששייך לנחלת כלל המדינות בעולם. למרות שמדינות מכירות בסכנה הממשית של משבר האקלים, הן עדיין מסרבות להגבלות מחמירות על פליטה של חומרים מזהמים לאוויר וזאת כדי למקסם את הרווחים שלהם.

דוגמה נוספת לטרגדיה של נחלת הכלל היא ניצול יתר של האוקיינוסים למטרות דיג. דייגים שואפים לדוג כמה שיותר דגים כדי להגדיל את ההכנסות שלהם. דיג-יתר מוביל להרס של החיים באוקיינוסים ואף מוביל לסכנת הכחדה של מינים רבים של בעלי חיים ימיים, כולל דגים למאכל.

הארדין מציע גם שני פתרונות לטרגדיה של נחלת הכלל. פתרון אחד הוא ***הפרטה*** של משאבי טבע תחת ההנחה שבעלים פרטיים ידאגו לשמירה על המשאב ולא ירצו להחריב אותו. פתרון אחר כולל ***חקיקה והסדרה על ידי המדינה*** של תנאי השימוש במשאב. בשני הפתרונות יוגבל השימוש של בני אדם במשאבי הטבע.

ב. *המקרה של חוף כיאט בחיפה*

חוף כיאט הוא רצועת חוף באורך של כקילומטר ביציאה הדרומית של חיפה. החוף קרוי של שם משפחת כיאט שהייתה בעלת רצועת הקרקע לאורך החוף והקימה בו חוף מוסדר ובו חדרי הלבשה, מסעדה ומתקנים שונים בתקופת המנדט הבריטי. לאחר גלגולים רבים עבר החוף לבעלות פרטית של איש העסקים יצחק תשובה ,שהקים בו את פרויקט "מגדלי חוף הכרמל". הקמת הפרויקט החלה בשנת 1993. תוכנית הבנייה כללה שישה מגדלים, בהם 1,200 דירות נופש ו-800 חדרי מלון, כמו גם מרכז כנסים וחנויות כולם על קו החוף.

בשנת 1995 תושב חיפה, פעיל איכות הסביבה, עורך דין אלי בן ארי, ראה את הבנייה המאסיבית בחוף ובדק את תוכניות הבנייה. בן ארי מצא סתירות עצומות בין מה שמצא בתוכניות הבניינים ובין היתרי הבנייה של העירייה. המבנה הראשון שאושר היה אמור להיות בן 9 קומות, וברוחב 56 מטרים. במקום זה, היזמים בנו בניין של 18 קומות, שכיסה 134 מטרים מחזית החוף. באמצעות עמותת אדם טבע ודין, נעשתה פנייה לבית המשפט להפסיק את הבנייה בטענה שאם הבנייה תימשך, תוקם למעשה חומה של מגדלים רבי קומות שתחסום את החוף והנוף אליו.

עמותת אדם טבע ודין הגישה בשנת 1996 עתירה כנגד תוכנית הפרויקט. הבנייה של הפרויקט נעצרה ומאז מתנהל מאבק ברשות יצחק תשובה, במטרה להשלים את הפרויקט, לבנות את 4 המגדלים שהקמתם אושרה בתוכנית המקורית ולהגדיל את שטח ייבוש הים במקום.

דיון בקבוצות:

בישראל, רוב חופי הים הם נחלת הכלל. הגישה אליהם פתוחה להנאת הציבור בכללותו. בשנים האחרונות מתרבות התלונות על זיהום של חופי הרחצה ומי הים התיכון על ידי מתרחצים. היעזרו בקטעי הקריאה כדי לענות על השאלות הבאות (בקבוצות)

א. האם הייתם תומכים בהעברה של חופי הרחצה בישראל מבעלות ציבורית לבעלות פרטית? מדוע?
ב. האם אתם חושבים שיש להגביל כניסת מתרחצים לחופי הארץ? מדוע?
ג. הציעו פשרה הגיונית בין **האינטרס הציבורי** לשמור על החופים פתוחים **והאינטרס הסביבתי** לשמור את החופים נקיים

C.3 Science activity for climax day 8: climate change (example activity)

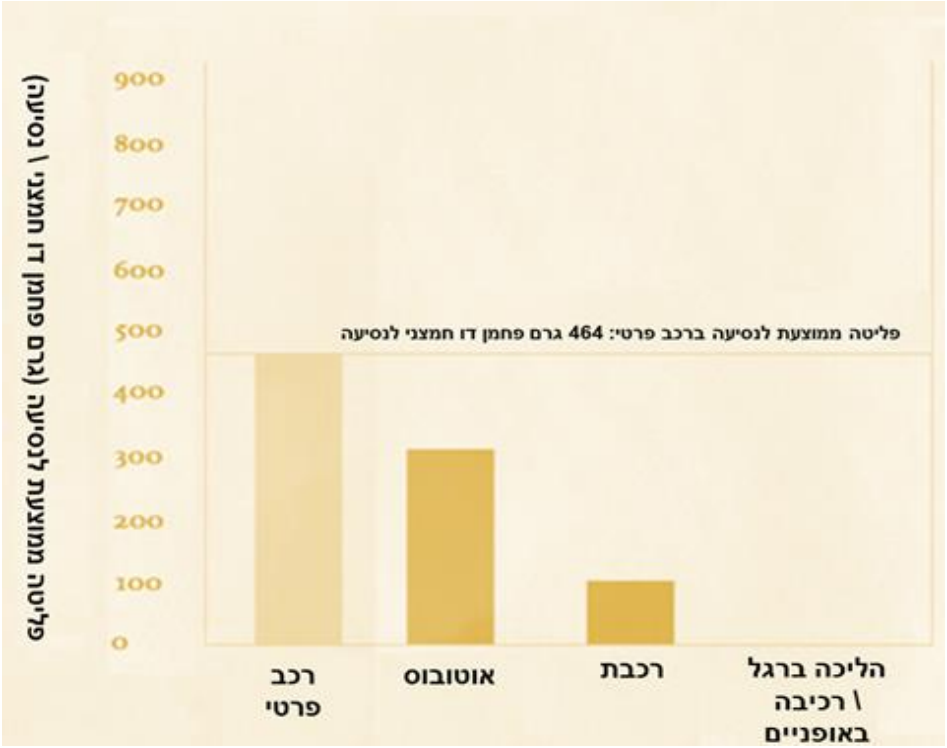
משבר האקלים ובעיית התחבורה

אנשים צריכים להגיע ממקום למקום, בין אם זה מהבית לעבודה, לבית הספר, או לסידורים שונים. הדרך שבה הם בוחרים לעשות את זה מהווה גם החלטה אקלימית חשובה: באירופה ובארה"ב, תחבורה מהווה את אחד הגורמים המשמעותיים לפליטת גזי חממה.

ברחבי העולם, תחבורה אחראית לכ25% מסך פליטות הפחמן הדו חמצני, מתוכם כ75% מפליטות הפחמן הדו-חמצני מגיעים מרכבי כביש (רכבים פרטיים, משאיות, אוטובוסים).

באירופה, רכב פרטי פולט בממוצע כ123 גרם פחמן דו חמצני לקילומטר. הרכב הפופולרי בישראל, טויוטה קורולה, פולט כ156 גרם פחמן דו חמצני לקילומטר. בארה"ב, היכן שאנשים נוהגים ברכבים גדולים יותר בממוצע, הנתון הזה מאמיר ל650 גרם פחמן דו חמצני לקילומטר. המשמעות של נתונים אלו היא שהדרך שבה אנחנו בוחרים להתנייד ביום יום יכולה להשפיע בצורה משמעותית על טביעת הרגל הפחמנית שלנו.

אחת הדרכים האפשריות לצמצום פליטות מכלי רכב היא מעבר מרכב פרטי לתחבורה ציבורית. נסיעה ממוצעת ברכב פרטי פולטת כ464 גרם פחמן דו-חמצני. רכבת מסיעה הרבה אנשים ולכן נסיעה ממוצעת בה אחראית לפליטת פחמו דו חמצני הנמוכה בכ80% מהכמות הנפלטת בנסיעה ברכב פרטי. נסיעה ממוצעת באוטובוס אומנם אחראית לפליטת פחמן דו חמצני גדולה יותר מנסיעה ברכבת, אך עדיין נמוכה בכ40% מנסיעה ברכב פרטי (איור 2). וכמובן, קיימת גם האפשרות של רכיבה באופניים או הליכה ברגל שהן הכי נקיות מבינת פליטת פחמן דו-חמצני אך אינן מתאימות למסע של מרחקים ארוכים.



איור 1. פליטות פחמן דו חמצני לנסיעה לפי סוג רכב בהשוואה לרכב פרטי (מקור: https://tinyurl.com/5f28pn8a)

<u>פעילות:</u>

פעילים סביבתיים נחשפו לנתונים האלה וכעת פועלים כדי לקדם את הצעת חוק האוסרת לחלוטין את השימוש ברכב פרטי.

היעזרו באיור הבא כדי למצוא את עמדתכם ביחס להצעת חוק זו. באיור - לב מסמל עמדה רגשית ומוח מסמל עמדה מושכלת.

1) חשבו האם אתם בעד או נגד הצעת החוק
2) לאחר שהבנתם באיזה צד אתם, הסבירו לשאר חברי הקבוצה איך הגעתם להחלטה שלכם:

- אם העמדה היא רגשית נסו להסביר אותה כך ששאר חברי הקבוצה יבינו את המניעים הרגשיים שלכם.
- אם העמדה היא מושכלת, נסו להיעזר במידע ובנתונים מהטקסט כדי לבסס אותה.

3) לאחר שכל חברי הקבוצה הסבירו את המיקום שלהם, עברו למשבצת אחרת בטבלה ונסו לנסח את העמדה שלכם לפיה (למשל, אפשר לעבור מנגד עם הלב לבעד עם המוח).

 בעד	 בעד
 נגד	 נגד

4) לפי מודלים מתמטיים עדכניים, כדי למנוע מהטמפרטורה הגלובלית לעלות ב-1.5 מעלות צלזיוס עד שנת 2030, פליטת גזי החממה צריכה לקטון ב-45%.

לפניכם רעיונות שונים שיכולים לסייע בהשגת המטרה. השתמשו בהם, בדף המידע ובפעילות הקודמת על מנת לנסח הצעת חוק יעילה ומקורית שתפחית את השפעת התחבורה על משבר האקלים ותתקבל בהצבעה על ידי רוב חברי הכנסת.

נתונים לגבי פתרונות אפשריים:

- רכבים חדשים יעילים יותר בניצול הדלק שלהם מרכבים ישנים
- רכבים גדולים פולטים כ85% יותר פחמן דו חמצני לקילומטר מרכבים קטנים
- בממוצע, רכב חשמלי פולט כ33% מכמות הפחמן הדו-חמצני שנפלט מרכב הממונע בדלק. אמנם, ייצור החשמל להנעת הרכב מייצר בעצמו זיהום
- בקופנהאגן שבדנמרק, הבנייה של תשתית נרחבת של שבילי אופניים צפויה לצמצם כמיליון נסיעות רכב בשנה, וכ- 1500 טון מפליטת הפחמן הדו חמצני בשנה

כדי לצמצם את פליטות הפחמן הדו-חמצני בתחבורה, אנו מציעים:

_____

_____

_____

_____

_____

_____

_____

_____