

Table S1. Pre-interview protocol for both children and teachers.

Nr.	Question
1	Can you give some examples for materials? [Show the materials]
2	What are these materials? [If they cannot identify the materials, the researcher helps them or tells them]
3	This is [steel, wood, PTFE, and foam]. Can you describe those materials for me? Pre-intervention task: order steel, wood, PTFE and foam from hard to soft (materials were hidden under towel)
4	Can you order those materials from hard to soft?
5	Can you explain why you ordered them is this way?
6	Why are some materials harder than others?
7	I have a metal nail here. What materials could I scratch with the nail? Explain.
8	What are these materials made of? Start with steel. [If they describe macroscopic properties such as shape or color, ask]
9	Is it one big thing or is it made of little pieces? [If they say a material is made of little pieces, ask]
10	Think of the smallest possible [use child/teacher/student's word] particles that this [material] is made of. Can you see them?
11ab	[If yes] Do they have a color? [If no, or after 12] What do you see if you have the most powerful [If yes] What color do they microscope? have?
12	Can you touch the smallest [use child/teacher/student's word] pieces/particles with your hand? What do you see if you have the most powerful microscope? [If they say the material is made of little pieces, ask]
13	Can you draw the smallest [use child/teacher/student's word] particles that this [material] is made of? What do they look like? [If needed point to any parts of the picture that are unclear and ask]
14	Can you explain your drawing? What did you draw here?
15	Are the little pieces close together or are they far apart? [If the term atom was not named yet; if already mentioned the participant is asked to elaborate what atoms are]
16	Have you heard the word 'atom' before?
17	Can you explain what atoms are and what they do?
18	How big are atoms? Compare their size to something you know.

Ordering materials. Participants were asked to order a bar of steel, a block of wood, a piece of PTFE (generally referred to as plastic) and a foam from hard to soft during the pre-interview. This was to find, if and what intuitive notion of material hardness is expressed by the participants. Then participants were encouraged to explain their selected order.

Drawings. Participants were asked to draw how the materials look through a (very strong) microscope (see post-interview).

Metal nail task. Later in the pre-interview, participants were asked which of the previous materials could be scratched with a metal nail. This was to see whether an idea of Mohs scratch hardness was present.

Various game tasks. The participants also completed various tasks during the interviews. The tasks were to order pictures or robots from the game with different atoms and bonds to different materials. Or, they were asked to fill robots with atoms and bonds as they think it corresponds to real materials.

Table S2. Post-interview protocol for participants' views on atoms after the game (both children and teachers).

Nr.	Question
1	Why are some materials harder than others?
2	Do you think there is a relationship between the materials and the board game?
3	Can you draw the particles of the materials again? Explain your drawing. Post task 1 and 2: what atom picture belongs to which material
4	Which picture belongs to which material?
5	How do atoms relate to materials in real life?
6	What property/feature of atoms relates to hardness of materials?
7	Do you think atoms have colors?
8	What does 'atom' mean for you now? Can you explain?

Table S2. Continued.

Nr.	Question
The following questions examine whether the children realize the events on the challenge cards are about material hardness:	
9	Consider the anvil falling on the robot; what property is challenged here? What material property does the robot need to possess so that is it not damaged by the anvil?
10	Consider the vase falling on the robot; what property is challenged here? What material property does the robot need to possess to keep the vase undamaged?
Post task 3: first it is asked to fill a 4 slot robot (not in the game) with tiles of the game to make it as hard as possible; then one should be made medium hard; then one should be as soft as possible (atoms do not have colors); they should respect the rules of the game (if they do not remember the "rule of 2" to get a dice, they are reminded to it);	
11	What tiles would you fill in this robot to make it as hard as possible? Why?
12	What tiles would you fill in this robot to make it medium hard? Why?
13	What would tiles you fill in this robot to make it as soft as possible? Why?
14	Could there be different grids than the ones you saw (2, 3, 4)?

Table S3. Questions regarding their interest and enjoyment (both children and teachers).

Nr.	Question
1	What is your opinion on the game?
2	What did you particularly like? Or not? Can you explain why?
3	Was there something you found difficult to understand? Anything specific?
4	Do you think you will be able to explain the rules of the game to other children? With the manual/rule booklet?
5	Would you play the game again? Why/why not?
6	Do you have any suggestions for us to make the game better?

Table S4. Additional questions for teachers during the post-interview.

Nr.	Question
1	Will children learn something from the game? What will they learn? Explain.
2	Do you see an educational value in the game?
3	Was your previous knowledge about atoms sufficient to play the game?
4	Do you feel that your previous knowledge of atoms is enough to implement the game in your class?
5	Do children need prior knowledge about atoms to play the game?
6	Do you think atoms are represented appropriately, compared to how they are shown in other media?
7	Is it necessary that atoms are part of the curriculum before the game can be used in class?
8	Do you think you will be able to explain the rules of the game to children? With the manual/rule booklet?
9	Is it simple enough for children?
10	What do you expect to be in the manual/rule booklet?
11	What would you need in case the children ask more about atoms?
12	Do you think the game helps to explain the concept of material hardness, that some materials are harder than others?
13	Do you think a board game is a good medium for education? Or is it better to use digital games?
14	Would you consider to use the game to teach material hardness? Explain your answer.

Table S5. Open-ended questions from the retention interviews (only children).

Nr.	Question
1	What do you remember from the game? You can use your own words to describe what you remember.
2	We also talked about materials, and you ordered them from hard to soft (plastic, wood, steel, and foam). Why do you think are some materials harder than others?
3	Do you think there was a relationship between the materials and the board game? If yes, can you describe this relationship?
4	The robots had to be filled in the backside, remember? Can you draw what you filled the robots with for a very tough challenge?
5	What do atoms look like?

Table S6. Experience scale [40].

	Adapted items	Original items
Exp1	I like playing games.	I like playing video games.
Exp2	I often play games.	I often play video games.
Exp3	Compared to children of my age, I play a lot of games.	Compared to people of my age, I play a lot of video games.
Exp4	I would describe myself as a gamer.	I would describe myself as a gamer.
Exp5 ^a	I play different types of games.	I play different types of video games.

^a This item was deleted for further analysis.

Table S7. Preference on games scale [40].

	Adapted items	Original items
Pref1	If I had the choice, I would choose to use games in the classroom.	If I had the choice, I would choose to follow courses in which video games are used.
Pref2	If I had to vote, I would vote in favor of using games in the classroom.	If I had to vote, I would vote in favor of using video games in the classroom.
Pref3	I am enthusiastic about using games in the classroom.	I am enthusiastic about using video games in the classroom.

Table S8. Interest/enjoyment (IE) scale [34].

	Adapted items	Original items
IE1	I enjoyed this game very much.	I enjoyed doing this activity very much.
IE2	This game was fun to play.	This activity was fun to do.
IE3	I thought this was an interesting game.	I thought this was a boring activity. (R)
IE4	This game held my attention.	This activity did not hold my attention at all. (R)
IE5	I would describe this game as very interesting.	I would describe this activity as very interesting.
IE6	I thought this game was quite enjoyable.	I thought this activity was quite enjoyable.
IE7 ^a	When I was playing the game, I was thinking about how much I enjoy it.	While I was doing this activity, I was thinking about how much I enjoyed it.

^a This item was deleted for further analysis.

Table S9. Effort expectancy (EE) scale [35].

	Adapted items	Original items
EE1	Learning how to play the game is easy for me.	Learning how to use mobile Internet is easy for me.
EE2	What I had to do in the game was clear.	My interaction with mobile Internet is clear and understandable.
EE3	I find the game easy to play.	I find mobile Internet easy to use.
EE4	It would be easy for me to become good at the game.	It is easy for me to become skillful at using mobile Internet.

Table S10. Value/usefulness (VU) scale [36].

	Adapted items	Original items
VU1	I believe this activity will be of some value for students.	I believe this activity could be of some value to me.
VU2	I think that playing this game will be useful to learn why some materials are harder than others.	I think that doing this activity is useful for ...
VU3	I think this will be important to do because it can support students' understanding of the microscopic world.	I think this is important to do because it can ...
VU4	I would be willing to use the game because it has some value to students.	I would be willing to do this again because it has some value to me.
VU5	I think the game will help me to explain the idea behind material hardness.	I think doing this activity could help me to ...
VU6	I believe playing this game will be beneficial to students.	I believe doing this activity could be beneficial to me.
VU7	I think this will be an important activity.	I think this is an important activity.




Figure S1. Four differently hard materials shown to the participants during the interview (steel, solid PTFE plastic, wood, and foam).

The questionnaire presented to the children


In the following is shown how the children saw and filled the questionnaire with pen and paper. For the children, part 1-1 was the experience scale (Table S6), part 1-2 was the preference scale (Table S7). Both were filled during the pre-interview. Part 2 was filled after watching the video that explained the rules of the game but before playing it (so still pre-interview). Part 2-1 was the interest scale (Table S8), part 2-2 was the effort expectancy scale (Table S9). Part 3 was filled after playing the game, so during the post-interview. Part 3-1 was again the interest scale (Table S8) and part 3-2 was again the effort expectancy scale (Table S9).


Part 1


Part 1-1


(strongly disagree)


(disagree)


(neither agree nor disagree)


(agree)


(strongly agree)

I like playing games					
I often play games					
Compared to children of my age, I play a lot of games					
I would describe myself as a gamer					
I play different types of games					

Part 1-2



(strongly disagree)



(disagree)



(neither agree nor disagree)



(agree)



(strongly agree)

If I had the choice, I would choose to use games in the classroom					
If I had to vote, I would vote in favor of using games in the classroom					
I am enthusiastic about using games in the classroom					

Part 2

Part 2-1



(not at all
true)



(not true)



(neither
true nor
untrue)



(true)



(very
true)

I think I will enjoy this game very much					
This game will be fun to play					
I think this will be an interesting game					
This game will hold my attention					
I will describe this game as very interesting					
I think this game will be quite enjoyable					
When I will play the game, I will think about how much I enjoy it					

Part 2-2



(not at all
true)



(not true)



(neither
true nor
untrue)



(true)



(very
true)

Learning how to play the game will be easy for me					
What I will have to do in the game will be clear					
I think the game will be easy to play					
I think it will be easy for me to become good at the game					

Part 3

Part 3-1



(not at all
true)



(not true)



(neither
true nor
untrue)



(true)



(very
true)

I enjoyed this game very much					
This game was fun to play					
I thought this was an interesting game					
This game held my attention					
I would describe this game as very interesting					
I thought this game was quite enjoyable					
When I was playing the game, I was thinking about how much I enjoy it					

Part 3-2



(not at all
true)



(not true)



(neither
true nor
untrue)



(true)



(very
true)

Learning how to play the game is easy for me					
What I had to do in the game was clear					
I find the game easy to play					
It would be easy for me to become good at the game					

The questionnaire presented to the teachers

In the following is shown how the teachers saw and filled the questionnaire with pen and paper. For the teachers, all parts were identical to the children’s questionnaire except that they also filled the value/usefulness scale (Table S10) after watching the instructional video but before playing the game (part 2-2), and also after playing the game (part 3-2).

Part 1

Part 1-1	1 (Strongly disagree)	2 (Disagree)	3 (Neither agree nor disagree)	4 (Agree)	5 (Strongly agree)
I like playing games					
I often play games					
Compared to people of my age, I play a lot of games					
I would describe myself as a gamer					
I play different types of games					

Part 1-2	1 (Strongly disagree)	2 (Disagree)	3 (Neither agree nor disagree)	4 (Agree)	5 (Strongly agree)
If I had the choice, I would choose to use games in the classroom					
If I had to vote, I would vote in favor of using games in the classroom					
I am enthusiastic about using games in the classroom					

Part 2

Part 2-1	1 (not at all true)	2	3 (somewhat true)	4	5 (very true)
I think I will enjoy this game very much					
This game will be fun to play					
I think this will be a boring game					
This game will not hold my attention					
I will describe this game as very interesting					
I think this game will be quite enjoyable					
When I will play the game, I will think about how much I enjoy it					

Part 2-2	1 (not at all true)	2	3 (somewhat true)	4	5 (very true)
I believe this activity will be of some value for students					
I think that playing this game will be useful to learn why some materials are harder than others					
I think this will be important to do because it can support students' understanding of the microscopic world					
I would be willing to use the game because it has some value to students					
I think the game will help me to explain the idea behind material hardness					
I believe playing this game will be beneficial to students					
I think this will be an important activity					

Part 2-3	1 (not at all true)	2	3 (somewhat true)	4	5 (very true)
Learning how to play the game will be easy for me					
What I will have to do in the game will be clear					
I think the game will be easy to play					
I think it will be easy for me to become good at the game					

Part 3

Part 3-1	1 (not at all true)	2	3 (somewhat true)	4	5 (very true)
I enjoyed this game very much					
This game was fun to play					
I thought this was a boring game					
This game did not hold my attention					
I would describe this game as very interesting					
I thought this game was quite enjoyable					
When I was playing the game, I was thinking about how much I enjoy it					

Part 3-2	1 (not at all true)	2	3 (somewhat true)	4	5 (very true)
I believe this activity could be of some value for students					
I think that playing this game is useful to learn why some materials are harder than others					
I think this is important to do because it can support students' understanding of the microscopic world					
I would be willing to use the game again because it has some value to students					
I think the game could help me to explain the idea behind material hardness					
I believe playing this game could be beneficial to students					
I think this is an important activity					

Part 3-3	1 (not at all true)	2	3 (somewhat true)	4	5 (very true)
Learning how to play the game is easy for me					
What I had to do in the game was clear					
I find the game easy to play					
It would be easy for me to become good at the game					

Additional questions during the retention interviews

The children were asked to tick the correct answers of various statements (Table 4 in the manuscript) and fill in gaps with correct words (Table 5 in the manuscript). These tasks are shown below like the children filled it with pen and paper (Figure S2 and S3).

Put a tick next to the correct sentences. There can be several correct sentences.	
<input type="checkbox"/>	Atoms are very small. With a microscope, you can see them.
<input type="checkbox"/>	Atoms are very small. Even with a microscope, you cannot see them.
<input type="checkbox"/>	Materials are made of atoms.
<input type="checkbox"/>	Atoms are in materials to support them.
<input type="checkbox"/>	Some materials are harder than others because the atoms have stronger bonds.
<input type="checkbox"/>	Some materials are harder than others because they are used for more challenging things.
<input type="checkbox"/>	There is only one type of atom for all materials.
<input type="checkbox"/>	Atoms can be mixed in materials.
<input type="checkbox"/>	Different materials can have different atoms.
<input type="checkbox"/>	Some atoms are stronger than other atoms.
<input type="checkbox"/>	There are no stronger atoms. Atoms only differ in how they can make bonds with each other.
<input type="checkbox"/>	The strength of a material is because atoms work together.
<input type="checkbox"/>	You can distinguish atoms by their colors.

Figure S2. Various statements that children could tick during the retention interviews.

Please fill in the gaps in the text. You can use the following words and you can use each word as often as you think. But not EVERY word needs to be used or is correct! If you do not know what to fill, leave it blank.

air	do	microscope	together
atoms	don't	particles	things
bonds	energy	quarks	thick
big	electrons	soft	thin
can	hard	strong	weak
cannot	interaction	stuff	
collectively	materials	tiny	

Everything we can see and touch is made of _____. One

_____ see them and they _____ have a color.

_____ also make up _____, for example
steel.

Steel is _____ because it is made of _____,
and the _____ between them are very strong.

Wood is not so _____, because the _____ are not
so strong. Steel and wood are different, because their
_____ have different capacities to make
_____. But they only work _____!

Figure S3. A gap text that children filled during the retention interviews.