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REGULAR ARTICLE

What Kills Science in School?: Lessons from Pre-Service Teachers' Responses to Urban children's Science Inquiries

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Abstract This opportunistic case-study highlights striking differences in 6 urban children's and 12 preservice suburban middle-class teachers' perception of science and discuss consequences of science education and beyond. I found that all of the interviewed urban children demonstrated scientific inquiries and interests outside of the school science education that can be characterized by diverse simultaneous discourses from diverse practices, i.e., "heterodiscoursia" (Matusov in *Culture & Psychology, 17*(1), 99–119, 2011b), despite their diverse, positive and negative, attitudes toward school science. In contrast to the urban children's mixed attitudes to science, the preservice teachers view science negatively. They could not see science inquiries in the videotaped interviews of the urban children. There seemed to be many reasons for that. One of the possible reasons for that was that the preservice teachers tried to purify the science practice. Another reason was that they did not see a necessity to be interested and engaged in the curriculum that they are going to teach in future. The pedagogical consequences and remedies are discussed.

Keywords Bakhtin · Alienation hypothesis · Heterodiscoursia · Curriculum purification · Dialogic pedagogy

This opportunistic case-study highlights striking differences in urban children's and preservice teachers' perceptions of science and discusses consequences for science education and beyond. On average, science is probably one of the most poorly taught academic subjects in US schools (Osborne et al. 2003; Potvin and Hasni 2014) as it has been demonstrated that there exists: 1) a lack of scientific knowledge in many school

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alumni, 2) coupled with their lack of scientific reasoning, and 3) yet graduates have a misguided self-confidence that they know some science facts and are good at science even when faced with evidence to the contrary (Schneps et al. 2003). My personal teaching experience of preservice US teachers also shows that despite having A's and B's high marks in their science classes in high schools and passing in the upper percentiles of high stake tests and exams in their recent past, very few undergraduate students, or at least my preservice teachers, can provide even ONE scientific fact that they can explain without referring to the authority of scientists or the textbook, i.e. based on dogmatism rather than scientific practice and, thus, does not constitute authentic scientific knowledge (Wertsch 1985).

For instance, in one of my past classes of 24 undergraduate students, a few of which were planning to become middle school science teachers, all of the students believed that if one jumps straight up, the person would not land in exactly the same place because of the Earth rotation. We ran an experiment in the class to test this idea and my students were very surprised that the jumper always landed in the same spot.

In one of my classes, on which I will focus in this paper, of 12 middle-class, suburban undergraduate students, nobody could provide one genuine scientific explanation for this result. In another example with these students, some declared that they knew well and could explain the changes of the seasons on the Earth, but instead provided a misconception that the season changes are caused by the Earth moving closer to or farther from the Sun, similar to the "Private Universe" video depicts (Schneps et al. 2003). In spite of years of curricular experience with "The Scientific Method" my student's idea of research is that it is a way to prove preconceived "correct" ideas, which my students often called "theories". At the same time, the high majority of my undergraduate students will claim that they know science and understand scientific reasoning and scientific method. Finally, with a few exceptions, they have reported that they strongly dislike science. I realize my students are a small sample of high school graduates in this county, but the entrance requirements to my University are fairly steep. For example, entering GPA[1] on average is higher than 3.2. What is responsible for this mass failure of school science education?

Over my years of teaching as I have contemplated this issue, I began to suspect that one of the probable reasons for this spectacular science education failure is self-perpetuating vicious circle of alienation from and trauma by science education, a hypothesis that I will try to build in this paper based on my opportunistic research. A recent 2016 survey study of 1500 high school students across the United States reports that science classes are the least liked (Zubrzycki 2016). More than half of my preservice teachers, most of whom will be elementary school teachers, reported *hating* science. They will teach science to young children and for whom they may further alienate and traumatize in their own turn (King 1991). But this possible vicious circle does not explain what causes this failure of science education in the first place.

One possible hypothesis among scholars of science education is that students in school are not well taught; science dispositions, elements of the scientific reasoning,

[1] "Grade Point Average" scoring on the scale of 0 to 4 (the highest) used in the US, "an indication of a student's academic achievement at a college or university, calculated as the total number of grade points received over a given period divided by the total number of credits awarded" https://en.oxforddictionaries.com/definition/us/grade_point_average.

and science method based on the analysis of the science practice (Andriessen 2009; Baker 2009; Schwarz 2009). There have been numerous efforts to improve this science education instruction with a problematic outcome (Schneps et al. 2003). Elsewhere together with my colleague Soslau, we criticized this approach to teaching practices (mostly the practice of argumentation) based on the extraction of some elements of science practices designed to engage students in (pretend) science (see Penner et al. 1997, for an example of such approach) rather than in a holistic science practice (Matusov and Soslau 2010). My colleague and I called this instructional approach *structural* because it focuses on structural elements of the scientific practice like knowing important scientific facts and theories, making hypotheses, understanding scientific methodology and so on and the pedagogical focus is to try to teach these structural elements to the students.

Our critique of this structural approach can be illustrated from an analysis and comparison with popular media. A good fiction movie about work of scientists (e.g., "A beautiful mind", "Kinsey") portrays more or less accurately many structural elements of the scientific practice. However, the actors portraying the scientists in the movies are not involved in science practices but rather in acting and performing these structural elements of the science practice and do so rather well (i.e., skillfully pretending). From the fact that students can skillfully demonstrate the structural elements of science practice, it does not necessarily mean they understand them or engage in science and science learning or even that their skillful imitation may necessarily lead to mastery of the structures of science. Thus, we argue in our essay that by skillfully enacting structural science elements taught by their teacher in the classrooms and on the tests, the students may be involved in similar acts of pretending doing science while in actuality they are involved in a practice of pleasing their teachers and competing on high stake tests. Like actors, who while playing famous scientists, may not learn to practice science or develop a deep understanding of it, school students may not learn deep science by enacting the structural science elements, however important these elements may be seen by the science educators (and even scientists themselves). Based on his research of science education in conventional schools, Lemke argued that many students in science education classes simply socialize in "talking science," like actors mimicking the science discourse without much engaging in it, but believing together with their science teachers that they are (Lemke 1990).

Another possible popular hypothesis for improving science education that has been entertained among science education scholars is that science education should focus on cleaning the students' minds from scientific misconceptions rather than drilling them with important scientific facts and science methods (e.g., Eaton et al. 1984). From this perspective, the important scientific facts and theories and even methods should not be simply taught as the structural approach suggests, but students have to be diagnosed first to reveal their misconceptions about important scientific facts, theories, and methods and then, after which, be revealed to the students. These misconceptions are then to be addressed by the teacher through "a conceptual change," that is, showing contradictions between the students' misconceptions and reality – what is wrong with these misconceptions, and why the scientific concepts are correct (Carey 1985).

I tried to use this approach in some of my undergraduate classes for preservice teachers. For example, when my students told me that they understood the phases of the Moon well, I asked them to develop an explanation for this and then to demonstrate it with a ball (modeling the Moon), the overhead projector (modeling the Sun) and their head (modeling the Earth). Since their explanation by all students without exception was based on their misconception that the Moon and The Earth rotate in the same plane (as the majority of the science textbooks and websites portray), my students could not explain the difference between the new phase of the Moon and the solar eclipse or between the full phase of the Moon and the lunar eclipse (actually my students could not enact the full phase of the Moon, according to their own diagram that they had drawn in advance, because their head, the Earth, covered the light from the overhead projector, the Sun, from the ball, the Moon). My students often became frustrated with me and not with the contradiction and their inability to show the Moon's phases. They initially were thinking that somehow I tricked them into this problem but their initial explanation was fine. Although a few of my students were very interested to learn the solution of the contradiction between their misconceptions or "preconceptions" (Hammer and Zee 2006) and the reality and, thus, learn scientific concepts (i.e., "How does it really work? How do things really behave?"), the majority seemed to be amazed by my demonstration of their ignorance but they did not develop any inquiry or interest about the Moon phases.

Through my pedagogical experience, I have come to a conclusion, which has to be tested on a systematic basis, that this Socratic method of teaching promotes a cognitive dissonance in students (Matusov 2009, Chapters 2 and 3; Plato and Bluck 1961) though it may work well for students who are not alienated from the academic subject matter (i.e., finding it interesting and not hating it), in this case, science curriculum. However, when students have been alienated from the academic subject, the Socratic method of teaching does not work well, "Socratic questions generally make for miserable science talks [in the classroom – EM], because they don't lead to a variety of reasonable possibilities" (Hammer and Zee 2006, p. 168). A further systematic research of this phenomenon and testing my observation hypothesis is needed (Hammer and Zee 2006; Rosebery et al. 2010).[2]

Through my opportunistic participant research that I describe below, I have come to the third hypothesis about why so many students are alienated from and traumatized by the conventional science education in school, which is the primary focus of this paper. An opportunistic research involves a practitioner facing with a puzzling phenomenon in his/her practice and trying to investigate it via diverse research craft[3] such as ethnography, autoethnography, action particpatory research, review of literature, philosophical investigation, and so on. In other words, there is a transactional relationship between the practitioner and the researcher roles, where practice and research mutually constitute each other.

I am not sure that my hypothesis is specific to science education and cannot be applied to any conventional school curriculum. I came to a conclusion that the students' alienation from the (science) school curriculum is not a byproduct (i.e., the ending point) of insensitive teaching (science) academic curriculum in school, but rather its precursor and a starting point. In their everyday life and through engagement in other practices, science interests, puzzlements, and inquiries

[2] Unfortunately, I cannot give the deserved description, literature review, and critical analysis of the listed two hypotheses. It would require a separate paper.

[3] I object using the term "methodology" because of its positivist nature (Matusov and Brobst 2013).

constantly emerge in students. The mentioned recent survey of teenagers in the US indicates that 80% of them interested in science outside of school (Zubrzycki 2016). However, a conventional school science education often declares these interests and inquiry illegitimately non-scientific and cleanses them out from the school curriculum. Through this process of delegitimizing the student's interests as scientific, I argue, the conventional school expels many students from the academic science and academic science from many of the students.

In my view, this process of alienation from science was nicely described by Bill Bryson in the introduction to his wonderful science book titled "A short history of nearly everything" about his own encounter with school-like science textbooks, although fortunately for Bryson, his interest in science survived this encounter while many other children and students are not so lucky:

> My own starting point [to writing about science – EM], for what it's worth, was an illustrated science book that I had as a classroom text when I was in fourth or fifth grade. The book was a standard-issue 1950s schoolbook battered, unloved, grimly hefty-but near the front it had an illustration that just captivated me: a cutaway diagram showing the Earth's interior as it would look if you cut into the planet with a large knife and carefully withdrew a wedge representing about a quarter of its bulk.
>
> It's hard to believe that there was ever a time when I had not seen such an illustration before, but evidently I had not for I clearly remember being transfixed. I suspect, in honesty, my initial interest was based on a private image of streams of unsuspecting eastbound motorists in the American plains states plunging over the edge of a sudden 4,000-mile-high cliff running between Central America and the North Pole, but gradually my attention did turn in a more scholarly manner to the scientific import of the drawing and the realization that the Earth consisted of discrete layers, ending in the center with a glowing sphere of iron and nickel, which was as hot as the surface of the Sun, according to the caption, and I remember thinking with real wonder: "How do they know that?"
>
> I didn't doubt the correctness of the information for an instant – I still tend to trust the pronouncements of scientists in the way I trust those of surgeons, plumbers, and other possessors of arcane and privileged information – but I couldn't for the life of me conceive how any human mind could work out what spaces thousands of miles below us, that no eye had ever seen and no X ray could penetrate, could look like and be made of. To me that was just a miracle. That has been my position with science ever since.
>
> Excited, I took the book home that night and opened it before dinner – an action that I expect prompted my mother to feel my forehead and ask if I was all right – and, starting with the first page, I read.
>
> And here's the thing. It wasn't exciting at all. It wasn't actually altogether comprehensible. Above all, it didn't answer any of the questions that the

> illustration stirred up in a normal inquiring mind: How did we end up with a Sun in the middle of our planet? And if it is burning away down there, why isn't the ground under our feet hot to the touch? And why isn't the rest of the interior melting – or is it? And when the core at last burns itself out, will some of the Earth slump into the void, leaving a giant sinkhole on the surface? And how do you know this? How did you figure it out?
>
> But the author was strangely silent on such details – indeed, silent on everything but anticlines, synclines, axial faults, and the like. It was as if he wanted to keep the good stuff secret by making all of it soberly unfathomable. As the years passed, I began to suspect that this was not altogether a private impulse. There seemed to be a mystifying universal conspiracy among textbook authors to make certain the material they dealt with never strayed too near the realm of the mildly interesting and was always at least a long-distance phone call from the frankly interesting.
>
> I now know that there is a happy abundance of science writers who pen the most lucid and thrilling prose – Timothy Ferris, Richard Fortey, and Tim Flannery are three that jump out from a single station of the alphabet (and that's not even to mention the late but godlike Richard Feynman) – but sadly none of them wrote any textbook I ever used. All mine were written by men (it was always men) who held the interesting notion that everything became clear when expressed as a formula and the amusingly deluded belief that the children of America would appreciate having chapters end with a section of questions they could mull over in their own time. So I grew up convinced that science was supremely dull, but suspecting that it needn't be, and not really thinking about it at all if I could help it. This, too, became my position for a long time (Bryson 2003, pp. 4-5)

My alienation hypothesis is that the students are lost through their emerging science inquiries being unwelcomed, ignored, unaddressed, and not recognized as legitimate science inquiries by school science. As soon as this happens, for many students, Socratic teaching method of cleaning them from their misconceptions or what exactly the school science curriculum "covers" become irrelevant as they become turned off by the academic science all together. Some of them might successfully "learn" science facts, theories, methods, and history to pass exams and please the teacher, but they are not ontologically engaged in the academic science itself with their hearts, minds, imagination, and a sense of responsibility (Levrini et al. 2018). Their success in academic science subject is institutional but not epistemological. Epistemologically, these institutionally successful students arguably failed to learn science.

In this article, I want to share what in my pedagogical experience made me to build this hypothesis and how it emerged as "a grounded theory" (Glaser and Strauss 1967) from it. A systematic testing of this hypothesis is necessary but is beyond the scope of this paper.

As one of the anonymous reviewers of a prior draft correctly noticed, the genre (and discourses) of this paper is mixed involving "the research report, a position paper on science curricula; and personal reflections" along with autoethnography (Boje 2014; Denzin and Lincoln 2005) and "a philosophical paper on science curriculum." In this paper, I practice or experiment with "heterodiscoursia" – a diversity of genres that I will discuss, against employing a pure genre, against which I will argue below.

Background of my Opportunistic Participation Research

My new class on building "communities of learners," CoL, (Matusov et al. 2012; Rogoff et al. 1996) in urban contexts was a part of newly developed minor's specialization program on urban education in teacher education. One of the main goals for this class that I set up was to help my teacher education students learn how to design a pedagogically sound learning activity that could be sensitive to educational interests, strengths, and needs of urban children. I wanted to develop a safe learning environment for my students' learning, in which their mistakes would not be very costly for them and the urban children with whom they were supposed to work.

For that purpose, I developed a teaching practicum for my students at a Local Urban Center (LUC) running afterschool program serving lower SES African-American children and youth. I asked my undergraduate students to attend the Center at least 12 times during the semester staying there for at least 1.5 h, to interview the children about their academic interests and experiences, to engage in diverse ongoing activities and informal interaction at the Center, and finally to design and perform a lesson of their choice. It was expected that the students would be familiar with the LUC and the children there due to their previous practicum experience, but because of the logistic problems it did not happen.

I decided to model in the class what I wanted my students to do with the children at the Local Urban Center – to develop a community of learners with my undergraduate students around Urban Education, the notion of Community of Learners, and some academic subject. I wanted my students to experience "building a community of learners" based on their interests, strengths, and needs first and then to try to do it themselves at the LUC with the children in the afterschool program there.

For this academic subject I chose science curriculum because I used to be a science schoolteacher and was both excited and familiar with science curriculum, I had prior and rather successful pedagogical experience of teaching science education to future teachers using the Socratic teaching method, and because, I was convinced, that the school science teaching has been really poor and my students need to learn it and how to teach probably more than any other academic subject. Based on my prior teacher education experience, I expected that my new students to be alienated and traumatized by their previous school science education. I turned to be right beyond my expectation!

I had 12 undergraduate students in my class. Although this class was a required class for students signed up for the new Urban Education minor's program, they all were highly dedicated to learning issues of Urban Education. Two of my students were not education majors and were interested in counseling and working with urban youth as a police. One education student was also considering either becoming a middle school math teacher in an urban setting or joining police force working with urban youth. Among the rest of the education students in my class, some wanted to become middle school teachers specializing in social studies or special education or multidisciplinary elementary school teachers. I had 11 female students and one male student. Through the students' self-identification, I had one African-American, two Latina, and three Jewish students, and the rest were Christian Caucasians. All of the students were young adults in their late teens, early twenties.

As soon as I introduced science curriculum, my students had rather strong resistance to it. Despite being amazed with their own science misconceptions that I revealed to them, the vocal majority actively resisted learning science in my class. One student wrote on her index card in feedback on a class (it was my routine practice to give me students index cards and ask them to write what they learn in this particular class, questions for me, what they expect to be in the next class, and feedback on the class – I call it "mind attendance roll"), "Feedback: [I] still do not understand why science is so much focus of our course." As I posted this feedback on our class web discussion and provided my response, other vocal students joined that,

> Also I am curious as to how in depth the science talk will go. So far I do not feel like it has been anything that any of us do not know but I worry that for some people, myself included, that if science is not one of our strongest subjects then we will not only be learning different educational techniques but also science too. I however do understand that science is a struggling subject in the US so it is something that we as teachers must figure out why so for that reason alone I understand and am ok with focusing on science if we can only focus on one subject. I just believe learning CoL [i.e., "Community of Learners", which was one of the curricular foci in the class – EM] for multiple subjects would be a good tool.

The latter seems to reflect an instrumental approach to CoL implying that it can be learned independently of any subject and then applied (I will discuss this later). But I also sympathized with my students because they had a challenge to learn about urban education, apparently understood by them as a standalone discipline, and the concept of community of learners not through their strongest but weakest side (cf. the notion of "deficit model", see Sautter 1994), which by itself seemed to contradict the notion of CoL (Matusov et al. 2012).

I had one student, urban African-American, who was actively interested in learning science as she was excited to learn about her science misconceptions and contradictions in her own reasoning about observed phenomenon. She wanted to learn more about the contradictions that I revealed and she started asking more and more scientific questions (we discussed seasons, the shortest trajectories of flying on the Earth surface, magnets, and so on). A few students agreed with my pedagogical argument about teaching science to them as one student wrote on the class online forum,

> I feel that we have to focus on a specific subject, so that we may learn how to build a community of learners. We need some structure and also because the majority of us said we did not really like science. It will allow us to understand how a community of learners can be built in a smaller scale and in all subjects areas even in the ones we may not enjoy. I believe most of us (at least I think so) have the notion that the only way to learn science is from memorization, and lecture, so using it will give us a new perspective.

For these few students, − i.e., students who are not alienated by science (but who may or may not know much science[4]), − my Socratic teaching method of revealing and challenging their science misconceptions gradually worked and I expected it to work even more with time.

However, for the vocal minority, my Socratic dialogic teaching approach based on developing cognitive dissonances in my students increased frustration and defensiveness to the point that they might lively discuss some science inquiry in class in small group of their interest based on mini-chapters from the book "Never shower in a thunderstorm" (O'Connor 2007) that I gave them[5] and then turned to me and said that "everything was boring." One student wrote on her index card, "I still don't understand why I can't teach social studies lessons @ the LUC? I want to teach Middle School Social Studies, NOT high school physics like you." In my reply, I offered PROs and CONs of focusing on science, − such as reconnecting with science that many of them will teach (PRO) while not being interested in science and thus making learning about communities of learning more difficult for them (CON) among others, − and invited them to continue discussing this important issue.

I started hoping that my students' engagement with the LUC children and youth about science might change their attitudes and I started preparing them with interviews about science interests and experiences with the LUC children. However, the most vocal group became even more worried because: 1) they expected that the urban children will not talk with them in general because the urban children did not know them well and 2) the children would refuse talking about science probably because it was not their favorite subject (like for most of my students). I hoped that through interviews with urban children, my students, this vocal majority, would probably project themselves into the urban children's skin disliking school science and, thus, would sympathize them.

I decided to test these students' expectations about interviewing urban children about science by doing it myself. I decided to go to an urban setting and interview children of different ages about their science interests and experiences with school science recorded on the video that I planned to show and discuss with my students. One of my graduate students lived in an urban area and she volunteered to arrange my access to urban kids and permission for interviewing and videotaping from them and their parents. I knew some of the urban children (but not well) and did not know others, which was experience of my students at the LUC.

Video-Interviewing 6 Urban Children and Youth about Science

I arrived at home of my grad student in a local urban area equipped with cheap digital camera without a tripod and a pile of science books with pictures that I

[4] Some educators (e.g., Adler 1983) argue that a Socratic method works well only after students learn science content through direct instruction. I strongly disagree with that and my student that I discussed in this paragraph is a good example of a student who did not know much science content but for whom a Socratic method worked well.

[5] I showed them in small groups a list of the inquiries from that book and asked to select a few that they had interest in, predict and justify their answers, and then check in the corresponding mini-chapters if they were right or not. The book is aimed at everyday science inquiries of young adults and my students had very good animated discussions to their own surprise that some of them initially refused to admit.

picked up in my university library. The books were not very good, in my judgment, but they had many interesting pictures of diverse scientific phenomena so I took them to promote discussions about science and they helped by generating ideas and memories, especially for young children. I decided not take a tripod with me because I thought that videotaping from hands, although shaky, would be more personal. Also, I planned to delegate videotaping to children themselves as I did in past to make the process more informal and the children more engaged and it worked this time rather well. I came around 5 pm on warm and sunny September early evening and many local children were playing outside. I hoped for a snowball effect when my grad student's children call their friends to be interviewed or they would come just out of curiosity and that exactly what happened.

I ended up interviewing 6 children of diverse ages (from 2nd grade to 10th grade), genders (two girls and 4 boys), and ethnicities (4 Caucasians and 2 African-Americans). I had 5 interviews because two children wanted to be interviewed together. Children came and went during the interviews, observing the process and sometimes joining in, helping with the answers, providing joking, teasing the interviewees (and at times me), elaborating on answers of the interviewees, asking the interviewees and me their own questions. They quickly became VERY enthusiastic about interviews and I had to finish my interviewing after about 1.5 h because I was running out of battery and disk space and it was getting late for the children (their parents started calling them for dinner) and me as I had to cut the videos for next day class to show and discuss them with my students.

Since the children were in and out, I had to explain the purpose of my interview again and again. I told the children that I wanted to show my students, future teachers, how kids relate to science, what science questions kids ask, what they like in science, so my students would become better science teachers or better teachers teaching science, if they would be elementary school teachers. I added that I want to show my students what kids think about science and teaching science in school and what advice the kids would give my students to become better teachers teaching science. My interviews were semi-structured, following the directions of the children's answers and interests. I asked the children the following questions:

1. Do you like science? Why? Why not? What do you (dis)like in science? Why?
2. What exactly do you do in science lessons in school? Please describe.
3. Do you have science questions outside of school? What are they? Why are you interested in them?
4. How do you know what you have learned in school about science is true? How do you know that your teachers tell you truth about science and do not lie? How do you know that for sure?
5. Do you know something about science not because you believe in what other people say about it but because you know it yourself? If so, how do you know that for sure?

The reasons of why I was asking questions number 4 and 5 were that I want to find out if the children could engage in what Bakhtin called "the internally persuasive discourse" of argumentation rather than in "the authoritative discourse" of believing authority (e.g., the teacher, the textbook, the science TV programs) (Bakhtin 1991;

Bakhtin and Emerson 1999; Matusov 2009, Chapters 5, 7, 8; Matusov and von Duyke 2010). It was interesting that these questions helped some older children to address to and expand on my question #3, which they initially answered negatively.

Summary of Findings from the Video Interviews

Below are summaries of the interviews that I chose to show my undergraduate students. Due to a lack of time, I chose only 3 particular interviews for the age and gender diversity of the interviewed children and because my students plan to interview only elementary and middle school children at the LUC.

Interview#1 Mary, 2nd Grade

Mary enthusiastically loves science because they do fun experiments in her school. When I asked for an example, she described a "game" in which the teacher showed several different liquids that the student could explore observing it to guess what kind of liquids they were (like shampoo, conditioner, plain water, and so on). If a student got the liquid correctly the student got a point, but if nobody got it right, then the teacher got a point. I asked Mary how the students knew what was the correct answer and Mary told me that they found the correct answer by teacher telling them and by touching and playing with the liquids but it was the teacher who told what was the right or wrong. When I pushed Mary what was fun in this activity, she replied: guessing, getting points, observing liquids, or something else, she told me that it was sensing, comparing, and feeling the liquids that made it fun.

Interview#3 Darryl and Isaiah, 5th Grade

Both Darryl and Isaiah like science because, as Isaiah says, "you can experiment with water, vinegar, and stuff and it is very cool to take notes." As a very interesting science lesson, Isaiah remembers of how to make a volcano using water, vinegar, and baking soda (he couldn't remember soda but other people in the room, Darryl, and I tried to help him, but then he remembered it himself). I asked if this is how a volcano works out, this is what inside of a volcano – and they say no. Isaiah explains that volcano happens after a big or small earthquake usually in summer or winter time but he was not sure as it might not winter but spring. He warns me that it is very dangerous and you should not be around a volcano when it happens. I asked why lava is coming. Darryl says it is from pressure and Isaiah elaborated that the pressure comes from the earth shaking. I asked the boys what makes the earth shakes. Darryl smiles and says, "I don't know," but Isaiah wants to pursue with his explanation using his hands that inside of the Earth there is hot stuff and one part breaks out and makes the Earth shake which makes a volcano act. But after a pause, he tells that he forget what makes it so hot. I ask them why volcano and earthquake happen in springtime and not in winter and the boys both reply because winter is really cold time. I ask them why they like the volcano experiment and what they learn from that. Isaiah tells that he learns from the experiment that the volcano dangerous and that earthquake causes volcano. Suddenly Darryl asks Isaiah, "Is it really earthquakes [that cause volcano eruption]? Are you sure of that?" Isaiah dismisses Darryl's doubts and puts him down, "Sure. I have learned a lot in a science class. You should pay more attention in a science class!"

Darryl says that he wants to be a scientist. I asked him why but he could not explain. As to science questions outside of school science, Isaiah wants to know how scientists make things like going into ocean without being bitten by a shark, what kind of protective equipment they have when they go in some dangerous place to explore (like volcano).

Darryl is interested in how to make a time travelling machine to go back to past or go forward into future. I asked him where he would like to go and why but he cannot explain well. Isaiah jumps into a conversation and tells that he would like to go back to fix some bad things that happened like creating hard times. I asked to give an example and he says that he like to fix them from losing their home and becoming homeless. He says that he likes "go back and fix those times." He wants to help his family. I asked him how he would fix those times. Isaiah talks about using tools like a screwdriver to fix the house his family lost. He also wants to go back in time and buy many things. Darryl wants to go back and save $1,000,000.

The boys also want to go back in time to see themselves as little babies, really-really little ones, to see their mothers holding them on their hands, and even to see their own birth. Darryl wants go back even forth in past. Isaiah wants to see Adam and Eve.

I asked them if they want to see dinosaurs and Darryl enthusiastically says, "Yeah!" But Isaiah asks, "Are you sure that dinosaurs were really alive?" I asked them how people know that dinosaurs were really alive if people cannot see them now. Isaiah is puzzled and says, "I don't really know." Darryl says that he knows that dinosaurs were real but Isaiah is not so sure. I asked Darryl how he knows if dinosaurs were real. Isaiah suggests looking in a library for science books to learn if dinosaurs were real but I ask him how people who wrote these book, scientists, know if it is true. Darryl suggests that maybe people who live during dinosaurs wrote books. But I counter-argued that people did not live in the time of dinosaurs and Isaiah enthusiastically agrees with me. Darryl replies that people may find fossils of dinosaurs – I asked him what fossil is, but he cannot explain.

Isaiah says that he believes about ancient Egypt because there is proof of writings and drawing left by people then but he doubts about the existence of dinosaurs because people did not live there and did not leave any written account about them. Also, he notices the dinosaurs were not mentioned in the Bible and thus their existence is doubtful. It was interesting to hear what the children consider as legitimate evidence of their inquiries. Another thing that Isaiah wants to know is how ancient "Chinese built this big-big wall" without use of modern machines.

Interview#4 Hannah, 6th Grade

Hannah tells that she HATES science because "it's very, very, VERY boring!" She describes how in her science classes they study the same things again and again for no purpose like, for example, studies of human body. She says she is not interested in how people breathe. She claims that everything is boring in her science classes. She does not see purpose in that. When I asked her if she has any science questions outside of school, she says no, because, she repeats again, she does not like science and is not interested in science at all, "I don't care how we all are breathing!" (She smiles and while saying that she smashes with her hand in the air, as if she smashes an annoying fly, for a more dramatic articulation of her negative attitude to science). She adds that she knows well that people need oxygen for breathing and she has learned it when she was in second grade.

I asked her how she knows that the teachers did not lie to her about people needing oxygen. She can't explain and I ask her if she knows something and it is not based on believing in what other people say. She thinks for a moment and says, "Yes! It's the Big Bang theory!" I asked her how she knows that the Big Bang really occurred and Hannah replies that it makes sense to her. She is clearly perplexed by my question repeating several times, "I don't know," but then she says that it helps her understand how planets started. I pointed out to her that she is actually interested in science, but she replies, "Only in the Big Bang theory!"

I asked her what makes sense for her in the Big Bang theory and she says that the planets should start at some point. I offer an alternative idea of planets existing forever. She says because everything evolves. I ask why, − why, for example, everything was not created by god. Hannah says that she does not believe that god creates everything because for her, god is a mythological character, "What kind of person has a bunch of power that control everything on a planet?! It doesn't make sense to me." At this moment, other urban children around get involved making suggestions of why god might create everything, Hannah replies that it is all magic and unreal power, the children also make jokes about god.

I asked Hannah how she knows for sure that the Earth was different at different time. But in her reply, she smiles and says that she is not sure and sometimes she thinks that everybody is a robot and somebody controls us. She laughs, "God is an only human and he controls us because we are robots." I support and encourage her new theme and label it "a free will problem." But she restates her own inquiry as apparently more epistemological, "No, how we *know* that we are NOT robots?!" I returned the question to her and she reiterates that god can be a child and we, people, are toys in his hands. I rephrased her ideas in terms of a puppet metaphor with god being a puppeteer. She likes this metaphor and uses her hands to show how god, puppeteer, controls us, his puppets with his seven billion hands. She gets really excited telling me that at times she thinks that she is the only real person and the people around her are puppets or computers or aliens.

I took her inquiry seriously and I told her that in the science of cybernetics, this problem was considered by scientists who developed a famous test to find out if a machine's intellect is equal to human's intellect: if in a test people cannot say the difference, it should be a human, if they can, it is machine. Hannah gets really excited about this idea but immediately tests it by counter-examples, "What if computer lies?" I replied, "It does not matter. If it says stupid things, it is machine if not, it is a human." But Hannah comes with very good, in my view, counter-argument, what if a smart machine tries to pretend that it does not equal to human but actually it does. I told her that it is a really excellent question and that I did not know the answer to it.

Hannah tells that she has started asking me counter-questions like I do it with her and I praised her for that. I told her that this is another science question that she seems to be interested but she replies that it can be philosophy because it tries to make sense and not science that she is interested here. I laughed with people around rephrasing, "So, science is what does not make sense?! I like it…" Hannah clarifies that science makes sense but philosophy is not. I wonder if she meant that science inquiries can be investigated and tested empirically while philosophy was speculative but I did not ask her for clarification at that time as I turned to interviewing another child present in the room.[6]

Watching and Judging Urban children's Connections to Science by my Preservice Teachers

Before showing the three videos in class, I focused my students on two main issues: 1) how children relate to and define science in comparison with their own relationship with science, 2) what they learn about how to organize meaningful interview with urban children from these videos. Here, for the purpose of my paper, I will discuss only the issue#1. I started with interviewing my undergraduate students in the class about their attitude by asking them similar questions that I asked the children and recording keywords in their answers on the blackboard – I called it "conceptual-emotional map of science" because it focused on both emotional relationship to and conceptual understanding of the science practice as the students and the urban children have known and experienced it (see Table 1). Then I asked my students to develop a similar list of keywords for the children's answers while watching my interviews of them on the videos (see Table 2). As you can see, my undergraduate students were very keen observers and they were surprised how much urban children were more positive toward science but their hypothesis was that it fades with age.

The striking difference between these two conceptual-emotional maps was not only in the fact that the urban children's map was richer, more holistic, more exciting, and more accurately approximating scientists' own perception of science practice (Brandes 1996) but also in the fact that suburban preservice teachers do not recognize urban children's perception of science as legitimate (Barton 2001). For example, when the African-American urban boys Darryl and Isaiah reported that they wanted to be a scientist in order to build a time machine to travel in past to fix "bad things" like their family losing a house and them being homeless for a while, my undergraduate students declared that these urban children's "naive perception" of science was a misconception and their time machine traveling endeavor fit better language arts (through fiction and adventure) and social studies (issues of poverty, homelessness, and helping the community) and not the science curriculum.

In the case of my interview of second grade Mary, my students liked how her teacher organized the science activity as a guessing game involving "kids playing with liquids" but they saw these aspects of the learning activity as motivators not intrinsically related to science. These motivators are like sugar wrap of bitter medicine (i.e., science). They disagree with me that the child's multifaceted experiences of sensing, comparing, and feeling liquids to guess what type of liquid it might has anything do with science. This purification of science curriculum seems to suck life out of science pursuits and makes science education dull, sterile, and irrelevant – what my undergraduate students

[6] I am not providing my description of the other interviews because I did not show them to my students in class.

Table 1 Suburban middle-class preservice teachers' conceptual-emotional map of science

• Irrelevant;	• Inquiries;
• Memorizing formulas and facts;	• Tests, exam, and State standards;
• Formulas and experiments;	• Lab reports;
• Tedious;	• Scary;
• Frustrating;	• Boring;
• Overwhelming challenges;	• Textbooks;
• Like;	• Biology and geography;

apparently experienced in their own schools and what they seem to be ready to perpetuate in their own teaching. Elsewhere (Matusov 2011b), I refer to Bakhtin's (1986) notion of "raznorechie" (разноречие, literally "a diversity of discourses" in Russian prompted by diverse sociocultural practices, social stratas, genres, degrees of formality, and so on) that I translated in English as "heterodiscoursia" as an important aspect of scientific (and any other) practice (see also, Rosebery et al. 2010). Suppressing heterodiscoursia evident in my interviews of the urban children (see also Table 2), as it often happens in a conventional school, leads to suppression of the practice itself.

Another causality of this purification and suppression of heterodiscoursia is the suburban preservice teachers' inability, if not reluctance, to recognize and appreciate the holistic nature of science inquiries in the urban students' discourse on science. For example, the middle school-aged Caucasian urban girl Hannah declared that she was interested in "How do we know that we all are not robots (or puppets in god's hands)?" She was not sure that it was a scientific or philosophical inquiry. In the interview, I told her about British mathematician Allan Turing, one of the main founders of computer science and artificial intelligence (without naming him), and his test about finding out a difference between artificial computer and human intelligences (Christian 2011). Hannah enthusiastically recognized the relevance of this information and asked me more about the Turing test.[7] Later I emailed a hyperlink to a relevant website http://en.wikipedia.org/wiki/Turing_test to her and she incorporated the Turing test into her inquiry as she emailed back to me,

[7] Katherine von Duyke pointed out that science might not be *the* central aspect of Hannah's inquiry of "How do we know that we all are not robots," which ontologically might be rooted in her desire to take control over her own life and in her experiencing her school as an oppressive and controlling institution. Although, my reference to science seemed to be useful and helpful for Hannah and she acknowledged this, it is important to warn educators against exploitation of students' ontology for engaging them in the curriculum of the teacher's choice. Instead of colonizing students' ontological interests with the teacher-defined curriculum, in my view, teaching curriculum should be helpful for the students' existing and emerging ontological inquiries. I want to argue that it is not that students' ontological inquiries should be used and exploited for school curricula, but rather school curricula should be used for students' ontological inquiries (i.e., school should be useful for the student's present). A somewhat similar, but not exactly the same, concern was articulated by Daniel Greenberg, a founder and theoretician of the Sudbury Valley School model. He warned with some bitter irony, "A really good progressive school teacher is one who watches a child closely, who observes that first glimmer of interest in, say, a rock, and who then promptly comes forward and tells the child, 'Oh, you are interested in rocks; we have a wonderful collection of books on geology, etc.' This approach is a turn-off to curiosity. What the child learns in an environment like that is that it doesn't pay to probe, and if you do, you have got to hide it like a criminal activity, because if anybody ever catches you, they will follow up on you and they will get you involved to a degree that you just don 't want to be and don't feel you ought to be" (Greenberg 1992, p. 96). I think usefulness of guidance for the student's activities at hand as judged by the student is the key here.

Table 2 Urban children's conceptual-emotional map of science as abstracted by the preservice teachers from the videotaped interviews

• Love!; • Hate!; • Fun! • Feeling things; • Guessing what is true; • Testing the guesses; • Playing games and contests on whose guess was right; • Learning new, exciting things; • Answering own questions; • Experimenting; • Modeling real events; Philosophy; • Religion;	• Studying dramatic and scary phenomena (like volcano and earthquakes); • Adventure; • Fantasy; • Imagination; • Helping people, community, and family to fix and repair from "bad things that happened in past"; • Asking big questions about the world and the self (i.e., self-awareness);	• Hating meaningless school science lessons and assignments; • Finding proofs and evidence; • Arguing; • Considering alternatives; • Asking questions; • Developing explanations; • Taking notes; • Listening to the teacher; • Doubting; • Carefully listening to others;	• Defending one's own ideas; • Trying to be open-minded; • Changing your mind under new evidence or argument; • Wanting to be a scientist; • Questioning ideas, authority, and experts; • Getting interested and excited; • Making sense; • Very, very, very boring.

> Hi Eugene, i wish i could take the Turing test, it seems very interesting... I think that test would work because if the machine were to write you their words would be more precise, and if the person was a girl, they would use "like" a lot in their writing, but a machine would not. Thanks for interviewing me, Hannah. PS to the future teachers in the classroom – take your future students seriously no matter what they say because the world can be viewed in many kinds of ways.

Even after I showed this exchange to my undergraduate students, they still rejected that the girl had any science inquiry but rather it was her "cool teenage fantasy focusing on her own self-awareness" (from a class online forum posting). Another student wrote on the class online forum,

> I guess when I was listening to your interview of the girl I really didn't feel like she was talking about the Turing test or anything about Artificial Intelligence. I kind of felt like she was talking about robots because that was something that she thought was cool and not because of the science behind it. I think it would have been great to have kept her talking about Turing's test and about the other scientists. I just felt that there could have been a few more questions asked about the scientists to see if she knew anything more about them.

What is shocking here for me is that for this student the ideas about science are a product of an authoritative voice (i.e., well-established and self-contained scientific facts), rather than something which can be responded to and engaged in by the student (Scott et al. 2006). Also, it is shocking to me here again how much the pre-service teachers minimize the urban children's inquiry and make de-contextualized, objectivized, overgeneralized, and excessively finalized assumptions of the children's developmental state stripping the children from their agency instead of reflecting upon the child's inquiry in and of itself and engaging themselves in the inquiries initiated by the urban children (Matusov and Smith 2007). I sense that this may actually more reflect the pre-service teachers' alienation from their own learning, rather than the children's inquiry. They are so alienated from science that they do not recognize the inquiry in the child. WORSE, they then make objectivized and finalized assumptions about the student making this inquiry and through these excessive objectivizations and finalizations of the children (Matusov and Smith 2007) they seem to gain position of their future teacher power over their future students!

Further class and web discussions with my undergraduate students, suburban preservice teachers, revealed that their own inability to recognize inquiries in the urban children's discourse on science was caused not only by their unfamiliarity with science itself but also by their overall attitude to teaching disinterested in the curriculum they plan to teach. They claimed that as teachers, they do not need to become excited and interested in an academic subject they are teaching, rather they need: 1) to know objective teaching techniques tested by educational science research (i.e., research and evidence based teaching), and 2) to effectively motivate their students by "getting to know the students" and addressing their social needs so the students will unconditionally cooperate with whatever curriculum the teacher prepares and is required by the State standards[8] (cf. "exchange of favors", Sidorkin 2002). This type of sterile and standardized teaching aims at delivering any curricular endpoint, preset by the authority of the State and textbook, to their obedient students without the teacher's personal risk-taking and engagement into instruction and curriculum.

Discussion of the Findings: Building an Alienation Hypothesis

These findings promote me to build an alienation hypothesis of why so many students and school alumni have been turned off by science (and probably other academic subjects) and have very shallow understanding of science achievements and how science works. The alienation hypothesis is an alternative to two other main hypotheses of the well-documented phenomenon: the structural hypothesis, emphasizing teaching important scientific facts and important elements involving in science practice, and the misconception hypothesis, focusing on revealing and cleaning the students' consciousness from their preexisting misconceptions about important natural phenomena by facing the students with contradictions between their erroneous thinking and reality (i.e., engaging the students in cognitive dissonance). According to the alienation hypothesis, the students' agency engaging in science in the students' everyday life outside of school is not welcomed in the science education. The students are asked to "shut up" about their subjectivities – opinions, feelings, worldviews, values, perception, and experiences – when these subjectivities do not fit the presented preset curricular endpoints by the teachers. The issue is not how to democratize the preset curricular endpoints about science by including, for example, indigenous non-European ways of knowing (Aikenhead and Ogawa 2007) – although I see it as a step forward, − but rather to move away from preset curricular endpoints as such in favor of the emergent curriculum (Osberg and Biesta 2008) and emergent definitions of science coming from the students as well as from the diverse professional science practices (Matusov 2009, 2011a). My findings help to reveal at least four important aspects for this alienation hypothesis.

First, the students' inquiries, interests, puzzlements, excitements, and questions about science are often kept out of the school official science curriculum in favor of making the students arrive at the preset curricular endpoints. This is probably true for any school curriculum, but I wonder if this is especially true for science in which science teachers often do not have any access to the students' subjectivities, "Traditional practices of science teaching don't really make room for student thinking" (Hammer and Zee 2006, p. 7). Arguably, language art in conventional schooling has more possibilities involving student agency than science – more comparative research is needed.

Even when students' can find some personal interest and excitement in the school curriculum predefined by the teacher, the teachers often try to suppress or divert it being afraid of losing their control over the public classroom curricular agenda (Kennedy

[8] My students "forget" to mention another important pedagogical curriculum for becoming a conventional teacher, classroom management strategies. They mentioned this curriculum later in the class.

2005; Tharp and Gallimore 1988; Wortham 1995, April). Kennedy (2005) defines this phenomenon as "off-script," when a student's contribution is on the teacher's task but off the teacher's predefined script. As her research shows, many teachers are more concerned and worry about students' being off-script rather than off-task as it seems to more challenge the teachers' authority and control in the perception of the teachers.

In our class discussion of the 6 urban children's science inquiries and interests, my undergraduate students, preservice teachers, offered additional, but arguably related, arguments against welcoming their future students' inquiries and interests in their future class curriculum besides the issues of teacher authority and control. My preservice teachers argued that they would not have time for them to learn and address about their students' inquiries and interests being busy to cover the state mandated curriculum and prepare their future students for the state mandated high stake tests and exams. Also, having a great diversity of students' own interests, excitements, and inquiries would create an unmanageable chaos since other students may not want to attend to their peer's curricular interests and the teacher cannot guide all these diverse topics of the students' interests at once. Finally, by pursuing the students' interests and inquiries, the teacher might miss covering important curricular facts that the students' may not be interested.

All of these concerns plus listed by the teachers in Kennedy's research described above, seem to justify for many teachers excluding the students' agency from the school curriculum. Or, putting it in a more succinct formulation, the student authorial agency (Matusov et al. 2016) in the academic curriculum and the conventional school teaching practice with its preset goals and expectations are incompatible. By excluding the student authorial agency from school academic curriculum, the school academic curriculum loses the student authorial agency so many students stopped seeing themselves being interested in these academic subjects. If Einstein was correct defining science as, "a refinement of everyday thinking" (Einstein 1936, p. 349), then excluding students' everyday thinking from school science education, excludes the students from the genuine science education itself (Hammer and Zee 2006). As Brandes, observing a steady decline of students' interest in science between 2nd and 5th grade, points out, "If children do not see science as something 'for them,' they may not engage in potentially stimulating science activities" (Brandes 1996, p. 39). In my interview, while 2nd and 5th grade urban children reported liking science, both 6th and 10th graders reported hating it – as my further investigation with them shows, the older urban children like science but outside of school curriculum, which I am not so sure about my undergraduate students (see my discussion below). This process can create a vicious circle when these alienated students become alienated teachers themselves.

Second, students' scientific interests and inquiries, especially emerging outside of school, are not often seen by their teachers as scientific because of the teacher's purification of what the science is about (Brandes 1996). My undergraduate students, preservice teachers, strongly refused to accept all urban children's inquires presented to them on the videotaped interviews as scientific but possibly belonging to other academic subjects if at all. My preservice teachers saw the 2nd grader's excitement of feeling liquids to define their nature as entertainment, the 5th graders' interest in time machine as fantasy, their doubts about the historical existence of dinosaurs as influence and interference by religion, their desire to help their families with travelling to past to fix the losing their house as social justice, the 6th grader's fascination with the Big Bang Theory as her goofing around, and her puzzlement of how define if we are not robots or puppets as teenage self-awareness. The preservice teachers do not see that entertainment, imagination, fantasy, religion, social justice, goofing, teasing, competition, philosophical self-awareness, vanity, aesthetics, desires, concerns, and so on feed science inquiries and are crucial part of science itself, often being an engine of science (Levrini et al. 2018).

I argue that science is hybridist and heterodiscursive in its nature (Latour 1987). While trying to purify the school science from all these para-scientific, hybridist, and heterodiscursive aspects, the teachers make the science dry, decontextualized, impersonal, boring, and essentially dead as the comparison between Tables 1 and 2 reveals. Brandes' (1996) research findings and the findings presented here suggest that school children increasingly believe that their interests and inquiries are not part of science, where science is exclusively equated with the school impersonal science by them. Thus, purification of science by the teachers and then by students expels many students from the realm of science in their own self-perception and self-image.

The issue of science purification in school – bracketing any non-scientific elements from science education or squeezing science inquiries from the students' ontological concerns and interests – is a contested issue in science education. For example, although such innovative science educators as David Hammer and Zee (2006) and educators developing "responsive teaching" in science and math education (e.g., see in the edited book, Robertson et al. 2016) suggest science teachers focusing on the students' holistic thinking to see and develop its potential for scientific refinement, they too seem to seek some type of science purification,

> What sorts of things could be the beginnings of scientific reasoning in children? Not everything they say and do, surely. It's nice to think of children as natural scientists, but aren't they also natural poets and storytellers and jokesters and more? (p. 13).
>
> …
>
> Not everything children are motivated to do is helpful for science, and of course, not everything that is sensible, mechanistic, and consistent with what children know is correct.
>
> If, for example, the children are having a wonderful time making up fanciful stories around some natural phenomenon-the gods make it thunder and rain, say-they might be motivated and engaged, and the activity might be of educational value, but it wouldn't be science. In such moments, you may need to choose between cultivating children's resources for science and letting them continue in an activity they are enjoying. If your immediate purpose is children's engagement, then they're there, and you should let them be. Jamie was in that sort of position, in "Falling Objects" (Chapter 5), when her first graders started reporting, show-and-tell style, results that couldn't make sense together (Hammer and Zee 2006, p. 165).

What is potentially scientific in what children say? Should it be some filter or criterion deciding what can or cannot be used in what the children say for science lesson? In their very helpful 2006 book, Hammer and Zee answer, "yes," and provide the criterion of a cause-effect mechanism, "thinking about tangible causes and effects, what physicists call *mechanism*" (Hammer and Zee 2006, p. 6, the italics is original). If one can see a potential for such cause-effect mechanism in children's talk, then children's talk can be seen as science talk that can be utilized in a science lesson. If not, then not.

I want to take an issue with Hammer and Zee on that and argue that "everything children are motivated to do" is potentially helpful for science (and any other academic curriculum) as well as science is not defined by "mechanistic thinking" as these authors argued (or defining any other predefined thinking as "scientific"). In my view, science is not defined neither by some kind of "scientific method" (e.g., using Popper's verification) or "scientific explanation" (e.g., tangible cause-effect mechanism proposed by Hammer and Zee). Rather, as Einstein pointed out in the quote before, science practice is based on refinement of people's experiences. This refinement involves a public discourse of testing ideas and expanding people's experiences. In this, I think I came closer to physicist Nils Bohr in his famous Copenhagen interpretation of quantum physics who argued that, "'It is wrong to think that the task of physics is to find out how nature is', Bohr would argue later. 'Physics concerns what we can say about nature.' Nothing more. He believed that science had but two goals, 'to extend the range of our experience and to reduce it to order'" (cited in, Kumar 2008, p. 262). Bohr's position was contrasted with Einstein's search for realism in physics, "What we call science has the sole purpose of determining what *is*."

Thus, everything that children say can become an entry point for the refinement of public discourse of testing ideas and expanding experiences. The issue becomes whether the participants (i.e., children) are interested in joining this refinement or not (or they are interested in some kind of other activity or discourse at that moment). As to structural criteria of science like "scientific method" and "scientific explanation," in my view, they are temporary by-products of science practice rather than its necessary precursors. For example, I argue that not only "thinking about tangible causes and effects mechanisms" do not applied in quantum physics (Kumar 2008) but also in psychology with its "reverse causality" phenomenon when a future events redefines the meaning of the past event (Matusov 1998). Science practice community constantly develops temporary and contested views about what science is and what it is not as product and by-product of its activity. I argue that this open, unfinalized, and public discourse on what science is also should be a part of science education rather than a gatekeeping filter on children's talk censoring their "unscientific ideas."

The issue here for me is not only whether peripheral science material, para-science, (i.e., scientific material that services non-scientific purpose, e.g., a joke about science, see below) and instrumental science (i.e., science being an instrument for non-scientific purposes and interests) can serve and provide motivation and material for the science itself – although this is an important concern in its own. Ignoring or suppressing heterodiscoursia around science by the teacher can cost by missing teachable moments. For example, Hammer and Zee (2006) provide an interesting case of first graders' apparent joke about gravity forces being "tired" to explain an observed inconsistency in their falling objects experiments. The children's joke was that was apparently dismissed, not supported, if not suppressed, by the teacher. However, later, during a science education workshop for teachers, some science educators observing the videotaped lesson commented that the children's joke might have very interesting scientific potentials, if taken seriously, and supported by a curious teacher because the students might imply that gravity is like wind that can change its power capriciously with time. Even if the students did not imply this meaning, the para-scientific joke could have sparked this idea in the teacher who could have introduced this alternative and potentially very fruitful conjecture to the children.

However, the bigger issue for me is whether purified, distilled, science inquiries without support from peripheral para- and instrumental science and non-science activities can survive on a long run for people at all and especially for students and young children. Using a biological metaphor, cutting non-organic matter from a live organism will kill the organism. Similarly, exploiting students' ontological interests by the teacher in order to only squeeze scientific inquiries from these interests, is parasitic exploitation of the students' lives undermining the student-teacher trust and the students' well-being.[9] In my view, the purpose of a science instruction is not to squeeze science from everything that the students are ontologically engaged or to suppress everything that is not scientific in the students' discourse during a science lesson but rather to establish, recognize, and respect a healthy, organic, "breathing," relationship among purely scientific activities, where the entire focus by the participants is on science, instrumental science activities, para-science activities, and even purely non-science activities, while the teacher helps the students to develop their voices in the science practice. Focusing and unfocusing on science in the classroom science education discourse should probably go hand-by-hand with each other, although they do not need to be symmetrical processes. This is probably true for any academic curriculum.

Third, school science does not engage students in considering the non-authoritative and non-belief nature of science knowledge in general and science knowledge that the students hold in particular (Brandes 1996). When asked how they know what they know, my preservice teachers often refer to the authority of scientists through reading books and school textbooks and listening to teachers but the students usually cannot explain how the scientists have come to these scientific facts. Some of my preservice teachers told me that they believed in scientists and teachers when, for example, I asked how they knew for sure that the Earth is rounded. When I attracted the teacher education students to urban children's attempts to justify their scientific knowledge, my preservice teachers argued against teaching these justifications in school during science lessons because these investigating discussions with children could be confusing and time consuming, distracting the children from learning solid scientific facts and preparing to the tests and holding advanced students by attending to slower learners. Also, they see student learning as an essentially individualistic process where a confusion of one student has nothing to do with a confusion of another student and students' confusions are viewed as the teacher's burdens rather than teaching assets

[9] My favorite example of such parasitic exploitation of students' life concerns and interests by purified academic curricula comes from the language art curriculum rather than from the science curriculum. A second grader writes in her diary checked by the teacher, "Im deprsd toody." In his response, the teacher, guided by the concern about purification of the academic curriculum, corrects the child's grammatical errors with his red pen while ignoring the disturbing meaning of the message and the child's apparent cry for help.

(Corser et al. 1989). Arguably, conventional school science education does not help students learn neither science consumption (i.e., how to find out and evaluate reliable, relevant, and valid science information for one's personal inquiries and needs) nor science production (i.e., how knowledge generated in the science practice, see Tinker 1991). Both science consumption and science production are based on what Bakhtin called the internally persuasive discourse in which everything can be testable (Bakhtin 1991; Matusov 2009; Matusov and von Duyke 2010; Morson 2004). In contrast, conventional school science education is mostly based on, what Bakhtin defined as, the authoritative discourse that leads teaching science as if it is a religious dogma to believe in (Matusov 2015a) or what Collins and Halverson (2009) refer to as "a civic church."

Fourth, many conventional teachers seem to think that the teacher does not need to be personally interested and invested in the academic curricular they teach as far as they know effective teaching, classroom management, content knowledge (i.e., a list of important facts for transmission), and motivation strategies to make their students interested in the curriculum and understand it (Hammer and Zee 2006). As one of my preservice teachers wrote on this topic,

> I do think it is important to be excited and enthusiastic in teaching younger kids, but I think being enthusiastic about them learning/teaching them/building their knowledge base is the kind of enthusiasm necessary, I don't need to be really-really excited and extremely interested in addition (which is such basic math I don't think anyone could possibly be extremely interested or excited about it) in order to teach it – you just need to know effective teaching strategies for addition. I think it is more important being excited about the students learning and about teaching itself.

This technological disinterested approach to the instruction, motivation, content knowledge, classroom management, and curriculum (Matusov 2011a) can prevent the teachers from recognizing the value of and supporting the students' "off-script" contributions (Kennedy 2005) and the student-initiated inquiries and make the teachers disoriented when they are faced with the students' learning initiatives.

Collaboration and genuine dialogue the students about their learning heavily depends on the teacher's curricular improvisation and flexibility rooted in the teacher's personal interest in, commitment in, and even excitement of the taught curricular (Sawyer 2004). Following Bibler's concept of "person of culture" – a person who actively contributes to production of culture (Berlyand 2009; Bibler 2009), − Lobok (2014) insists that a good teacher has to be a "person of culture" meaning that the teacher has to be an epistemological learner of the taught curriculum, constantly learning and being interested in the curriculum (Matusov 2009, chapter 4; Miyazaki 2007, July). When the teacher does not expect to be a person of culture and does not expect to be interested, invested, and excited about the taught curriculum, he or she is not ready for improvisation with the students and collaboration with them. The students' academic initiatives become seen as a threat for the teacher's control of the guidance and order of the class and as Kennedy's research shows many conventional teachers try to suppress the students' learning initiatives and with them the students' agency in these academic subjects.

Finally, on the basis of my findings, I want to hypothesize that mainstream school science education differently fails suburban middle-class versus low SES urban students through alienation of the science curriculum. While older urban children seem to increasingly dislike school science similar to my suburban undergraduate students, in contrast to my suburban students, they apparently can separate "real science" from "school science" and shelter their own scientific inquiries and questions from meaningless school science. Unlike older suburban students, the older urban children seem to continue seeing science excitement and themselves in science.

I hypothesize that the reason for this difference can be caused by the fact that suburban students choose to cooperate with school science instruction and accept the school definition of science despite its meaninglessness and disconnection with their own interests due to economic, institutional, and social benefits that this cooperation holds for them (e.g., access to college). In contrast, urban children with low SES decide to resist the meaningless, purified school science and thus shelter their own intimate connections with science often at expense of their institutional failure (see Table 3). As one of my students reflected on this difference, she wrote on the class online forum,

> There really is a big difference that can be seen with the maps. I agree it makes sense that there are students in the middle class setting find science boring because they are only trying and learning the information that they will be tested on. It is interesting to see the difference between the urban students and the middle class students. I know for as long as I can remember I disliked science. I also know that as the science got more difficult I lost interest in it. Not because I had a traumatic experience but because the science I was doing was irrelevant to my life.

This hypothesis is compatible to a sociological view of schooling primarily as "a sorting machine" (Labaree 2010; Varenne and McDermott 1998; Waller 1932) for social reproduction (Bourdieu 1977) rather than for genuine education.

Of course, these may be common but not the only possible pathways to science education. Not all students are alienated from science or experienced alienated science teaching and even if they experience alienation, they may develop different pathways as well. More research is needed to investigate this and the other hypotheses I constructed here on the basis of my findings.

Table 3 Hypothesis about diverse effects of school science alienation on suburban vs. urban students

	Suburban students	Urban students
Attitude to school	Compliance	Resistance
Institutional achievement	Success	Failure
Attitude to school science	Hate	Hate
Personal interest in science	Killed	Preserved

What Did I Do with the Problem of Science Alienation in my Class?

When I presented parts of this paper at the 2011 Ethnography Forum, the audience asked me to tell what I did with the problem of my preservice teachers' science alienation in my class. My story led to an interesting discussion so I decided to add it here.

After I recognized the problem of science alienation in my preservice students, and its core root in the school authoritarianism and instrumentalism, I was faced with a teaching dilemma. Should I continue pushing my class in the direction of my students, who were obviously traumatized by science education, learning science and science pedagogy or not? On the one hand, I wanted to do it to help them recover and since about a half of them would be required to teach science in their future elementary classrooms, it could be nice to break a vicious circle of alienated teachers teaching science to make their students alienated from science. But on the other hand, my traumatized students developed *anti-agency in science* – i.e., student authorial agency of actively seeking a way out of science practice, while learning how to pass school tests.

Even when I managed to create a successful science activity in my class so the students were almost forced to authentically engage in my science lesson, they seemed to feel their necessity to resist their own enjoyment of their emergent science discussions. For example, when I gave them a table of content of the book "Never shower in a thunderstorm: Surprising facts and misleading myths about our health and the world we live in" (O'Connor 2007) that seems to be written about science inquiries with young adults in mind, my students enthusiastically selected science inquiries from the book that they were ontologically concerned about (e.g., whether riding bikes leads to impotency, whether cutting hair makes it grow faster, whether oversleeping leads to gaining weight). They made predictions, discussed articles in the book, and even searched on the Internet for research updates on their laptops and smartphones. But then they said that "Although I enjoyed the lesson today, I don't want to do science again because I am sick and tired of it." However, a very few students became appreciated science and started developing their agency in science through these learning activities. Thus, a student wrote on the class online forum,

> I just want to say that I appreciated the science lesson/activity that we did on Tuesday. I, being one who was never interested in science, mainly because I did poorly in it, was really interested. I feel as though some of the comments made in class were rude and disrespectful. We are all adults, which is why adult content was allowed in the activity. However, if we were doing this with children, we would be able to pick and choose the topics that would be available. It made me realize that science can be made into something interesting, and that not all science has to feel like [boring schoolish – EM] science. And that there are ways to get those who dislike the subject matter to become interested and begin to enjoy the curriculum, and science education. All that being said, THANKS EUGENE!!!!

Unlike the urban children in my interviews, I could not engage all of my undergraduate students in science curriculum of their interest to the point that they all appreciated it. One hypothesis that I have developed is that many of my undergrad students, preservice teachers, were too traumatized by and too cooperated with the school science curriculum meaningless to them too acknowledge their appreciation of science. Alternative hypotheses were suggested by my colleagues. Thus, Lama Jaber (personal communication, March 6, 2011) suggested that some of my students' resistance to the science curriculum was in part rooted in their broken expectation for the class that was supposed to focus on "urban education" and not on science education. Katherine von Duyke (personal communication, March 28, 2011) attracted my attention that the difference between my interview success in "science recovery" with the urban children and failure with some of my undergraduate students was caused by the school context of my discussions with my preservice teachers. Based on the situated cognition framework (Lave 1988), she hypothesized that I might be more successful if I discussed the existence of their science inquiries outside of the campus settings. I think all of these hypotheses seem to me reasonable and requiring testing.

I tried to democratize my classes. I decided to quit the science curriculum in my class and redesigned on the fourth week of the 15-week semester, using a framework of "open curriculum", "open syllabus," (i.e., designing only one week ahead to base my curriculum on emerging interests, inquiries, and needs by my students) (Matusov 2015b; Matusov and Marjanovic-Shane 2017). I came to a conclusion that I had to engage their authorial agency. They had declared many times by now that they came to my class to study "urban education" and not science curriculum. After analysis of my students' inquiries and areas of their interests, I declared that the class would have a new directions tentatively focusing on:

1) urban education "mythbusting" (i.e., searching and generating statements about urban education and people living in urban settings and testing them with statistics, research, and interviews at the Center),
2) analysis of teachers' dilemma in urban schools,
3) learning about diverse pedagogies (e.g., culturally relevant pedagogy, culturally responsive teaching, bottom-up teaching),
4) preparing a videotaped lesson at the Center and reflection on it), and
5) focusing on recognizing "teachable moments," missed or achieved.

The students liked the change,

> I'm really happy with the changes that have been made in the class the past week or so. I think the discussions are becoming more interesting and like to hear about the different views and experiences people have in our class. When there isn't much discussion in a class it's easy to assume that everyone sees the topic or issue a certain way, but when further discussed its interesting and very informative to learn about all the different perspectives and ideas people have.

I used diverse curricular examples for the 2–5 aspects of our class. I developed learning activities that I used with my students in class and then at the Center so they could explore differences among diverse populations of the students. For example, in a response of one of the students that people in urban setting have more children than people in suburban settings (we treated this statement as "a myth," i.e., an untested statement), I developed a learning activity by giving my students index cards and asking to draw "their family." Then I guide my students to "decode" the pictures by focusing on geometrical-topological portray of the family (only horizontal or also vertical), heights of the figures, their order, who was included and who was not and why, and so on. That led to reflective interviews about nature, diversity, and types of suburban families. I repeated the same activity with the children at the Center videotaping my interaction with the urban children. In class we viewed my videotaped interviews and discussed the differences and similarities between the suburban students' replies about their families and urban children's replies about their families. Also, we discussed emergent teachable moments that I utilized or missed in the reflective interviews with the children and how my students would use these missed teaching opportunities and what questions would they ask. Also, during each class meeting, I asked my students to write on index cards teachable moments missed by me that they noticed in the class.

They loved to recognize teachable moments and think how they would promote them with their questions, "…I feel that teaching moments are very important because I feel that from these come learning moments which are crucial for children to be engaged." Some of them recognized that for recognizing teachable moments, the teacher must become interested in the taught curriculum and must engage him/herself in the curricular learning. They started liking event-based teaching, in which the teacher expects to be surprised by the students' contributions and provokes the students for teachable moments, rather than curricular endpoint-based teaching, in which the teacher wants the students to arrive at a preset curricular endpoint at the end of the lesson (Matusov 2017). However, they also struggle with eventful teaching that goes in a conflict with conventional transmission of knowledge pedagogy valued by many powerful school administrators and policymakers who make teachers accountable,

> I think that the teaching moments and CRP [i.e., "Culturally Relevant Pedagogy" (Ladson-Billings 1995)] are very important when it comes to teaching different topics in school. But I have had one concern that I've begun to think about as we are developing our lesson plan projects. When does a teaching moment become too off topic from the original lesson plan? Is it okay if you follow the teaching moment instead of strictly staying on topic to complete the lesson? If you were being observed by someone as you did this in class, would it reflect positively on you as a teacher for taking advantage of a teaching moment, or would it reflect poorly on you as a teacher for going off topic and not devoting enough time to the original lesson?

In my view, focus on eventful teaching involving teachable moments, to which my students seemed to develop a sense of "ontological attraction" and "nostalgia," allows preservice teachers to reconnect with the academic curriculum and to invite their own agencies in the academic subjects (Matusov 2017). However, their worries about being punished for this type of authorial teaching are well placed as well.

Incidentally and paradoxically, although having a legitimate choice of their learning activities at their urban practicum, a half of the students chose science curriculum for the lessons at the Center with urban children. Their lessons were rather problematic from my point of view often focusing on transmission of ready-made knowledge but while watching the videotaped lessons in class, the students were interested in searching and discussing their missed teachable moments in these lessons, "I was disappointed in my lesson, but after doing the formative assessment I was able to look at all the things I saw as 'failures' of my missed teaching moments in the lesson as just learning moments for myself! I can now take all those mistakes and situations and be able to handle them better in the future." The preservice teachers' educational nostalgia for teachable moments in their own teaching can be an important step for some of the students to heal their science education trauma (and even probably a trauma of schooled education) and regain their agency in the science practice and live long education (Matusov 2017). I hope at these learning experiences around teachable moments can provide my students with pathway to eventful dialogic teaching and becoming "a person of culture." This requires a philosophical shift from defining education as "reproduction of culture" (Bourdieu 1977) to defining education as "production of culture": education as culture making (Berlyand 2009; Bibler 2009).

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Ethical Approval This article does not contain any studies with human participants performed by any of the authors.

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