

Appendices

Appendix 1 Consent forms

University of Cambridge

Faculty of Education

[Address redacted]

Tel: [Phone number redacted]

[Email address redacted]



UNIVERSITY OF
CAMBRIDGE

Faculty of Education

Information for Parents

Research Project

Mixed Reality Simulation: A New Method to Develop Science Teachers' Contingent Responsiveness in Leading a Science Discussion

Dear parents/guardians,

My name is Lydia Cao. I am a research student in the Faculty of Education, University of Cambridge. I am currently collaborating with Edopia School to design and study a teacher professional development (TPD) program. The purpose of the research is to produce a locally viable and sustainable TPD program at Edopia School to benefit the learning of teachers and the students. In addition, the TPD designed at Edopia will serve as a prototype to be scaled in other institutions and/or countries.

Part of the study involves the teachers videotape 20 mins of their discussion with students twice throughout the TPD. I am writing to ask for your consent for your children to be video recorded and explain how I will handle the video recordings. If you do not consent your children to be video recorded, your children will be seated outside the frame of the camera during the recording to ensure that they receive the same quality education.

Safety and Privacy

This research will be conducted in accordance with the ethical guidelines of the British Educational Research Association [BERA] <http://bit.ly/BERAethics2018> and guidelines of Edopia School. With your permission, the participating teachers will record their class discussion with students twice throughout the TPD. The video recordings are used to understand how teachers interpret the situation and make instructional decisions on the fly.

Video recordings will be securely stored in OneDrive of the University of Cambridge for 5 years before being permanently deleted. Access to video recordings is limited to your children's teacher, myself and my two supervisors. Participants will be anonymized when reporting the results. Your children's participation in this study is voluntary, and you are free to withdraw your children's participation at any time and without giving a reason. After withdrawal, all data related to your children would be destroyed unless it has been collected in a group setting.

With your permission, I will use the recordings and the transcripts only for training and research purposes, and subsequent publications/presentations, and your children will remain anonymized. Only anonymized screenshots and videos will be used, which means the images of your children will not be visible.

The result of this research will be summarised and shared with you in the format of a brief report. The full thesis will be accessible through the Cambridge online archive <https://www.repository.cam.ac.uk>.

If you have any further questions, please feel free to contact me at [Email address redacted] or my supervisors, Dr Sara Hennessy [Email address redacted] or Prof Rupert Wegerif [Email address redacted]. If you would like to participate, please sign the consent form in the next page and return it to me at [Email address redacted].

Thank you for your time and attention. Your contribution is invaluable for this research and teacher education.

Yours sincerely,

Lydia Cao
PhD Student
Faculty of Education
University of Cambridge

Parent/Guardian Consent Form

By signing this consent form you agree to the activities your child participates in being videotaped, and to these recordings being used for research purposes (in accordance with the conditions outlined in the information sheet). You also agree to the recording files and the transcripts of the recordings being archived and used for research purposes by the named researcher at the University of Cambridge.

Please answer each statement concerning the collection and use of the research data.

1. I have received the information sheet.	YES <input type="checkbox"/> NO <input type="checkbox"/>
2. I have been given the opportunity to ask questions about the study.	YES <input type="checkbox"/> NO <input type="checkbox"/>
3. I agree for my child to be video recorded.	YES <input type="checkbox"/> NO <input type="checkbox"/>
4. I understand that I can withdraw consent for the use of the recordings at any time without having to give an explanation.	YES <input type="checkbox"/> NO <input type="checkbox"/>
5. I agree to anonymized screen shots from the video files (in accordance with conditions outlined in the information sheet) being reproduced in scholarly publications and professional development materials.	YES <input type="checkbox"/> NO <input type="checkbox"/>
6. I understand that the project has received ethics clearance through the University of Cambridge's ethical approval process for research involving human participants, and I understand who will have access to the data, how it will be stored and what will happen to the data at the end of the study.	YES <input type="checkbox"/> NO <input type="checkbox"/>

Name of child: _____

Name of the parent/guardian: _____

Signature: _____

Date: _____

----- For Researcher's Use Only -----

Name of researcher: _____

Signature: _____

Date: _____

Information for Teachers

Research Project

Mixed Reality Simulation: A New Method to Develop Science Teachers' Contingent Responsiveness in Leading a Science Discussion

My name is Lydia Cao. I am a research student in the Faculty of Education, University of Cambridge. I cordially invite you to be part of this cutting-edge research, in which you will learn to teach effectively by practising with virtual students in a simulated classroom. This teacher professional development (TPD) will enrich your teacher learning experience and support you to develop effective teaching skills and the ability to make instructional decisions on the fly. Your participation will also make an impactful contribution to teacher learning.

Purpose of the research

This research aims to develop a simulation-based TPD using the Mursion simulator (<https://www.mursion.com/>), where you can learn to interpret and respond to student ideas on the fly (see Figure 1) when leading a science discussion. Another aim of this study is to gain an understanding of how teachers develop this capacity in a simulated classroom.

Photo of a teacher interacting with avatar students in front of a TV screen removed for copyright reasons. Copyright holder is Anthony Rimel, Western Oregon University

Figure 1 A teacher interacting with virtual students (Rimel, 2020)

TPD Process

Your participation in this study is voluntary. Please note that your performance in this study will NOT be used as the basis for evaluating your performance in your current job.

This TPD is comprised of:

- TPD orientation (1h)

- 4 self-paced online TPD modules to provide the foundation for dialogic teaching (1h/module)
- 4 live simulation sessions to enact dialogic teaching (1h30min/session)
- a pre- and post-TPD video recording of your own class (20min/each)

You will also be invited to watch the pre- and post TPD video recordings with the researcher (1h/each). You will point out the moments that you found interesting and/or difficult and think out loud to make your thinking process visible.

The total number of hours involved in this study is approximately 14h. Your participation in this study will count towards your TPD hours at your job.

Safety and Privacy

This research will be conducted in accordance with the ethical guidelines of the British Educational Research Association [BERA] <http://bit.ly/BERAethics2018> and guidelines of Edopia School. To ensure your safety, this study will be conducted remotely through zoom meetings. With your permission, the zoom meetings will be recorded. The video recordings of TPD sessions are used to observe interaction among the participants to understand how learning takes place during the TPD.

Video recordings will be downloaded from zoom cloud to be securely stored in OneDrive of the University of Cambridge for 5 years before being permanently deleted. Access to video recordings is limited to myself and my two supervisors. The video recordings will be immediately deleted from zoom permanently after download. Participants will be anonymized when reporting the results (unless you prefer to be named) and your participation in this study is voluntary. You are free to withdraw your participation at any time and without giving a reason. After withdrawal, all data related to you would be destroyed unless it has been collected in a group setting.

With your permission, I will use the recordings and the transcripts only for training and research purposes, and subsequent publications/presentations, and you will remain anonymized. Only anonymized screenshots and videos will be used, which means the images of you will not be visible.

The result of this research will be summarised and shared with you in the format of a brief report. The full thesis will be accessible through the Cambridge online archive <https://www.repository.cam.ac.uk>.

If you have any further questions, please feel free to contact me at [Email address redacted] or my supervisors, Dr Sara Hennessy [Email address redacted] or Prof Rupert Wegerif [Email address redacted]. If you would like to participate, please sign the consent form in the next page and return it to me at [Email address redacted].

Thank you for your time and attention. Your contribution is invaluable for this research and teacher education.

Yours sincerely,

Lydia Cao
PhD Student
Faculty of Education
University of Cambridge



Teacher Consent Form

**Mixed Reality Simulation: A New Method to Develop Science Teachers' Contingent
Responsiveness in Leading a Science Discussion**

I, the undersigned, have read and understood the participant information sheet above about the study and have had the opportunity to ask questions and get satisfactory answers about the study. I understand that I have the right to withdraw from the study without any consequences at any point of the research. I also understand who will have access to the information provided and what will happen to the data at the end of the study. I am aware that this study has been reviewed by and received ethics clearance through the University of Cambridge Faculty of Education Research Ethics Committee. If need be, I can find out more about this research study by contacting the researcher [Email address redacted], or her supervisor at the department Prof Sara Hennessy [Email address redacted], or Prof Rupert Wegerif [Email address redacted].

Fully informed of my rights, I agree to participate in the study, carried out by Lydia Cao, a full-time PhD student at the Faculty of Education, University of Cambridge.

Name : _____

Signature: _____

Date: _____

----- For Researcher's Use Only-----

Name of researcher: _____

Signature: _____

Date: _____



Information for Teacher Educators

Research Project

Mixed Reality Simulation: A New Method to Science Teachers' Contingent Responsiveness in Leading a Science Discussion

My name is Lydia Cao. I am a research student in the Faculty of Education, University of Cambridge. I cordially invite you to be part of this collaborative research, which will ultimately produce a locally viable and sustainable teacher professional development (TPD) program at your school. The TPD co-designed with you at your school will eventually serve as a prototype to be scaled in other institutions and/or countries. Your participation not only will benefit your students and your school, but also will make an impactful contribution to teacher education. At the end of the project, I will provide a briefing report for you and your colleagues that summarises the findings across all participants.

Purpose of the research

This research aims to develop a simulation-based TPD using the Mursion simulator (<https://www.mursion.com/>), where science teachers can learn to interpret and respond to student ideas on the fly (see Figure 1). Another aim of this study is to gain an understanding of how science teachers develop this capacity in a simulated classroom.

Photo of a teacher interacting with avatar students in front of a TV screen removed for copyright reasons. Copyright holder is Anthony Rimel, Western Oregon University

Figure 1 A science teacher interacting with virtual students¹⁴

¹⁴ <https://wou.edu/education/highlights/mursion-lab-gives-students-opportunity-to-train-in-virtual-classroom/>

This study is collaborative in nature, aiming to meet the learning needs of your teachers, fit your school context and the demands of your curriculum. Your ground-level instincts and craft wisdom are highly valued, and you will play an active role as a co-designer in collaboration with researchers from the University of Cambridge. This is an opportunity to design a TPD that is viable and sustainable at your school.

Research Process

This TPD will undergo two iterative cycles to improve the design. Each cycle is comprised of three steps. You will be involved in the design process and implementation (see Figure 2, in green). Together, you, the simulation specialist and the researcher will refine the initial design principles, co-design the TPD sessions, and co-write simulation scenarios through virtual meetings. You have the option to participate in one cycle or both cycles.

Each iteration involves:

- 1-4 design meetings (1h/meeting) (depending on the cycle, the number of meetings will vary but will not exceed 4 meetings/cycle)
- TPD orientation (1h)
- 4 TPD sessions (1h30min/session)

The number of hours involved in this project is about 14h/cycle.

After each iteration, you will collaborate with the researcher and the simulation specialist to improve the design according to the findings of the formative evaluation. After two cycles, the design will be finalized.

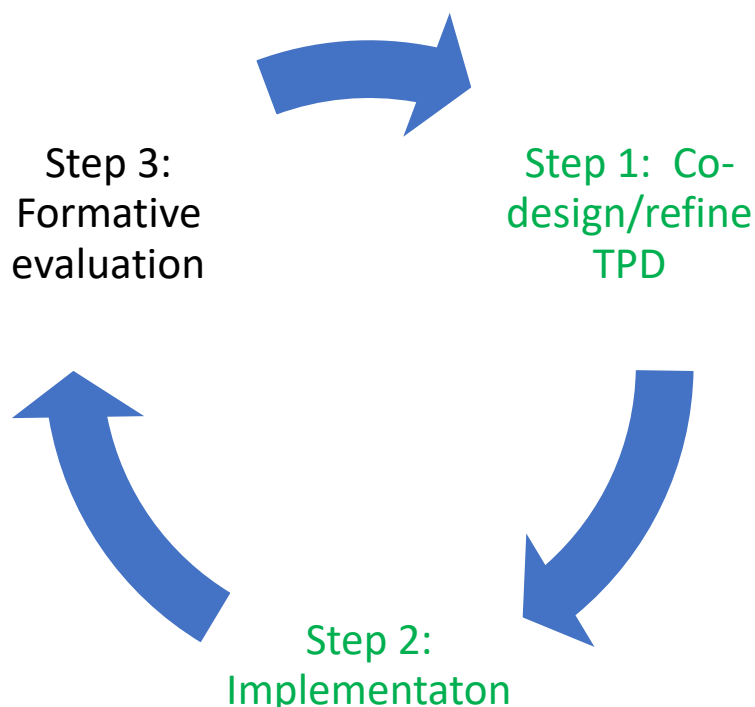


Figure 2 this process will undergo three iterative cycles before finalizing the design

During TPD sessions, you will model dialogic teaching and facilitate discussions to help your teachers to unpack the simulated scenario, to unearth the underlying pedagogical reasoning, and to evaluate and reconsider their instructional decisions. You and the researcher will create a facilitation guide to support you when leading a discussion with your teachers.

Safety and Privacy

This research will be conducted in accordance with the ethical guidelines of the British Educational Research Association [BERA] <http://bit.ly/BERAethics2018> and guidelines of Edopia School. To ensure your safety, this study will be conducted remotely through zoom meetings. With your permission, the simulations, zoom meetings will be recorded. The video recordings of TPD sessions are used to observe interaction among the participants to understand how learning takes place during the TPD.

Video recordings will be downloaded from zoom cloud to be securely stored in OneDrive of the University of Cambridge for 5 years before being permanently deleted. Access to video recordings is limited to myself and my two supervisors. The video recordings will be immediately deleted from zoom permanently after download. Participants will be anonymized when reporting the results (unless you prefer to be named) and your participation in this study is voluntary. You are free to withdraw your participation at any time and without giving a reason. After withdrawal, all data related to you would be destroyed unless it has been collected in a group setting.

With your permission, I will use the recordings and the transcripts only for training and research purposes, and subsequent publications/presentations, and you will remain anonymized. Only anonymized screenshots and videos will be used, which means the images of you will not be visible.

The result of this research will be summarised and shared with you in the format of a brief report. The full thesis will be accessible through the Cambridge online archive <https://www.repository.cam.ac.uk>.

If you have any further questions, please feel free to contact me at [Email address redacted] or my supervisors, Dr Sara Hennessy [Email address redacted] or Prof Rupert Wegerif [Email address redacted]. If you would like to participate, please sign the consent form in the next page and return it to me at [Email address redacted].

Thank you for your time and attention. Your contribution is invaluable for this research and teacher education.

Yours sincerely,

Lydia Cao
PhD Student
Faculty of Education
University of Cambridge

Teacher Educator Consent Form

**Mixed Reality Simulation: A New Method to Science Teachers' Contingent Responsiveness in
Leading a Science Discussion**

I, the undersigned, have read and understood the participant information sheet above about the study and have had the opportunity to ask questions and get satisfactory answers about the study. I understand that I have the right to withdraw from the study without any consequences at any point of the research. I also understand who will have access to the information provided and what will happen to the data at the end of the study. I am aware that this study has been reviewed by and received ethics clearance through the University of Cambridge Faculty of Education Research Ethics Committee. If need be, I can find out more about this research study by contacting the researcher [Email address redacted], or her supervisor at the department Prof Sara Hennessy [Email address redacted], or Prof Rupert Wegerif [Email address redacted].

Fully informed of my rights, I agree to participate in the study, carried out by Lydia Cao, a full-time PhD student at the Faculty of Education, University of Cambridge.

Name : _____

Signature: _____

Date: _____

----- For Researcher's Use Only -----

Name of researcher: _____

Signature: _____

Date: _____

Appendix 2: Coding scheme for dialogic functions

Coding scheme for dialogic functions				
Dialogic function	Definition	Example moves	Example utterance	Notes
Initiate	Teachers initiated a new thread of discussion/ideas.	Teachers asking open/close-ended questions to students.	What are the three types of rocks? What do you think happened to the ships in the field?	Only code "initiate" if teachers start a new thread of discussion/ideas. If teachers asked a question that is contingent to students' response (e.g., follow-up questions), code either as widen, deepen, maintain, or shape. If teachers started a monologue to initiate a new thread of discussion, it is also considered initiate. In other words, initiate does not necessarily have to be a question.
Feedback	Teachers provide feedback on students' response.	Evaluate the correctness of the response; Provide appraisal type of feedback "well done, good job, not quite". Provide the teacher's answer/interpretation.	Well done, that's correct. That's a good idea. They want to do something more creative. That's, that's fair enough. That's a good answer. So I personally thought that maybe they want to use all these tiny pieces of rock because maybe they'd get thrown away otherwise, you know, so instead of wasting a material, they thought that we use that to make something beautiful. Yes. Excellent. Everything in land, air and water makes up our environment.	
Widen	Increase degree of different perspectives in dialogue	Invite students to elaborate/say more about their ideas. Invite multiple students to add more perspectives. Invite students to build on each other's ideas. Invite students to ask questions. Follow up on student ideas/ questions. Acknowledge multiple ways of thinking and conceptualization.	Can you say more about what you mean by global warming, Jasmine? Anyone would like to add on to what Ethan just said? What do you mean by global warming, Jasmine? Who would like to build on to what Dev's idea? That is an interesting idea, Ethan. What do you guys think?	1. Invite a different student to answer the same question is coded as widening. 2. The difference between widening and deepening is that widening increases the degree of differences, not the degree of reflection. So if teachers were asking different questions regarding the same topic that requires the same level of reflection (such as describing), it should be coded as widening. For example: Teacher: Why did we go to the lake? Student: To see trash Teacher: Who throws trash? Student: People Both questions require students to describe what they observe, which did not increase their degree of reflection (no reasoning required). Therefore, the second turn of the teacher should be coded as widening.

Deepen	Increase the degree of reflection in dialogue	<p>Encourage students to move surface observation to the underlying reasoning/structure.</p> <p>Ask students to explain the reasoning/provide evidence for their ideas.</p> <p>Ask students to examine their ontological, epistemological assumptions, and the underpinning model of causality etc.</p> <p>Challenge student ideas by highlighting evidence and/or reasoning, a different conceptualization, and mental model;</p> <p>Challenge student observation and assumption.</p>	<ol style="list-style-type: none"> 1. Why do you think that all of the water evaporated? How is it possible? 2. What is the evidence of evaporation here? 3. How do you know that it happened? 4. You said the drum is vibrating, what is vibrating in the drum? 	<p>Many deepening intentions are signalled by "how" and "why" questions. It is important to note that "what" question could also be "deepening".</p> <p>For example, students were saying that sound is made from vibration. The teacher asked students what is vibrating in this case, which is considered "deepening" as it requires students to increase their degree of reflection to figure out what part of the drum is vibrating as it was not obvious student what is actually vibrating in a drum.</p>
--------	---	---	--	---

Maintain	Signal the ongoing nature of dialogue/Keeping the dialogic space open.	<p>Give students time to think about their responses.</p> <p>Restating the question.</p> <p>Revoicing children's ideas and. broadcast it to the whole class.</p> <p>Summarize what has been said and signal the continuation of the dialogue.</p> <p>Encourage students to reflect on what they have learned and what questions they still have (What I learned, what I still wonder about).</p> <p>Make plans with students about the next step of inquiry.</p> <p>Juxtaposing ideas and holding ideas together in tension.</p>	<p>[in the middle of the discussion] So, from your research, it is clear that it is not just one reason which is making the Aral Sea dry up, and there are multiple reasons one is evaporation. The other one is the diversion of water for the plants. And then there is another one, the global warming. We are still I'm not sure about global warming. Jasmine thinks that, you know, the temperature rises. And that's why the water, you know, expedites the evaporation of water. But then Dev has another opinion that you know, it just increases the temperature by one degree or one. Just one degree. So yes. So Savannah, anything else? Anything that will help us, you know, know more about this?</p> <p>[in the middle of the discussion] Ava made a very interesting point. She said global warming is supposed to be 'global', but her lake didn't dry up, so the reason can't be global warming. What do you guys think? (If called a specific student, then code both maintain and widen)</p> <p>[in the end of the discussion] Okay, so you guys have four theories. So far, you think they might have been evaporated or absorbed, there was a low tide or there might have been global warming. So how about you find out some more about it and see what exactly happened? As we move on to next classes? How does that sound?</p>	<p>Maintaining a dialogic space might look different depending on the context. For example, at the beginning of an inquiry, maintaining could look like noting down different ideas in a shared space and making plans to further investigation. In the middle of a discussion, maintaining might look like juxtaposing different ideas in tension. At the end of a discussion, maintaining could be summarising what has been talked about and making plans about the next steps. Towards the end of a unit, maintaining could be asking students what they have learned and what questions they still have.</p> <p>"Maintain" differs from widening and deepening in a way since it has no specific direction rather it signals the continuation of the dialogue. The teacher was trying to keep the dialogic space open, such as revoicing children's ideas and then broadcasting them to the whole class. If the teacher called upon a specific student after revoicing, then it is coded as both maintaining and widening.</p>
----------	--	--	--	---

Shape	Make visible the expectations and ground rules of the particular kind of dialogue.	Remind students of rules of engagement (e. g., respecting each other; taking turns to speak; listening to each other). Make visible the kind of talk that is used in the discipline and how to participate (e.g., rules of argumentation, scientific inquiry); Reflect with students on how classroom norms are being enacted in classroom discourse.	<ol style="list-style-type: none"> 1. I want you guys to hear each other's answers today. Alright, and we're going to be focusing on figuring out if it changes our own understanding a little bit or not. Alright. So before I tell you guys, your first task, I want you guys to remember that. It's really important to listen very carefully to your peers. 2. One by one Ethan. 3. Remember argumentation is not about winning; it is about evaluating the merits and weaknesses of the argument. 4. In what ways do you think our discussion went well today? 	
-------	--	--	---	--

Appendix 3: A coded transcript (dialogic functions)

Line	Conversation	Speaker	Utterance	Initiate	Feedback	Widen	Deepen	Maintain	Shape
1	Minahil_Post-PD	Minahil	Okay so who is going to tell me what are we discussing these days?	0	0	0	0	0	0
2	Minahil_Post-PD	Students	Environments!	0	0	0	0	0	0
3	Minahil_Post-PD	Minahil	One by one, yes Maham?	0	0	1	0	0	0
4	Minahil_Post-PD	Maham	Environment, and the other day when we first started environment, there were ice sculptures.	0	0	0	0	0	0
5	Minahil_Post-PD	Minahil	Yes. Before environment, we were doing ice sculpture. Yes, Faria?	0	0	1	0	0	0
6	Minahil_Post-PD	Faria	It was not ice sculpture. it was waster sculptures.	0	0	0	0	0	0
7	Minahil_Post-PD	Minahil	Yes it was water sculptures. But what are we talking.. what are we discussing?	0	0	0	0	1	0
8	Minahil_Post-PD	Unidentifiable	Environment	0	0	0	0	0	0
9	Minahil_Post-PD	Faria	Environment is everything all around us.	0	0	0	0	0	0
10	Minahil_Post-PD	Minahil	Environment is everything around us. Yes Maham. Can you put down your mask for a while so that we can hear you properly?	0	0	0	0	0	0
11	Minahil_Post-PD	Maham	The sky, the birds, the trees, the mountains, these are the environment.	0	0	0	0	0	0
12	Minahil_Post-PD	Minahil	Yes. Maham is saying the sky, the birds, the mountain, everything is a part of our environment. [even the cloud]	0	0	0	0	1	0
13	Minahil_Post-PD	Maham	Environment is air land and water.	0	0	0	0	0	0
14	Minahil_Post-PD	Minahil	Yes. Maham is saying that environment is air land and water. Yes. You want to say something Faria?	0	0	1	0	1	0

15	Minahil_Post-PD	Faria	On our first day of environment, we play the game see think and wonder.	0	0	0	0	0	0
16	Minahil_Post-PD	Minahil	And for that we play the game, see think and wonder. Okay, can you focus here Kashif? Can you listen to the teacher? Okay, so for to know more about environment we did an activity called see think wonder. Who will tell me what did we do yesterday? Where did we go yesterday?	0	0	0	0	0	0
17	Minahil_Post-PD	Kashif	To the trash place.	0	0	0	0	0	0
18	Minahil_Post-PD	Faria	To the Ravel lake.	0	0	0	0	0	0
19	Minahil_Post-PD	Minahil	To Ravel lake. Yes Maha?	0	1	1	0	0	0
20	Minahil_Post-PD	Maha	Environment is everything.	0	0	0	0	0	0
21	Minahil_Post-PD	Minahil	Environment means everything Yes. So where did we go yesterday Faria?	0	0	0	0	1	0
22	Minahil_Post-PD	Faria	Ravel lake.	0	0	0	0	0	0
23	Minahil_Post-PD	Minahil	Why did we go to the Ravel lake?	0	0	0	1	0	0
24	Minahil_Post-PD	Faria	To spot the trash.	0	0	0	0	0	0
25	Minahil_Post-PD	Minahil	Yes Maham?	0	0	1	0	0	0
26	Minahil_Post-PD	Maham	We went there because... to see trash and see what it smells out of ...and see how much people are littering.	0	0	0	0	0	0

27	Minahil_Post-PD	Minahil	Yes, what did you think Ahmed also went with us. Ahmed can you stop playing with this sharpener? Ok, you can play with it. Can you participate? Thank you. Ahmed, why did we go to our lake yesterday?	0	0	1	0	0	0
28	Minahil_Post-PD	Ahmed	To find trash.	0	0	0	0	0	0
29	Minahil_Post-PD	Minahil	To find trash. So Maham is saying we went around the Ravel lake to find trash and to see why people are throwing trash in the in our environment.	0	0	0	0	1	0

30	Minahil_Post-PD	Maha	[inaudible]	0	0	0	0	0	0
31	Minahil_Post-PD	Maham	This is not our environment. It is everybody's environment. Allah created it.	0	0	0	0	0	0
32	Minahil_Post-PD	Minahil	Yes, Allah has created this environment, and it is everybody's environment. Laraib what did we find in the in the rain or near Ravel lake? What did you see?	0	0	1	0	0	0
33	Minahil_Post-PD	Laraib	Trash.	0	0	0	0	0	0
34	Minahil_Post-PD	Minahil	Trash. who threw the trash in the Ravel lake?	0	0	1	0	0	0
35	Minahil_Post-PD	Laraib	People!	0	0	0	0	0	0
36	Minahil_Post-PD	Minahil	So why do people trash in the Ravel lake? Yes Maha what do you think?	0	0	0	1	0	0
37	Minahil_Post-PD	Maha	[inaudible]. With people throwing trash everywhere, Allah will be sad.	0	0	0	0	0	0
38	Minahil_Post-PD	Minahil	Yes Exactly. We should take care of the environment. What do you think Maham?	0	0	1	0	1	0
39	Minahil_Post-PD	Maham	Exactly. I think because those people ...I said... people are throwing trash because they do not have education. they do not have proper school.	0	0	0	0	0	0
40	Minahil_Post-PD	Minahil	Yes. So one of the reason that people are throwing this trash is that they don't have education. hmm, Maham can you explain this a little further. What do you mean when people don't have education, they throw trash on the ground?	0	0	1	0	0	0
41	Minahil_Post-PD	Maham	I mean, like... [inaudible] does not have education. When that happens, if you do not know what you have to do, and you don't what to do. That' why.	0	0	0	0	0	0
42	Minahil_Post-PD	Minahil	Okay. So I asked you all that why are people throwing trash on the grounds. So Maham is saying that those people do not have education. What do you think Faria? Is it something related to education like people throw the garbage on the on the floor and here and there is that does this have something related to education when people are not educated? Do they throw trash here and there.	0	0	0	0	1	0
43	Minahil_Post-PD	Faria	I don't know what education means.	0	0	0	0	0	0

44	Minahil_Post-PD	Minahil	Okay, like when they do not go to school. Does anyone want to add something to it? Okay, I'll rephrase my question. When we...Yes	0	0	1	0	0	0
45	Minahil_Post-PD	Maham	I was not there, that's why I don't know	0	0	0	0	0	0

46	Minahil_Post-PD	Minahil	Yes, you weren't there. I have taken a few pictures and I'm going to show you. But guys let's... we have come up with a with an interesting point from Maham. Maham is saying that when people do not have education, they throw trash on the ground like education means when people do not study when they do not go to school, they throw trash in the ground. Who agrees to it? okay, why why do they do it?	0	0	0	0	1	0
47	Minahil_Post-PD	Maham	Because they throw trash everywhere. Why do they throw trash everywhere? Don't they know that it's bad? Everybody keeps doing that, and Allah will get sad. People with education, they pick up the trash, they don't throw the trash.	0	0	0	0	0	0
48	Minahil_Post-PD	Laraib	Who are these people?	0	0	0	0	0	0
49	Minahil_Post-PD	Minahil	Who are these people? These are all your class friends see? Actually this is level B. I've also taken the level b to Ravel lake to see what is happening around the lake and you know people are throwing trash Yes, Maham. Do you want to add something to your point?	0	0	1	0	0	0
50	Minahil_Post-PD	Maham	Why do they not know...[inaudible]?	0	0	0	0	0	0
51	Minahil_Post-PD	Minahil	Maham is saying that when they do not have enough money they don't go to school so they don't learn. So can we learn this without going to school?	0	0	0	1	0	0
52	Minahil_Post-PD	Students	No.	0	0	0	0	0	0
53	Minahil_Post-PD	Minahil	That we shouldn't throw trash around us and we should put it in the garbage bin?	0	0	0	0	1	0
54	Minahil_Post-PD	Maham	I know, we can...People can tell us.	0	0	0	0	0	0
55	Minahil_Post-PD	Minahil	People can tell a person...Exactly. Our mom tell us if we don't go to school. Before we start going to school, who tell us that we should not throw trash on the floor and we should put it in the bin?	0	1	0	0	1	0

56	Minahil_Post-PD	Maham	Our mom, dad, grandma, grandpa, uncle, auntie...	0	0	0	0	0	0
57	Minahil_Post-PD	Minahil	Exactly. Maham is saying that even if you don't go to school there are people around us who tell us that we should not throw trash here and there and gather we should put them in the garbage bin like our parents. Even before we go to school. Our parents tell us you should not throw trash here and there. Yes. Do you want to add something to this conversation?	0	1	1	0	0	0
58	Minahil_Post-PD	Ahmed	...maybe everyone throw trash [inaudible].	0	0	0	0	0	0
59	Minahil_Post-PD	Maham	All of us in school right? A few minutes, I just pulled out the snack out of my bag. Did I litter? you learn from school and you pay attention! You don't disturb a person when doing work or see anything.	0	0	0	0	0	0
60	Minahil_Post-PD	Maham	Actually if we litter, Allah would not like us. If we would litter, the police officer will come. Allah will put something in their mind, someone is throwing trash.	0	0	0	0	0	0
61	Minahil_Post-PD	Minahil	Exactly. So actually Allah like cleanliness so we should not litter. okay so instead of ...can you sit on your seat and focus? so what should we do? one thing that you all say that we should put the trash in the bin. Okay what else can we do with the trash? Yes one by one. Yes, Faria.	0	1	0	1	0	0
62	Minahil_Post-PD	Faria	If you are in a place it does not have bin, you can keep it in your hand and put it in the bin when you go back to school or in your house.	0	0	0	0	0	0
63	Minahil_Post-PD	Minahil	Faria is saying when there is no dust bin around, you can just keep it in the bag and take and take into your school and put it in the trash can later.	0	0	0	0	1	0
64	Minahil_Post-PD	Maham	You don't have to just put them in the trash, you can keep that, you can make something out of it. Even like I give you pringle boxes and I want to make something out of it.	0	0	0	0	0	0
65	Minahil_Post-PD	Minahil	Okay, we have one more point. Maham is saying even if we don't put the trash. Wait Maham, I will come to you. Maham is saying that instead of putting the trash in the bin, we can make something useful out of it. How can we? So Maham give me two pringle boxes that day and she said... sorry you cannot come in here; we are having a class. Okay, Maham gave me to Pringle boxes and she said that we are going to reuse it we are going to make something something creative out of it, we're going to make something else out of it when we are going to have our hands on project. Yes, Maham.	0	0	1	0	1	0

66	Minahil_Post-PD	Maham	Exactly also, I like Faria said, throw it into the dustbin. What if there is too much, you shouldn't say recycling and making any useful things.	0	0	0	0	0	0
67	Minahil_Post-PD	Minahil	Do you think we can use the trash some other ways?	0	0	0	1	0	0
68	Minahil_Post-PD	Minahil	Oh okay Nouman, how can we use something useful how can we make something useful out of the trash?	0	0	0	1	0	0
69	Minahil_Post-PD	Nouman	boxes, something else...	0	0	0	0	0	0
70	Minahil_Post-PD	Minahil	Okay, so we can use something else out of it. Okay, instead of, ok Maham?	0	0	1	0	0	0
71	Minahil_Post-PD	Maham	I want to say whenever the garbage gets full, before it gets more full, you have to throw it in another trash can, you have to throw it into trash can, other people will take it to resource places and make something out of it. These cups were made out of trash.	0	0	0	0	0	0
72	Minahil_Post-PD	Faria	Once I made an organizer out of cardboard.	0	0	0	0	0	0
73	Minahil_Post-PD	Minahil	That we were supposed to throw? the useless stuff? Actually that's a very good idea. We can use make a resource organizer with cardboard. So Faria was actually saying, that before we throw anything we should be careful that you know we can pick up the stuff which is which we can reuse You can reuse it or or...	0	0	0	0	1	0
74	Minahil_Post-PD	Maham	Before it gets full, just throw it away, so other people...	0	0	0	0	0	0
75	Minahil_Post-PD	Minahil	Other people means noticing that the other people like the people who picks up the... you know, they pick up the important stuff from the garbage the garbage box and they take it to the recycling factories and they make useful stuff out of it. Exactly, that's what we should do. Maham?	0	1	1	0	0	0
76	Minahil_Post-PD	Maham	All of these stuff I heard... these cups. I think we can recycle and make decorations. If there is anything trash in the project room, I've already made things, like this. .	0	0	0	0	0	0
77	Minahil_Post-PD	Maham	Like we can make ... out of trash. Like we also made that big water sculpture we're going to make even more of them and hang it outside. it is going to be so cool, but we didn't... we use trash paper to make that thing.	0	0	0	0	0	0

78	Minahil_Post-PD	Minahil	So, we use this useless plastic to make a water sculpture in our previous project. So, all of you are actually saying that instead, first of all, we should not throw the trash on the floor, we should get we should be educated about it that we should not throw trash here and there, we should put it in the garbage bin. Secondly, we should try to make something useful out of it that we can use stuff that we most of the stuff that we throw in like dustbin can be reused or maybe we can give it to the recycling companies so that they can make something useful out of it. Is this correct?	0	0	0	0	1	0
79	Minahil_Post-PD	Students	Yeah.	0	0	0	0	0	0
80	Minahil_Post-PD	Minahil	Okay. So, thank you so much class for this useful discussion. Now we are going to write we are going to actually draw on our copies whatever we have done so far. All right. So we are going to draw on your notebook. You are going to draw whatever you saw in your previous class. Yes, but first. Yes.	0	0	0	0	0	0
81	Minahil_Post-PD	Maham	Can I help you?	0	0	0	0	0	0
82	Minahil_Post-PD	Minahil	Oh yeah, you want to say something else? wait, we are going to draw now.	0	0	0	0	0	0

Appendix 4: Attention coding framework

Codes	Definition	Examples
Climate	Observations related to student behaviours, classroom management, engagement, classroom rules.	Students were paying attention and they looked bored.
Pedagogy	Observations related to pedagogy and teaching strategies.	I teach grade 1, and I find content on rocks is difficult, so I tried to make the lesson simple and age-appropriate for my students.
Student Characteristics	Observations on students' characteristics and personalities.	James is a very bright student and he has a lot of knowledge.
Student Science ideas	Observations on the student ideas, thinking, and reasoning about science, which has some empirical and theoretical evidence.	Ethan made a connection between the science experiment that the water disappeared after 17 days to their question about the ships in the field.
Student Lived Experience	Students' lived experience, stories, and ideas.	I think evaporation is like water disappearing. You know, when you leave the dishes out to dry, the water disappears the next day.
Classroom Equity	Observations related to provide equitable opportunities for students to engage in sense-making and positioning students as competent sense-makers	I want to make sure everyone gets a chance to talk about their ideas.

Appendix 5: Interpretation coding framework

Codes	Definition	Examples
KS (Knowledge about students)	Interpretation of the noticing based on what teachers know about the student(s), such as their personalities and characters; student prior knowledge, including where they might have gotten a certain idea; the class dynamics and typical student behaviours.	The students were talking about recycling because we saw a video on recycling in the previous lesson. This girl is new to the school, and that's why she is very shy and not participating. Students really sit with their friends, which could be distracting for them.
CK (Content Knowledge)	Interpretation of the situation based on teachers' knowledge about the subject.	You know, science is about logic, and students are mixing up their learning in the religion class with science
PK (Pedagogical Knowledge)	Interpretation of the situation based on general pedagogical principles.	Children have to make a personal connection with the topic in order to understand the materials better, so I tried to help them to make the connection with their own life. I want to make sure the lesson is age-appropriate for the children, so I decided to skip this part/
PCK (Pedagogical Content Knowledge)	Interpretation of the situation based on teachers' knowledge about how to teach a subject (not just knowing the content of the subject). Examples of PCK include: regularly taught topics in one's subject area, the most useful forms of representation of the concepts in a subject area, the most powerful analogies, illustrations, examples, explanations, and demonstrations; typical misconceptions; how to represent the content in a way that is comprehensible for novice; what makes the subject easy and difficult.	Students usually have a lot of misconceptions about global warming, so I have to address it. I tried to use the example of a vibrating phone to illustrate the connection between sound and vibration.

Appendix 6: A coded transcript (attention and interpretation)

Conversation	Topic	Speaker	Utterance	Climate	Pedagogy	Characteristics	Equity	Science	Lived Experience	KS	CK	PK	PCK
Minahil_PostPD_Interview	Moment 1	Minahil	I want to tell you one one interesting thing. So you know when we ask our children this question that why is a particular thing like that? Most of our children, you know, answer us because Allah made it like that that is their ultimate answer. So and when they don't know the...you know, the technical answer to a question or the logical answer to the question there you know, that's the end of everything that they say Allah made it No, God made this so then there's no further discussion on it. So you know, this this keeps happening in our class a lot and then you know, we cannot say that No, I mean, of course Allah made everything but we want we want a solid logical answer. it's really sometimes difficult for it because they're taking this course Islamic. They take their you know, we teach our religion Islam, it's a part of, you know, their, their academics. So of course that teacher is focusing totally on that and it is	0	0	0	0	0	1	0	1	0	0

			impacting the of course the children in a way in a different way and we are teaching them logic and science so what they really mix that up											
Minahil_PostPD_Interview	Moment 1	Minahil	Yeah, for me, like as a mother, I have always told my children that you know, I am my new teacher, I started working just a year ago with little children. I previously used to teach to the older children my own subject that I have studied. But this is my first experience with a little children. So when my children were that age, I always tried to connect everything with science, like I always told them that there is nothing is illogical in this world. You know, of course, I introduced Allah them and God and you know, everything is created by him, but I always told him that there is always there is a science behind everything, like nothing is without purpose, or Allah just did everything like that. So I try to incorporate that here in my classes. But this was my way of parenting my children.	0	0	0	0	0	0	0	0	0	0	0

Minahil_PostPD_Interview	Moment 2	Minahil	Yeah, I told you that you know, this table...I told you that she [a student] has some issue in talking and they're having a therapy at home as well like they have therapists so if it's a little difficult to understand her sometimes and it is difficult for her to keep up the pace with the with the other students. So since we did that in our simulation class that you know, we have to keep all the children on the same pace and you know, we have to include them the concept you know, involving all the children in the discussion, so when I answer that what she understands that why we went to the lake for. I asked her why are people throwing trash in there our lake. She said that, you know, people throw trash in the Ravel lake, and Allah will be sad. So, you know, she gave her answer according to her	0	0	1	1	0	1	1	0	1	0
--------------------------	-------------	---------	--	---	---	---	---	---	---	---	---	---	---

Minahil_PostPD_Interview	Moment 3	Minahil	I want to talk a little about answer. Yeah. But we got some further and then we had a little discussion over it. But before I think we move forward, this was the time [as we talk about] why people throw trash in the end again, what this girl Yumna said because they don't have education. So I was a little shocked sort of the answer. Because she, she's so small, and she related it to the education that says people you know, in our country, a lot of people are not educated. So they don't know that it's not good to throw trash. So here I just this during the class, this just clicked into my mind the scenario that we discussed in our, in our workshop, one of our workshop with you that the teacher was asking the children that why do we Why do plants need to grow, and the children were saying sunlight and soil and all the important things that plants need to grow, but one of the child said that plant needs earthworms grow. Now, that just clicked to my mind in particular time. Because personally, I would say that, you know, education doesn't have anything to do with these things, you know, we don't have to throw trash. I mean, if	0	1	0	0	1	1	0	0	1	0
--------------------------	-------------	---------	---	---	---	---	---	---	---	---	---	---	---

		<p>you're educated or not, you don't have to throw trash. But she said that, and it just clicked in my mind that I think I should talk a little more about it. And then I should, you know, give them my point of view that how Alright, people throws trash because they're not educated, but you know, this is something, these are the basic things that we know, since we are very small, even before we get education, and we further the... you know, talked about it and other children. And also I think, okay, you will see, but I also realised later, when I watched my video, that although I tried to widen the sensemaking space at one place, saying that, you know, I didn't just ignore her this point of view. I tried to widen that, but then I later realised that I also funnelled my discussion, in a certain direction telling them that see, no, it really doesn't have to do anything with education that you will find later in my discussion. So these two points, although I tried to be really on point and try to maintain and widen in the sense making space, but then I realised that Oh, I also made a mistake that I just funnelled the answer in a certain direction.</p>											
--	--	---	--	--	--	--	--	--	--	--	--	--	--

			I personally feel that, you know, in the science classes, before, I was not aware of all these terms, the talk moves and the sense making space and you know, I realised I, now I realised that mostly, the science teachers and all the teachers, they try to, you know, especially in our school, because in other schools, they have a curriculum, they have a set curriculum, they have books they have external, they teach the text, and then they get the answers from the, then on, then the teachers make them write the answers on the notebooks, and that that's what they have to reproduce in the exams, but in our school, you know, since we don't do this, but I personally feel that we do give them that we keep giving them directions, you know, according to what we want the final result to be, so this is what we actually do. So, but now, since we are after the workshops, and we are aware of these things, we try not to do that, but that is something natural that I think we do, like specially the science teachers that we want them to certain [direction].											
Minahil_PostPD_Interview	Moment 4	Minahil		0	1	0	0	0	0	0	0	0	1	0
			And again, one of the child talked about Allah once again in the during the discussion the girl in the you know, at the back of this of this girl Sybil she said that you know Allah they don't know Allah will be sad if this throw the trash so this is this is what we hear a lot. Also this girl in the yellow this was I think her second or third day so she was really shy and she had moved from back from America I think I America so that's why we were not pushing her too much to participate and I just wanted to [let you know].											
Minahil_PostPD_Interview	Moment 5	Minahil		0	0	1	1	0	1	1	0	0	0	0

Minahil_PostPD_Interview	Moment 7	Minahil	Now finally comes the point of reduce, reuse and recycle with you know, unplanned we talked about the education although my plan was to discuss more about Reduce Reuse Recycle but since the child was interested in knowing about education, you know, that's why we talked about it and finally we are talking about Reduce Reuse recycle and I'm asking them that you know if what should we do if you know when the trash so they're saying that you know we should put it in the dustbin and what will happen what if what if there is no dustbin around and they're saying that we can put it in our bags and we can throw it in the bin or school we can put it in the dustbin and since we have already we already covered the topic of Reduce Reuse recycle that's why they're saying that we can make something useful out of it just like I gave you the Pringle boxes she gave me you know she got the Pringle boxes those chips boxes and she told me that when we are doing our hands on project I will use it I you know I will reuse it for something I'll make something new.	0	0	0	0	1	1	1	0	0	0
Minahil_PostPD_Interview	Moment 8	Minahil	They are now you know talking about the like the theoretical part that we have already covered like we can reuse it again and instead of throwing in the trash when we can just you know save certain things that are useful and make something else out of it like that those plastic bowls which are made out of you know they have been re so they're talking about recycling that you know they can be taken to the recycling place and made something out of something else and then she pointed towards plastic cups they are made out of the recycling material	0	0	0	0	1	0	1	0	0	0
Minahil_PostPD_Interview	Moment 9	Minahil	One of the one of her own re you know experience of reusing stuff that I made a toy organiser with a cardboard box and then that's what that were you supposed to it was it's used useless and you were trying it and then you thought of reusing it.	0	0	0	0	0	1	0	0	0	0

Minahil_PostPD_Interview	Moment 10	Minahil	They're talking about their own experiences of recycling stuff and you know, the reusing stuff and recycling stuff that I have used this for recycling and that I reuse this thing? You know, to avoid throwing trash here and there.	0	0	0	0	0	1	0	0	0	0
Minahil_PostPD_Interview	Moment 11	Minahil	We have a table on the like, where I'm standing there is a table and we have made some boxes for the pencils to key events, baskets out of use us, you know use this basket we decorated baskets that we were supposed to throw and then we created them so that's what I think she's saying that, you know, you can give decorative items on it to make them useful and reuse them. Now they're just your own experiences get how they have decorated different stuff and how we can decorate different stuff or reuse and recycle, recycle, about recycling, introducing the concept of recycling was a little difficult to these children reuse and reduce. They understood, but they you know, it was still the end of the project, it was difficult for, for us to, you know, explain how things get recycled, because, you know, we did not have the resources to take them to a recycling company and show them how things get recycled, we tried our best to introduce that concept. So all they know is that they are taken, the stuff is taken to the recycling company, and then they recycle it. But, you know, in another class, they talked more about, you know, we can reuse our clothes, we can reuse our clothes by giving it to our younger siblings, and we can reduce buying toys. So these were the sort of answers that we kept getting.	0	0	0	0	0	1	1	0	0	0
Minahil_PostPD_Interview	Moment 12	Minahil	They are talking about the water sculpture now that we use that out of, you know, this plastic and paint.	0	0	0	0	0	1	0	0	0	0

Appendix 7: Avatar personalities

Removed for copyright reasons. Copyright holder is Mursion.

Simulation session 4

Background information:

Children worked in groups or individually to make a scientific explanation about the ships in the field.

Learning activities that students have complete so far:

- o Conducted the Mini-lake investigation
- o Read an article on the Aral sea
- o Learned about the Particle model through computer simulation and science theatre
- o Learned about in the scientific explanation, they need to include claim, evidence, and reasoning.

Children now know that “the field” used to be the large body of water body, the Aral sea. You asked children to think about the causes of the ships in the field and the process that led up to the drying up of the Aral sea over time. You also encouraged children to look beyond the visible things and explain the process underlying the drying up of the Aral Sea.

Teachers should make explicit that science argumentation is not about “winning” the argument, though you will try to persuade others with good evidence and reasoning. Science argumentation is about getting closer to the ‘truth’ through such exchange and dialogue.

A good scientist will be grateful for a good argument, which makes them realize the insufficiency of their explanatory models to build better ones.

Start REMEMBER TO PRESS RECORD

- Bennett introduction (set up the scene for the teachers) 1-2 minutes, interactive, getting teachers comfortable talking to avatars
 - o Hello, and welcome back to your final session in our virtual classroom! How are you doing today?
 - o As you may remember, my name is Bennett, and I am your host avatar and your guide. Today, you will participate in your last set of simulations.
 - o Let’s take a moment and recall some of what you learned in your most recent workshop with Lydia. Can you tell me what some of your takeaways were?
 - o Fantastic, thank you for that reflection on the workshop. The simulation sessions are follow-ups to your workshops, where you can put into practice what you learned, in a safe and controlled environment.
- Remind teachers the background of the simulation:
 - o Let me start by quickly reminding you the background of the simulation (SHOW SLIDE)
 - o You asked children to draw **evidence from multiple sources** of their learning experience and use **reasoning** to explain the causes that led up to the drying up of the Aral Sea over time. You encouraged children to **look beyond the visible things** and explain the **process underlying** the drying up of the Aral Sea.
 - o Children worked in groups or individually to make a scientific explanation about the ships in the field.

- You have seen three explanations from children in the simulation preparation package.
- Remind teachers the tasks:
 - Now, in today's simulation, your task is to lead an explanation discussion. During an explanation discussion, you will (NEXT SLIDE)
 - 1. Engage students in authentic science practice around using **evidence** and **reasoning** to support their **claims**.
 - 2. Facilitate children to consider the **merits** and **weaknesses** of each other's explanations.
 - 3. Use your professional judgement to decide when to **open, widen, deepen, maintain close, or shape** the sense-making space and use the corresponding **talk moves**.
 - 4. Help students to collectively **move their thinking forward**. (STOP SLIDE)
 - Remember explanation discussion is often intertwined with scientific argumentation. Science argumentation is not about "winning" the argument, rather the goal is to get closer to a more powerful explanatory model by examining each other's evidence and reasoning. Therefore, it is normal if children do not reach an agreement or a clear-cut conclusion. Don't worry if you cannot reach a conclusion by the end of the simulation, but make sure you wrap up the discussion to inform students of the next steps for them to push their thinking forward.
 - Today's simulation will take place in two parts.
 - 1) One teacher will serve as the lead teacher for the task first, with the other teacher serving as an assistant and observer
 - 2) After some reflection together, the second teacher will conduct the same task, integrating what they learned from watching the first teacher.
 - We will take a break between two rounds, for you to switch roles.
 - When you are the lead teacher, you should plan to do most of the teaching and interacting with the students. The assistant/observer, while you watch your colleague leading a discussion with the students, use the note catcher (link) to record your observations:
 - At which moment(s), do you think the teacher helped students move their thinking forward? At which moment(s), do you think she could have responded to students differently?
 -

Link to note catcher: (SEND LINK)
 [Link redacted for privacy purposes]

- Who would like to be the lead teacher for the first round? Great. I will have you switch roles in the break between parts 1 and 2.
- You will have 20 minutes to work with the students. A student will let you know when you have 2 minutes left to wrap up the discussion, and when time is up. Then I will meet you back here to reflect.
- If you feel the need, you can pause your simulation one time during your time in order to confer with your partner teacher for one minute. To utilize your one pause, just say “pause simulation” and then, when you are ready to begin again, say “start simulation”

- Do you have any questions?
- Let’s get started. Before we enter the classroom, I will now give you 2 minutes to get ready for the simulation together, and then the students will appear. That will be your cue to begin teaching. If you are ready before the 2 minutes are up, just say ‘Start Simulation.’

- Answer any questions
- Give teachers 2 minutes to prepare

Script starts:

1. Three scientific explanations of the ships in the field

Group 1: Ava and Savannah

Group 2: Dev

Group 3: Jasmine and Ethan

Teacher will call on someone to open up the floor to present their explanation models.

Ava/Savannah: the ships in the field were stranded there because there is no more water in the Aral Sea. We learned that the field was actually a lake called the Aral Sea. The water all dried up because people took away Aral sea’s water, which comes from the rivers.

When being asked to elaborate or to give evidence. (preferably that the teacher will the other person to have equitable participation) Either Ava or Savannah will continue:

Ava/Savannah: The evidence is in the Aral Sea article we read. It says that the two rivers, normally flow into the Aral Sea were diverted to water cotton crops. We compare the Aral Sea to the lake that Ava goes to every summer, the only difference is that water in Ava’s Lake is being protected, not taken away by people. Therefore, our conclusion is that the Aral Sea disappeared because people took its water.

Children will remain quiet after the explanation unless the teachers asked someone else to present or to consider the merits and weakness of the argument.

Dev: I think that The Aral Sea dried up because more water left the lake through evaporation than the water coming in. I agree with Ava and Savannah that people diverted

the rivers that go to the Aral sea, but the water inside the Aral Sea has to go somehow, which I think is through evaporation.

If being asked to elaborate or to give evidence and reasoning. Then the following lines.

Dev: We saw that in the mini-lake investigation that the water slowly evaporated from the mini-lake over time once we removed the lid of the container. Because water evaporated over time and the Aral Sea did not get filled up by the two rivers anymore. It dried up just like our mini lake.

Ethan/Jasmine: We think the Aral Sea dried up because of the diversion of the rivers, evaporation, and global warming.

When being asked to elaborate or to give evidence. (preferably that the teacher will the other person to have equitable participation) Either Ethan/Jasmine will continue:

Ethan/Jasmine: Our first reason is the same as everyone. The rivers that feed the Aral sea were cut off. I don't remember the names of the rivers. So there is less water, sometimes even no water goes inside the Aral sea. Our second reason is evaporation. The water in the lake becomes water vapour in the air, so we can't see it anymore. Our third reason is global warming. Because when it is warmer, there is more evaporation. Our evidence for this is that the weight of the water dropped more when there is a lamp. The lamp made the mini lake warmer.

2. Argumentation points:

1. Global warming:

Ava: Sorry to disagree with the global warming statement. I just don't think it is true. I mean global warming is supposed to impact everywhere, that's why it is called global warming. As you see, the lake that I go swimming in every summer does not disappear, so global warming cannot be a reason to make the Aral Sea disappear.

Dev: I also think global warming can't be a reason because I did some research that the average global temperature has risen by one degree. I don't think one degree would make that big difference.

Ethan: only one degree? I didn't know that. It always seems so much hotter though. You know the heatwave this summer. I haven't never been so hot in my life.

Jasmine: I mean the 1 degree is the average. Some places must be hotter than others. I know this from the news, there are so many droughts in the world.

Ava: Well, the news also says that global warming causes floods. I don't understand how there can be both drought and flood. I mean global warming is supposed to be hot and dry. So I don't think global warming is a cause for the Aral sea to dry up.

Ethan: Yeah, I now think global warming might not be a reason. Dev thought so. He is usually right.

Jasmine: But I am convinced that global warming has something to do with it. If asked to say more.

Jasmine: Because scientists think that global warming is real, and I have read that it made a lake in California dry up.

Teachers would ideally remind students that science needs good evidence and explanation by “structuring” the sense-making space

2. Rain and condensation

Savannah: I noticed that nobody has mentioned rain and condensation so far. I just realized that. In our mini lake, we saw water droplets on the lid. We said it is condensation...hmm..like when water vapour becomes water again. It is basically like rain. That's why it rains. Aren't the water evaporating the Aral sea supposed to rain back?

Ethan: But there are no more water droplets after we removed the lid. There is no more rain. The Aral sea is not inside a container.

Savannah: But then where did the water vapour go then? It has to go somewhere.

Ava: I agree with Savannah. The water vapour has to go somewhere. We saw that when it cannot escape with the lid on, it stays inside the container. So when we took the lid off, they must go inside the classroom or outside the window.

Dev: It makes sense. If the water just disappears, we will never have rain.

Jasmine: I think some of the water will rain back to the Aral sea, but maybe not all of them. Maybe wind blow them away and it will rain somewhere else.

Savannah: I read in a book that in the amazon forest, it is super hot. So water evaporates and then it almost rains back right away.

Ethan: the Aral sea region is not in the amazon rainforest though. It looks very dry, almost like a desert. Yes, in the reading, it says it is like a desert.

Dev: I think we should look this up. How much does it rain in the Aral sea? My guess is that it does not rain a lot, and as Jasmine said I think the evaporated water must have been carried away by wind or something.

3. Simple linear causality and relational causality

Dev: Well. I don't think that it was the evaporation that caused the lake to dry up. I don't think it is the cause. I think the cause is the imbalance between the water evaporated and the water that is coming back into the river.

If asked to say more:

Dev: All lakes evaporate, and they don't normally dry up. Just as Ava said. They don't dry up because they get water either through rain or from other rivers. So there is a balance there. When they lose more water than the water coming in, they will dry up. It is like if you keep spending money but not making money, you will go bankrupt.

Ava: We think the cause for the water to dry up are the people who cut the rivers flowing into the Aral sea.

Ethan: That's the obvious cause, but there are things we don't see that lead up to it. If there is no evaporation, even people cut the water, the water won't leave the Aral sea.

Savannah: ah I see. So we are talking about the invisible process behind it.

Ethan: yeah yeah! It is like if I ate something that makes me feel sick, the food is the visible cause, but there is an invisible process too. The bacteria interacted with my body in some ways that make me sick. Though I don't know how the invisible process work.

Ava: ah, that makes sense. I thought we were talking about the obvious cause.

Some argumentations can lead to a 'conclusion' (like the causal mechanism one). Some argument might lead to more research and learning.

Mid-point reflection with Bennett:

- Welcome back. How did that feel?
- Let's take a moment to reflect:
 - At which moment(s), do you think your response helped students move their thinking forward?
 - At which moment(s), do you think you could have responded to students differently?
- Let's have our observer share her reflection. What did you record in your note catcher?

Second Round:

It is now time to return to the classroom for the second teacher to complete the same task. At this time, you should switch roles, so that the lead teacher becomes the observer and vice versa.

You will have about 20 minutes to work with the students, and then I will meet you back here to reflect.

I will give you another 2 minutes to prepare, and then the students will appear. That will be your cue to begin teaching. If you are ready before the 2 minutes is up, just say 'Start simulation.' Afterwards, I will meet you back here to wrap up.

Closing Remarks:

- Welcome back. Let's briefly reflect on that second simulation. How do you feel?
 - At which moment(s), do you think your response helped students move their thinking forward?
 - At which moment(s), do you think you could have responded to students differently?
 - Let's have our observer share her reflection. What did you record in your note catcher?


- Thank you both for taking the time to join me in the virtual classroom today. I hope you enjoyed seeing our avatar students again.
- I am about to send you a link to a feedback survey in the Zoom chat. (SEND LINK)

[Link redacted for privacy purposes]

Can you please open that link now and take a moment to complete the survey as soon as you log out of the Zoom? Thank you, we really appreciate that.

- I really enjoyed working with you over the course of four simulations. I know the children feel the same. You have come a long way since the very first simulation. Very well done! Thank you for being so dedicated to improving your teaching. I hope you find the experience in the virtual classroom useful and will apply what you learned in your own class. I hope to work with you again in the future.

Appendix 9: Graphic organiser during the simulation

Name _____		Observer 	
	What did the teacher do/say?	Did the teacher open, widen, deepen, maintain or shut down the sense making space?	What feedback do you have for the teacher?
Moment 1			
Moment 2			
Moment 3			

Appendix 10: An example of guided collaborative inquiry

Task: Read the following transcript of class discussion in the three classrooms.

In your breakout room, discuss



Must haves	1) What differences do you notice in the three classrooms? For example, the teacher's teaching moves, questions the teacher asked, length of student talk, the quality of discussion and student learning etc.
Amazings	2) How do you relate what you noticed in the three teachers to your own teaching practice?

Time: 35 min

Discussion routine: Talk roles

Product: You will jot down notes of your discussion on the note catcher provided. The summariser of each small group will present to the whole group on the main takeaway of their discussion within 2 minutes.

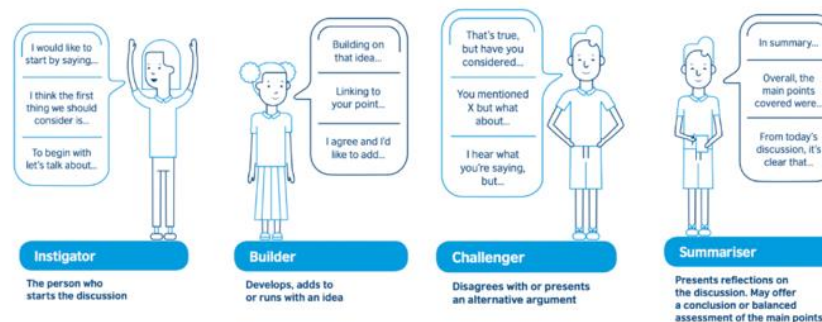


Image credit: It's good to talk – oracy lesson plan © British Council

Appendix 11: List of talk moves organised by dialogic functions

Talk moves organised by dialogic functions		
Dialogic intention	Productive talk moves	Example utterance
Widen	Say more: invite individual students to elaborate on their own contributions;	Can you say more about your theory on the how the tide brought the ship to the field?
	Build-on: invite students to build on each other's ideas.	Anyone has a different idea or wants to build on Ethan's idea?
Deepen	Pressing: invite students to provide evidence and reasoning.	Why do you think the salt is still there even though you can't see it?
	Challenge (counterargument): challenge student ideas by highlighting evidence and/or reasoning.	You think that water disappear during evaporation. Let's revisit what happened during the mini-lake investigation. Where did the water go when we have the lid on?
	Synthesise/Invite synthesis: Compares, evaluates, or resolves two or more contributions in a reasoned fashion; Combines different ideas and perspectives to produce new understanding. (One step further than summarize)	Let's compare what Ethan's idea and Jasmine's idea. How are they similar and different?
Maintain	Revoicing/invite revoicing : repeat/paraphrase to highlight or clarify student contribution/ encourage active listening by inviting students to explain what others mean.	- Let me paraphrase what you said. You are saying that the salt is still in the water because the weight of salt and water remained the same. If the salt truly disappears, the total weight should have gone down. Am I right? - Who can paraphrase Ethan's idea?
	Summarise/Invite Summary: summarizes and juxtapose different ideas that have been voiced - reiterate what have been said.	Let's summarize what hypotheses have been said about the ships in the field. Ethan thinks that a tide brought the ship to the field. Jasmine said that global warming made the lake dry up. Ava said global warming is not possible for lakes to dry up and she used the example of the lake she visits in the summer./ Who would like to summarize all of the ideas that have been said so far?
	Focus: remind students to focus on the main conceptual thread of the discussion. E.g., ask students how their ideas contribute to the discussion/solving the puzzlement.	That is an interesting comment, Ethan. Can you help us to understand how this connects to what we are trying to make sense of?
	Park ideas and make plans: When students reached a ceiling of sense-making (the discussion is not going anywhere as more research and learning need to take place), sum up the questions and make a plan for the next steps.	OK, it seems that we all have really good reasoning here. Let's do more research on this topic and come back to revisit this topic in the next class. It seems that we do not agree on what global warming is. Let's do some research on global warming. What do you think we need to research?
Shape	Rules of participation (ground rules): remind students of the ground rules they agreed on during a discussion. Metacognitively reflect/ work on ground rules of exploratory talk.	- Who can remind us what are the ground rules for discussion that we agreed upon in class? - Remember to challenge your classmates in a gentle and respectful manner. - What went well in our discussion today? what needs improvement?
	Practice of Science: making the epistemic practice of science explicit and remind students. Metacognitively reflect on the epistemology of science.	-Remember, scientific argumentation is not about winning the argument, , but examining each other's arguments critically to get closer to build more powerful explanatory models. - In science, claims must be supported by evidence and reasoning. - How is knowledge produced in science?

Appendix 12: Talk moves coding scheme

Talk moves coding scheme		
talk moves categories	Definition	Example utterance
Open-ended Questions	Pose open-ended question with multiple entry points	What do you think happened to the ships in the field?
Uptake	Take up student inquiry	Okay, so that's an interesting point even what exactly is the connection between evaporation and condensation in this whole thing in the whole water disappearing from the sea?
Think Time	give students time and space to think before voicing their ideas in public.	Quiet think time, write down their thoughts, quick exchange with the partner.
Say more (elaborate)	invite individual students to elaborate on their own contributions;	Can you say more about your theory on the how the tide brought the ship to the field?
Add-on/Build-on	invite students to add multiple perspectives to a given question; invite students to build on each other's ideas. including invitations to agree/disagree	What do you think about this question, Ava? Anyone has a different idea or wants to build on Ethan's idea? Anyone agrees or has a different idea than Jasmine?
Press	invite students to provide evidence and reasoning.	Why do you think the salt is still there even though you can't see it?
Challenge (Counterargument)	challenge student ideas by highlighting evidence and/or reasoning, a different conceptualization, mental model/consider alternative ideas	You think that water disappear during evaporation. Let's revisit what happened during the mini-lake investigation. Where did the water go when we have the lid on?
Synthesize/Invite synthesis	Compares, evaluates, or resolves two or more contributions in a reasoned fashion; Combine different ideas and perspectives to produce new understanding. (One step further than summarize)	Let's compare what Ethan's idea and Jasmine's idea. How are they similar and different?
Revoice/Invite revoice	repeat/paraphrase to highlight or clarify student contribution/ encourage active listening by inviting students to explain what others mean.	- Let me paraphrase what you said. You are saying that the salt is still in the water because the weight of salt and water remained the same. If the salt truly disappears, the total weight should have gone down. Am I right? - Who can paraphrase what Ethan's idea?
Summarize/Invite summary	summarizes and juxtapose different ideas that have been voiced - reiterate what has been said.	Let's summarize what hypothesis have been said about the ships in the field. Ethan thinks that a tide brought the ship to the field. Jasmine said that global warming made the lake dry up. Ava said global warming is not possible for lakes to dry up and she used the example of the lake she visits in the summer.
Ground rules	remind students the ground rules they agreed during a discussion, e.g., we listen to each other without interruption. We challenge each other with respect. Metacognitively reflect/ work on ground rules of exploratory talk.	Who can remind us of what are the ground rules for discussion that we agreed upon in class? Ava, you have a very good point. remember to challenge your classmates in a gentle and respectful manner. What went well in our discussion today? what needs improvement?
	making the epistemic practice of science explicit and remind students. Metacognitively reflect on the epistemology of science.	-Remember, scientific argumentation is not about winning the argument, , but examining each other's arguments critically to get closer to build more powerful explanatory models. In science, claims must be supported by evidence and reasoning. How is knowledge produced in science?

Appendix 13: A coded transcript (talk moves)

Line	Conversation	Speaker	Utterance	Open-ended	Uptake	Think Time	Say more	Add-on/Build on	Press	Challenge	Synthesize	Revoice/Invite revoice	Summarize/invite	Focus	Rules of participation	Practice of science
1	Minahil_Post-PD	Minahil	Okay so who is going to tell me what are we discussing these days?	1	0	0	0	0	0	0	0	0	0	0	0	0
2	Minahil_Post-PD	Students	Environments!	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Minahil_Post-PD	Minahil	One by one, yes Maham?	0	0	0	0	0	0	0	0	0	0	0	1	0
4	Minahil_Post-PD	Maham	Environment, and the other day when we first started environment, there were ice sculptures.	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Minahil_Post-PD	Minahil	Yes. Before environment, we were doing ice sculpture. Yes, Faria?	0	0	0	0	0	0	0	0	1	0	0	0	0
6	Minahil_Post-PD	Faria	It was not ice sculpture. it was waster sculptures.	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Minahil_Post-PD	Minahil	Yes it was water sculptures. But what are we talking.. what are we discussing?	0	0	0	0	0	1	0	0	0	0	0	0	0
8	Minahil_Post-PD	Unidentifiable	Environment	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Minahil_Post-PD	Faria	Environment is everything all around us.	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Minahil_Post-PD	Minahil	Environment is everything around us. Yes Maham. Can you put down your mask for a while so that we can hear you properly?	0	0	0	0	0	0	0	0	1	0	0	0	0
11	Minahil_Post-PD	Maham	The sky, the birds, the trees, the mountains, these are the environment.	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Minahil_Post-PD	Minahil	Yes. Maham is saying the sky, the birds, the mountain, everything is a part of our environment. [even the cloud]	0	0	0	0	0	0	0	0	1	0	0	0	0
13	Minahil_Post-PD	Maham	Environment is air land and water.	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Minahil_Post-PD	Minahil	Yes. Maham is saying that environment is air land and water. Yes. You want to say something Faria?	0	0	0	0	1	0	0	0	1	0	0	0	0
15	Minahil_Post-PD	Faria	On our first day of environment, we play the game see think and wonder.	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Minahil_Post-PD	Minahil	And for that we play the game, see think and wonder. Okay, can you focus here Kashif? Can you listen to the teacher? Okay, so for to know more about environment we did an activity called see think wonder. Who will tell me what did we do yesterday? Where did we go yesterday?	1	0	0	0	0	0	0	0	1	0	0	1	0
17	Minahil_Post-PD	Kashif	To the trash place.	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Minahil_Post-PD	Faria	To the Ravel lake.	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Minahil_Post-PD	Minahil	To Ravel lake. Yes Maha?	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Minahil_Post-PD	Maha	Environment is everything.	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Minahil_Post-PD	Minahil	Environment means everything Yes. So where did we go yesterday Faria?	0	0	0	0	0	0	0	0	1	0	0	0	0
22	Minahil_Post-PD	Faria	Ravel lake.	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Minahil_Post-PD	Minahil	Why did we go to the Ravel lake?	0	0	0	0	0	1	0	0	0	0	0	0	0
24	Minahil_Post-PD	Faria	To spot the trash.	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Minahil_Post-PD	Minahil	Yes Maham?	0	0	0	0	0	0	0	0	0	0	0	0	0

26	Minahil_Post-PD	Maham	We went there because... to see trash and see what it smells out of ...and see how much people are littering.	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Minahil_Post-PD	Minahil	Yes, what did you think Ahmed also went with us. Ahmed can you stop playing with this sharpener? Ok, you can play with it. Can you participate? Thank you. Ahmed, why did we go to our lake yesterday?	0	0	0	0	0	0	0	0	0	0	0	0	0
28	Minahil_Post-PD	Ahmed	To find trash.	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Minahil_Post-PD	Minahil	To find trash. So Maham is saying we went around the Ravel lake to find trash and to see why people are throwing trash in the in our environment.	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Minahil_Post-PD	Maha	[inaudible]	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Minahil_Post-PD	Maham	This is not our environment. It is everybody's environment. Allah created it.	0	0	0	0	0	0	0	0	0	0	0	0	0
32	Minahil_Post-PD	Minahil	Yes, Allah has created this environment, and it is everybody's environment. Laraib what did we find in the in the rain or near Ravel lake? What did you see?	0	0	0	1	0	0	0	0	1	0	0	0	0
33	Minahil_Post-PD	Laraib	Trash.	0	0	0	0	0	0	0	0	0	0	0	0	0
34	Minahil_Post-PD	Minahil	Trash. who threw the trash in the Ravel lake?	0	0	0	1	0	0	0	0	0	0	0	0	0
35	Minahil_Post-PD	Laraib	People!	0	0	0	0	0	0	0	0	0	0	0	0	0
36	Minahil_Post-PD	Minahil	So why do people trash in the Ravel lake? Yes Maha what do you think?	0	0	0	0	0	1	0	0	0	0	0	0	0
37	Minahil_Post-PD	Maha	[inaudible]. With people throwing trash everywhere, Allah will be sad.	0	0	0	0	0	0	0	0	0	0	0	0	0
38	Minahil_Post-PD	Minahil	Yes Exactly. We should take care of the environment. What do you think Maham?	0	0	0	0	1	0	0	0	0	0	0	0	0
39	Minahil_Post-PD	Maham	Exactly. I think because those people ...I said... people are throwing trash because they do not have education. they do not have proper school.	0	0	0	0	0	0	0	0	0	0	0	0	0
40	Minahil_Post-PD	Minahil	Yes. So one of the reason that people are throwing this trash is that they don't have education. hmm, Maham can you explain this a little further. What do you mean when people don't have education, they throw trash on the ground?	0	1	0	1	0	0	0	0	1	0	0	0	0
41	Minahil_Post-PD	Maham	I mean, like... [inaudible] does not have education. When that happens, if you do not know what you have to do, and you don't what to do. That' why.	0	0	0	0	0	0	0	0	0	0	0	0	0

42	Minahil_Post-PD	Minahil	Okay. So I asked you all that why are people throwing trash on the grounds. So Maham is saying that those people do not have education. What do you think Faria? Is it something related to education like people throw the garbage on the on the floor and here and there is that does this have something related to education when people are not educated? Do they throw trash here and there.	0	0	0	0	1	0	0	0	1	0	0	0	0
43	Minahil_Post-PD	Faria	I don't know what education means.	0	0	0	0	0	0	0	0	0	0	0	0	0
44	Minahil_Post-PD	Minahil	Okay, like when they do not go to school. Does anyone want to add something to it? Okay, I'll rephrase my question. When we...Yes	0	0	0	0	0	0	0	0	0	0	0	0	0
45	Minahil_Post-PD	Maham	I was not there, that's why I don't know	0	0	0	0	0	0	0	0	0	0	0	0	0
46	Minahil_Post-PD	Minahil	Yes, you weren't there. I have taken a few pictures and I'm going to show you. But guys let's... we have come up with a with an interesting point from Maham. Maham is saying that when people do not have education, they throw trash on the ground like education means when people do not study when they do not go to school, they throw trash in the ground. Who agrees to it? okay, why why do they do it?	0	0	0	0	1	0	0	0	0	1	0	0	0
47	Minahil_Post-PD	Maham	Because they throw trash everywhere. Why do they throw trash everywhere? Don't they know that it's bad? Everybody keeps doing that, and Allah will get sad. People with education, they pick up the trash, they don't throw the trash.	0	0	0	0	0	0	0	0	0	0	0	0	0
48	Minahil_Post-PD	Laraib	Who are these people?	0	0	0	0	0	0	0	0	0	0	0	0	0

49	Minahil_Post-PD	Minahil	Who are these people? These are all your class friends see? Actually this is level B. I've also taken the level b to Ravel lake to see what is happening around the lake and you know people are throwing trash Yes, Maham. Do you want to add something to your point?	0	0	0	1	0	0	0	0	0	0	0	0	0	0
50	Minahil_Post-PD	Maham	Why do they not know...[inaudible]?	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	Minahil_Post-PD	Minahil	Maham is saying that when they do not have enough money they don't go to school so they don't learn. So can we learn this without going to school?	0	0	0	0	0	0	1	0	0	0	0	0	0	0
52	Minahil_Post-PD	Students	No.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	Minahil_Post-PD	Minahil	That we shouldn't throw trash around us and we should put it in the garbage bin?	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	Minahil_Post-PD	Maham	I know, we can...People can tell us.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	Minahil_Post-PD	Minahil	People can tell a person...Exactly. Our mom tell us if we don't go to school. Before we start going to school, who tell us that we should not throw trash on the floor and we should put it in the bin?	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	Minahil_Post-PD	Maham	Our mom, dad, grandma, grandpa, uncle, auntie...	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	Minahil_Post-PD	Minahil	Exactly. Maham is saying that even if you don't go to school there are people around us who tell us that we should not throw trash here and there and gather we should put them in the garbage bin like our parents. Even before we go to school. Our parents tell us you should not throw trash here and there. Yes. Do you want to add something to this conversation?	0	0	0	0	1	0	0	0	1	0	0	0	0	0
58	Minahil_Post-PD	Ahmed	...maybe everyone throw trash [inaudible].	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	Minahil_Post-PD	Maham	All of us in school right? A few minutes, I just pulled out the snack out of my bag. Did I litter? you learn from school and you pay attention! You don't disturb a person when doing work or see anything.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	Minahil_Post-PD	Maham	Actually if we litter, Allah would not like us. If we would litter, the police officer will come. Allah will put something in their mind, someone is throwing trash.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	Minahil_Post-PD	Minahil	Exactly. So actually Allah like cleanliness so we should not litter. okay so instead of ...can you sit on your seat and focus? so what should we do? one thing that you all say that we should put the trash in the bin. Okay what else can we do with the trash? Yes one by one. Yes, Faria.	1	0	0	0	0	0	0	0	0	0	0	0	0	0
62	Minahil_Post-PD	Faria	If you are in a place it does not have bin, you can keep it in your hand and put it in the bin when you go back to school or in your house.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	Minahil_Post-PD	Minahil	Faria is saying when there is no dust bin around, you can just keep it in the bag and take and take into your school and put it in the trash can later.	0	0	0	0	0	0	0	0	1	0	0	0	0	0
64	Minahil_Post-PD	Maham	You don't have to just put them in the trash you can keep that, you can make something out of it. Even like I give you pringle boxes and I want to make something out of it.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	Minahil_Post-PD	Minahil	Okay, we have one more point. Maham is saying even if we don't put the trash. Wait Maham, I will come to you. Maham is saying that instead of putting the trash in the bin, we can make something useful out of it. How can we? So Maham give me two pringle boxes that day and she said... sorry you cannot come in here; we are having a class. Okay, Maham gave me to Pringle boxes and she said that we are going to reuse it we are going to make something something creative out of it, we're going to make something else out of it when we are going to have our hands on project. Yes, Maham.	0	0	0	0	0	0	0	0	1	0	0	0	0	0
66	Minahil_Post-PD	Maham	Exactly also, I like Faria said, throw it into the dustbin. What if there is too much, you shouldn't say recycling and making any useful things.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	Minahil_Post-PD	Minahil	Do you think we can use the trash some other ways?	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	Minahil_Post-PD	Minahil	Oh okay Nouman, how can we use something useful how can we make something useful out of the trash?	0	0	0	0	0	1	0	0	0	0	0	0	0	0
69	Minahil_Post-PD	Nouman	boxes, something else...	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	Minahil_Post-PD	Minahil	Okay, so we can use something else out of it. Okay, instead of, ok Maham?	0	0	0	0	0	0	0	0	0	0	0	0	0	0

71	Minahil_Post-PD	Maham	I want to say whenever the garbage gets full, before it gets more full, you have to throw it in another trash can, you have to throw it into trash can, other people will take it to resource places and make something out of it. These cups were made out of trash.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	Minahil_Post-PD	Faria	Once I made an organizer out of cardboard.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	Minahil_Post-PD	Minahil	That we were supposed to throw? the useless stuff? Actually that's a very good idea. We can use make a resource organizer with cardboard. So Faria was actually saying, that before we throw anything we should be careful that you know we can pick up the stuff which is which we can reuse You can reuse it or or...	0	0	0	0	0	0	0	0	1	0	0	0	0	0
74	Minahil_Post-PD	Maham	Before it gets full, just throw it away, so other people...	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	Minahil_Post-PD	Minahil	Other people means noticing that the other people like the people who picks up the... you know, they pick up the important stuff from the garbage the garbage box and they take it to the recycling factories and they make useful stuff out of it. Exactly, that's what we should do. Maham?	0	0	0	0	1	0	0	0	0	0	0	0	0	0
76	Minahil_Post-PD	Maham	All of these stuff I heard... these cups. I think we can recycle and make decorations. If there is anything trash in the project room, I've already made things, like this. .	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	Minahil_Post-PD	Maham	Like we can make ... out of trash. Like we also made that big water sculpture we're going to make even more of them and hang it outside. it is going to be so cool, but we didn't... we use trash paper to make that thing.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	Minahil_Post-PD	Minahil	So, we use this useless plastic to make a water sculpture in our previous project. So, all of you are actually saying that instead, first of all, we should not throw the trash on the floor, we should get we should be educated about it that we should not throw trash here and there, we should put it in the garbage bin. Secondly, we should try to make something useful out of it that we can use stuff that we most of the stuff that we throw in like dustbin can be reused or maybe we can give it to the recycling companies so that they can make something useful out of it. Is this correct?	0	0	0	0	0	0	0	0	0	1	0	0	0	0
79	Minahil_Post-PD	Students	Yeah.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	Minahil_Post-PD	Minahil	Okay. So, thank you so much class for this useful discussion. Now we are going to write we are going to actually draw on our copies whatever we have done so far. All right. So we are going to draw on your notebook. You are going to draw whatever you saw in your previous class. Yes, but first. Yes.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	Minahil_Post-PD	Maham	Can I help you?	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	Minahil_Post-PD	Minahil	Oh yeah, you want to say something else? wait, we are going to draw now.	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 14: A sample simulation guide

LEARN TO LEAD PRODUCTIVE SCIENCE DISCUSSIONS

SIMULATION 4 GUIDE

Lydia Cao, University of Cambridge



Explanation discussion



Book your simulation
[link redacted]



WHAT YOU WILL FIND IN THIS GUIDE



Simulation task

Background (p. 1)
Your task (p. 2)
Reminder on what explanation discussion is (p.3)
Why can't I just tell them? (p.4)



Science repertoire

What is a scientific explanation? (p.8-11)
What is scientific argumentation? (p.12-13)
An article on the Aral Sea (p. 14)



Student work

You will find students work with commentaries to help you identify the merits and weaknesses of their arguments (p.5-7)



Pedagogical toolkit

Talk moves you've seen (p.15)
New talk moves (p.16)
Full list of talk moves with examples (p.15)
Ground rules for exploratory talk (p.18)

SIMULATION TASK DESCRIPTION

BACKGROUND

After the consolidation discussion on the mini-lake, you realized that children have reached a "ceiling" on their sense-making at some point, so you provided additional learning opportunities for them. This is what they have done:

- 1) read an article on the Aral Sea (p. 12) ,
- 2) learned about the particle model of evaporation and condensation, and
- 3) how to make a scientific explanation—they understand that they need to make a claim and support it with evidence and reasoning.

This is what you instructed them to do:

You asked children to draw **evidence from multiple sources** from their learning experience and use **reasoning** to explain the causes that led up to the drying up of the Aral Sea over time. You encouraged children to **look beyond the visible things** and explain the **process underlying** the drying up of the Aral Sea.

Children worked in groups or individually to make a scientific explanation about the ships in the field.

SIMULATION TASK DESCRIPTION

YOUR TASK

Your task is to lead an explanation discussion. During the explanation discussion, you will:

1. Engage students in **authentic science practice** around using **evidence and reasoning** to support their **claims**.
2. Facilitate children to consider **the merits and weaknesses** of each other's explanations.
3. Use your professional judgment to decide **when to open, widen, deepen, maintain close, or shape** the sense-making space and use the corresponding **talk moves**. (i.e., Zooming in to the moment).
4. Help students to **move their thinking forward** (i.e., Zooming out to see overall direction)





REMINDER



Explanation discussion is NOT about telling the "correct" answer. Give students the agency to piece together multiple sources of evidence they have gathered over a series of learning activities and use reasoning to make sense of the puzzling phenomenon.

During explanation discussions, **your main job is to facilitate students to critically evaluate each other's claims, evidence, and reasoning and consider the merits and weaknesses of their arguments.**

Explanation discussions are often intertwined with scientific argumentation. **Science argumentation is NOT about "winning" the argument**, rather the goal is to get closer to a more powerful explanatory model by examining each other's evidence and reasoning.

It is normal if children do not reach an agreement or a clear-cut conclusion. Sometimes, argumentation leads to a conclusion, sometimes it leads to more learning and research. It is often through exchanging with others, we realize the weakness of our own argument and misconceptions, which guide us to do more research and build better arguments. **As their teacher, you will have the opportunity to see where their current understanding is and recognize the "ceiling" of their sense-making, so you can help them move their thinking forward with additional learning experiences.**

In summary, **the focus of explanation discussion is for students to engage in the authentic scientific practice of** using evidence and reasoning to justify their claims to consider different possibilities for genuine questions, just as a community of scientists!

WHY CAN'T I JUST TELL THEM?

As much as we would like to hand over the "right" answers to children, human brains don't work this way. The human mind is a builder of mental models and theories rather than a blank slate. We cannot replace a mental model by depositing another one. Sense-making is critical for deep understanding to take place.

The reason that we all tend to hold on to the misconceptions is that it makes sense to us — it comes from our lived experience and we have done the intellectual heavy lifting to come to this understanding.

After instructing students on photosynthesis, most students (including Harvard graduates) still hold on to the misconception that wood comes from light, soil, water, and minerals, but in fact, most of the mass of the trees comes from carbon dioxide.

If you have time, I highly recommend this fascinating video of Harvard graduates (3 min. 45 sec. to 17 min. 41 sec) being interviewed about where trees come from. Be ready for some surprises!



[Click here for the video](#)



I think this video is a powerful illustration of why telling students the right answer or just doing hands-on activities is not enough for deep understanding. Students need the agency to make sense of things for themselves and do the heavy intellectual lifting. Otherwise, they will either quickly forget what they have learned and hold on to their previous conceptions. Even if students remember, they will not be able to apply the knowledge elsewhere. (Think about how useful it is that we remember how to execute the division of fractions. Can we apply this knowledge elsewhere without understanding?)

STUDENT WORK

Here are three written explanations of students. Think about these questions yourself before reading the commentary.

- 1) what are the merits and weaknesses of each argument?
- 2) In what ways do you think students can improve their arguments?

SAVANNAH, AVA'S WORK

The ships in the field were stranded in the field because there was no more water in the Aral Sea (we learned that the field was actually a lake called the Aral Sea). The water all dried up because people took away the Aral sea's water, which comes from the rivers.

The evidence is in the Aral Sea article we read. It says that the two rivers, Syr Darya and Amu Darya that normally flow into the Aral Sea were diverted to water cotton crops. We compare the Aral Sea to the lake that Ava goes to every summer, the only difference is that water in Ava's Lake is being protected, not taken away by people. Therefore, our conclusion is that the Aral Sea disappeared because people took its water

COMMENTARY

Savannah and Ava identified one factor that led to the drying up of the Aral Sea, which is the diversion of the Amu Darya and the Syr Darya that normally replenish the Aral Sea.

*They think that an active and **intentional agent** is required in cause-and-effect relationships. In other words, they think for something to happen, there has to be an active agent with intentions, such as people doing something, which is not necessarily true. For example, many children attribute the fact they can drink from a straw to their own agency (I suck the juice up the straw to drink). However, the scientific explanation is a form of **relational causality** — the juice comes up with pressure outside the straw than inside the straw.*

*This type of **agent-based causality** is very prevalent because it has its roots in infancy. We learned we can make things happen as babies — I can hit the bell to make a sound; I can cry to make mommy come. Causes and effects are intertwined with my agency and intention. Therefore, agent-based and intentional causality is a powerful way for us to perceive causality, which persists even when we get older. However, without looking beyond it, we tend to miss many complex causality patterns (e.g., relational causality) and overlook non-obvious causes.*

Savannah and Ava also thought about cause-effect in a simple linear pattern — one thing makes another happen, without considering the interactions and relationships among different factors. They also focused on the event rather than viewing the event within a broader context.

STUDENT WORK

JASMINE AND ETHAN 'S WORK

The ships ended up in the field for three reasons.

1. Diversion of rivers: We learned that the field was actually a lake, called the Aral Sea. The rivers that feed the Aral Sea were diverted to water the cotton field, so there is less water coming into the Aral sea.
2. Water evaporation: The Aral Sea slowly dried up because of water evaporation. Our evidence is that in the Mini-lake, we see that the weight of water decreased over time. This means the water is leaving the container. This process from water to water vapor is called evaporation. So we know water evaporates from the container. In nature, water from lakes and the ocean also evaporates.
3. Global warming, which made evaporation even faster: When it is warmer, evaporation happens faster (We saw this in the mini-lake when we put a lamp over it, the water weight decreased faster). When it is warmer, there is more evaporation, so we think that more water leaves the lake.

Due to the three reasons, diversion of the rivers, water evaporation, and global warming, the Aral Sea dried up.

COMMENTARY

Jasmine and Ethan identified three factors that led to the drying of the Aral Sea. However, they did not consider the interactions among the three factors and treated each factor as a simple linear causal pattern (one thing makes another thing happen) as Savannah and Ava. They claimed that evaporation caused the lake to dry up, which is not correct.

*They correctly described the **mechanism of evaporation** on a microscopic (unobservable) level. However, they assigned the wrong **ontological status to global warming** and thought about it as an event, such as heating up something, but in fact, global warming is a process that involves numerous factors at multiple levels (local and global level) across time.*

STUDENT WORK

DEV'S WORK

The Aral Sea dried up because more water left the lake through evaporation than water coming in.

We read in the Aral Sea articles that the rivers that go to the Aral Sea were diverted to water crops. So there is less water going inside the Aral sea.

We also saw that in the mini-lake investigation that the water slowly evaporated from the mini-lake over time once we removed the lid of the container. Evaporation always happens (we know this because whether we put a lamp or just in room temperature, we saw water disappearing). Because we did not give it more water, it dried up.

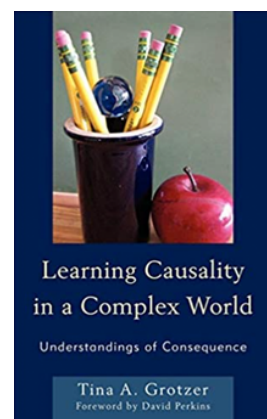
Therefore, because water evaporated over time and then the Aral Sea does not get filled up by the two rivers anymore. It dried up just as our mini lake.

COMMENTARY

*Dev identified the **relational causality** that led up to the drying of the Aral Sea (the imbalance between the loss of water due to evaporation and inflowing water from the rivers).*

He did not explain the mechanism of evaporation and described evaporation as water disappearing rather than becoming water vapour. He did not support his claim “the water slowly evaporated from the mini-lake over time” with evidence. How did he know that the water evaporated? It is not always possible to perceive a slight water loss due to evaporation. For example, he could use the drop in the weight of the container to support his claim.

Want to learn more about causality in science? Read **Learning Causality in a Complex World: Understandings of Consequence** by Tina Grotzer



SCIENCE REPERTOIRE

WHAT IS SCIENTIFIC EXPLANATION?

There are many ways we use the word "explain" or "explanation" in science and our day-to-day life, but they are different from "scientific explanation". For example, sometimes "explanation" is used as a clarification for the meaning of a term or laying out of one's reasoning about a problem. For instance, "Can you explain how you calculated the amount of force needed to lift that load with the pulley system?" These explanations—or more properly explications—is in many ways an authentic communicative practice in the daily work of scientists who clarify ideas and findings for each other and various audiences (Knorr-Cetina, 1999; Latour & Woolgar, 1979), **however these products of intellectual work are qualitatively different from a scientific explanation.**

SCIENCE REPERTOIRE

CAUSAL EXPLANATION

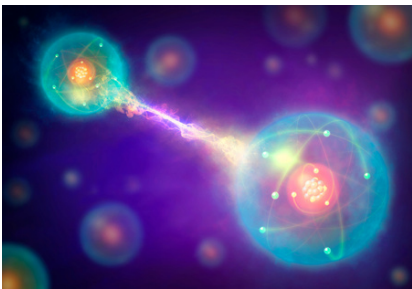
A common type of scientific explanation is **causal explanation**. Causal explanations reference observation and patterns in data, and explicitly seek underlying reasons for these (see Salmon, 1989).

By “underlying” we refer to entities, processes and properties that are not directly observable. In school settings, causal accounts use underlying mechanistic properties, processes, etc., to explain observable phenomena (Driver et al., 1996; Hammer, Russ, Mikeska, & Scherr, 2008; Perkins & Grotzer, 2005).

Assembling these explanations can make students more aware of scientific epistemology (how does science produce knowledge?) —specifically the conjectural relationship between observation and theory. Causal explanations can be conceptually rich to connect data (the observable) and theory (the unobservable).

SCIENCE REPERTOIRE

OTHER TYPES OF EXPLANATIONS



Not all branches of science, however, seek mechanistic causal explanations. Fields such as computational biology and quantum physics utilize **statistical and probabilistic reasoning** to make sense of phenomena for which there may not be any definable cause or regular mechanism (Knorr-Cetina, 1999; Nersessian, 2005; Pickering, 1995). Other fields, such as classical physics, employ laws (statements of observed regularities, often codified in equations) rather than underlying causes to account for the operation of simple machines or to describe the motion of objects.

SCIENCE REPERTOIRE

HOW TO BUILD SCIENTIFIC EXPLANATIONS?

Scientific explanations require time and tools and opportunities to think with others. **The phenomenon being explained required a series of observations or experiments, the coordination of multiple science concepts, and repeated opportunities by students to reason with these resources in order to refine their explanations or models.**

For example, in our simulations, students engaged in a series of activities, such as forming hypotheses about the ships in the field during the elicitation discussion, conducting the mini-lake investigation followed up by a consolidation discussion to grapple with various science concepts (e.g., dissolving, evaporation, etc.), learning about the particle model (which is not depicted in the simulation but provided as background), and researching and reading articles on the Aral Sea. Students are given these opportunities to construct and refine their explanatory models about the ships in the field.

This drawing together of learning experiences that have occurred over time is not common in schools; students are most often asked to “explain” the results of a single experiment (which typically is a restatement of data trends) and then move on, rather than **using experimental results together with other observations and ideas to revise thinking about a phenomenon of some richness and complexity** (Banilower, Boyd, Pasley & Weiss, 2006; Bowes & Banilower, 2004; Roth & Garnier, 2007).



SCIENCE REPERTOIRE

WHAT IS SCIENTIFIC ARGUMENTA TION?

Scientific argument incorporates explanation with evidence and reasoning. Here the goals are to articulate one's understandings and work to persuade others, in order to collectively make sense of the phenomenon under study.

Science argumentation is not about “winning” the argument, rather the goal is to get closer to a more powerful explanatory model by examining each other’s evidence and reasoning.

Science arguments have three key components: claim, evidence, and reasoning.



SCIENCE REPERTOIRE

WHAT IS A CLAIM?

A claim is a statement about some event, process, or relationship in the natural world that you believe to be true. A claim, however, is not simply a statement about trends in data (Ambitious science). An explanation often is composed of multiple claims.

WHAT IS EVIDENCE?

Evidence is information about the natural world that is used to support a claim. In scientific argumentation, evidence includes data, such as observations and measurements about the natural world. Students often have difficulty using appropriate and sufficient evidence to support their claims (Argumentation toolkit).

WHAT IS REASONING?

Reasoning is the process of making clear how your evidence supports your claim. In scientific argumentation, clear reasoning includes using scientific ideas or principles to make logical connections to show how the evidence supports the claim. Students often have difficulty making their reasoning clear in an argument. For example, they will frequently state a science concept without explaining how it helps explain the link between the claim and evidence (Argumentation toolkit).

SCIENCE REPERTOIRE

THE ARAL SEA ARTICLE



CLICK HERE

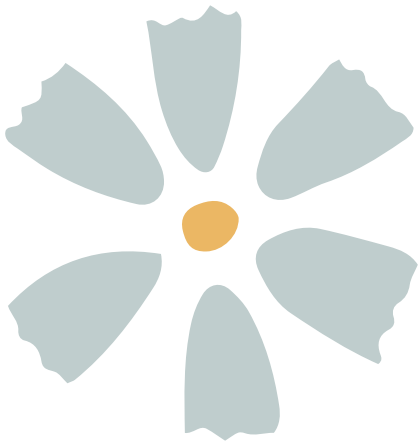
PEDAGOGICAL TOOLKIT

TALK MOVES THAT WE'VE SEEN SO FAR

Talk moves that you've seen before:

1. Probe
2. Think time
3. Say more (it was called gentle follow-ups when it was first introduced)
4. Build-on
5. Pressing
6. Revoicing/Invite student to revoice
7. Summarize
8. Focus





New Talk Moves



CHALLENGE

challenge student ideas by highlighting evidence and/or reasoning

SYNTHESIZE

Combine different ideas and perspectives to produce new understanding. (One step further than summarize)

MAKE PLANS

Make plans and invite students to make plans about the next steps of learning.

PARK IDEAS

When students reached a ceiling of sense-making, and more research and learning need to take place, summarize the questions and make a plan for next steps.

RULES FOR PARTICIPATION

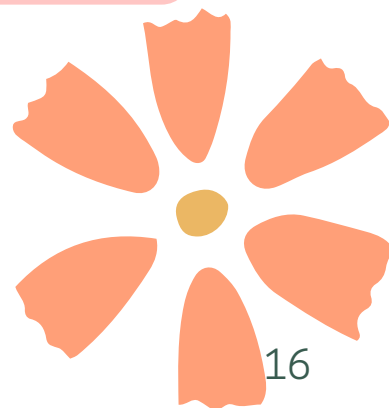
remind students the ground rules they agreed for discussions.

SCIENTIFIC PRACTICE

making the epistemic practice of science explicit and reminding students. Metacognitively reflect on the epistemology of science.



Check part 2 for the full list of talk moves with examples



PEDAGOGICAL TOOLKIT

FULL LIST OF TALK MOVES



Click here for the full list with
examples
[Link redacted]

*Note:

I have used dialogic space and sense-making space interchangeably. :-)
They mean the same thing here.

Highlighted in grey are the unproductive moves.

Talk moves are used flexibly among different types of discussions (elicitation, consolidation, and explanation) though some moves could be used more frequently in one type than others. For example, you probably will rarely use “pressing” during elicitation discussion but use it more often during consolidation and explanation discussions.

GROUND RULES

EXPLORATORY TALK



Listen carefully
to each other

Share ideas, justify
your contributions by
making your reasoning
and thinking visible



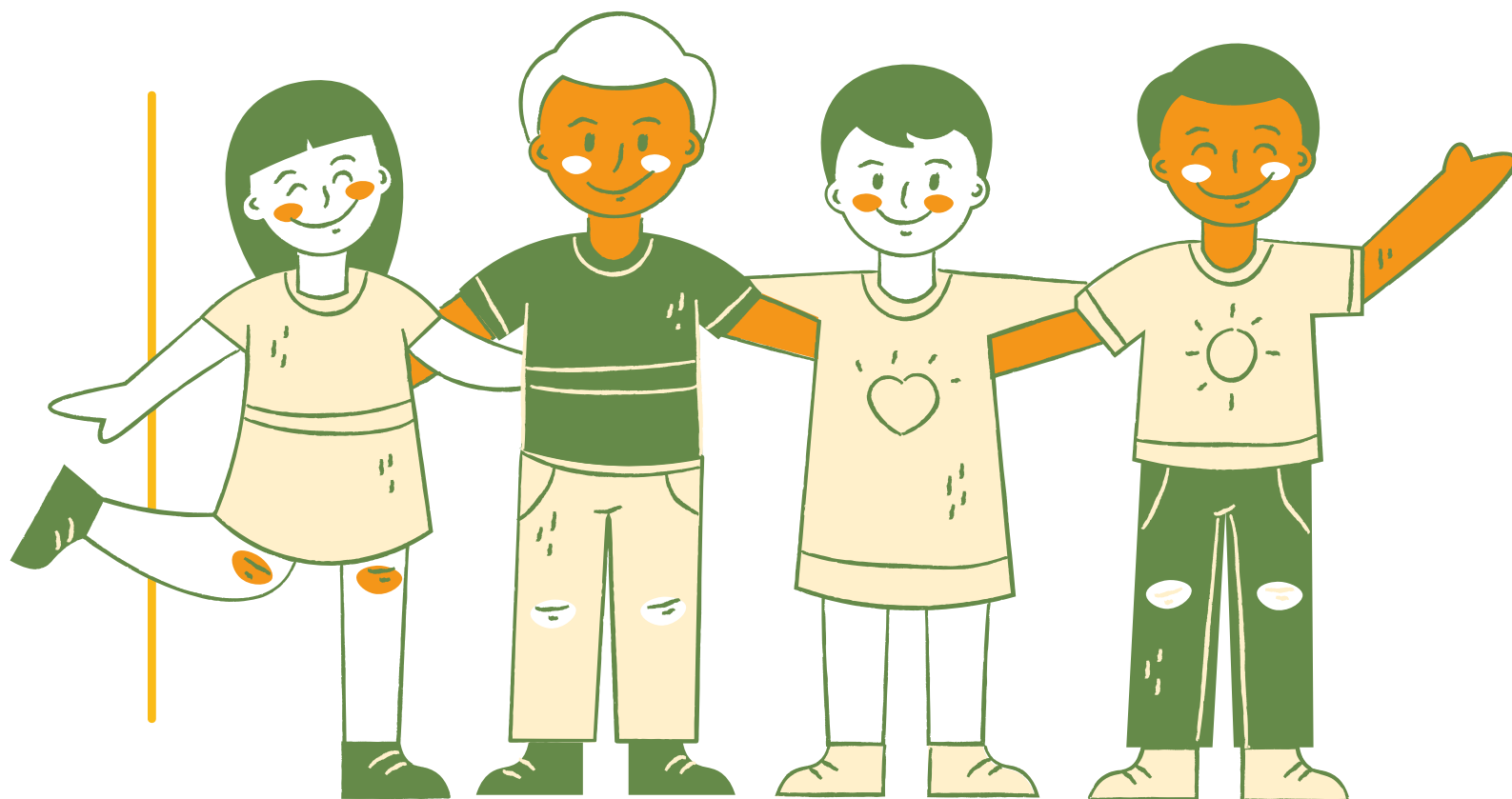
Build on each
other's ideas



Critically and respectfully
engage and challenge different
ideas and ways of thinking

*Note:

Here are the ground rules for science discussions that students have agreed upon. You can remind them of these ground rules as you see fit.



Thank You

Have questions?

- ✉ Don't hesitate to reach out to me at
[Email address redacted]
Looking forward to seeing you at the
simulation.