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SCIENCE OR MAGIC? REACTIONS OF 5 YEARS OLD PUPILS TO A COUNTER-INTUITIVE EXPERIMENT

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Abstract: Testing the reproducibility of an experiment is considered a good practice in science, and the possibility to reproduce an experiment is a condition of its scientificity. We investigate the ability of children to consider a counter-intuitive phenomenon as reproducible. The study involved 62 five-year-old children from 4 classes. They were presented with a bottle in which a hole had been pierced and asked if it was possible to stop the water from flowing through the hole without closing. They were then shown that this result can be obtained by screwing the bottle's cap. This experiment is counter-intuitive enough to be used by some illusionists as a magic trick. It was explained to them that it happens because, since no air can enter into the bottle, therefore no water can leave it. Individual interviews were realised by the children's own teachers. The questionnaire involved questions about their understanding of the notion of reproducibility and the importance of testing reproducibility both by the child himself and by others.

Keywords: Kindergarten, Reproducibility, Magic

1. Introduction

Since Roger Bacon at least, the effective test of the reproducibility a physical phenomenon is considered good scientific practice (Bacon, 1267), and the inability to reproduce an experiment a signature of a methodological deficiency. Nevertheless, testing the reproducibility of an experiment still appears today as an issue for professional research (Nature, 2016; McNutt, 2014). For example, the French CNRS (National Center for Scientific Research) has recently published a guide to promote responsibility and integrity in research in which they emphasized the necessity for researchers to ensure the transparency of the operations to allow the reproducibility of their experiments (CNRS, 2014) in physical sciences as well as in fields where the concept of reproducibility may appear less simple such as biology or social sciences (Zwaan et al., 2017).

This issue also appears, although implicitly, in the Next Generation Science Standards under the label "Planning and Carrying Out Investigations". (Appendix F, NGSS Lead States, 2013). The NGSS recommends that the number of trials has to be considered as early as Grade 3-5; that grade 6-8 students have to reflect on "how measurements will be recorded and how many data are needed to support a claim" ; and that grade 9-12 students have to reflect on the "accuracy of data needed to produce reliable measurements". The important issue that "all scientists performing the same procedures may not get the same results" (Lederman et al., 2014) thus appears irrelevant at Kindergarten level. The French national curriculum for Kindergarten (2 to 5 years old pupils), elementary school (6 to 11 years old children) and middle school (12 to 15 years old students) asks teachers to practice scientific inquiry but doesn't introduce reproducibility at all: it is asked that pupils 1/ identify scientific questions 2/ propose one or many hypotheses to answer to the question 3/ conceive an experiment to test them 4/ measure directly or indirectly physical quantity 5/ interpret experimental results to

conclude and communicate them with argumentation 6/ develop simple model to explain observed facts and implement approaches which are specific to sciences (Journal Officiel, 2015). At high school level, although students have to deal with errors and uncertainty of measurements and have to learn how to express a numerical result in an acceptable way (e.g. relative precision), the link with the reproducibility of an experiment is never explicitly done. Even if one could be tempted to assume that Science Teachers themselves have fully integrated the test of the reproducibility of an experiment as a core practice and consequently to consider the mention of reproducibility in the curriculum as useless, a recent French study shows that it is not always the case. Only 36% of French Physics Teachers who participated to a massive study from the French Institute of Education affirmed that an (scientific) experiment imply to be repeated many times when a multiples choices questionnaire was proposed to them, (IFE, 2011; 2376 participants). A previous study performed with French Kindergarten and elementary school teachers revealed a similar difficulty: only 12% of them cited the verification of the reproducibility of an experiment as a mean to distinguish a scientific experiment from an non scientific one (Blanquet, 2014).

Regarding pupils, Schauble (1996) and Varelas (1997) highlight that elementary school pupils have difficulties to *“conceptualize the procedure of repeating trials and finding the best representative of the results of these trials”* when these trials yield to different measurements. According to Varelas, *“some children seemed either not to have constructed an idealization which would allow them to reason that repeating exactly the same experimental situation would yield exactly the same result, or unwilling or unable to coordinate that idealization with their empirical knowledge that repeated trials do not actually produce exactly the same results”* (1997, p. 866). Metz (2010) asked 2nd and 4th-5th Grade pupils how to reduce the uncertainty of the results of their own experiments and brought out, among other results, that one strategy used by 5% of these 2nd Grade and 58% of these 4th-5th Grade was to replicate the experiment.

Studies involving Kindergarten children and proposing them explicitly to express their point of view regarding the reproducibility of an experiment nevertheless remain scarce. In a previous study, we showed that the notion of reproducibility appears accessible to 5 years old children who were interviewed on an experiment they had done at school (Blanquet, 2014, Blanquet & Picholle, 2015). This article aims to explore the ability of 5 years old pupils to consider an experiment as reproducible, independently of what has been done inside the classroom with their teacher before.

As dealing with quantitative experiments appears challenging for young children, we decided to use a qualitative experiment, for which it is easy to observe that repeating the same experimental situation will yield the same result, even if very small variations of the parameters of the experiment occurs (under the condition that the chosen experiment is robust enough). For instance, an object sinks or floats, falls or not, water freezes or not, etc.

The use of a qualitative experiment allows separating the understanding of repeating an experiment from dealing with the dispersion of measures, which is the focus of numerous studies. One difficulty of this approach consists in the fact that a child might consider as obvious the reproducibility of phenomena well-known to him, or even of a phenomenon he merely has already seen. To avoid this obstacle, we decided to use a counter-intuitive phenomenon.

Such a choice offers another advantage as a non-scientific approach would be to consider a seemingly counter-intuitive phenomenon as magical. Believing in Magic and in wizardry imply to attribute to some individuals with a special gift the ability to produce phenomena which non-gifted persons can not reproduce. From this point of view, Magic is diametrically opposite to scientific methodology, which claims the possibility for anyone to reproduce a phenomenon as a root of experimental science. Such claims are not unusual, as established by a 16-year-long project of the University of Nice, France. Henri Broch, a physicist, Gérard Majax, an illusionist, and Jacques Theodor, a physicist and sponsor, proposed a challenge with a \$250.000 prize to anyone who would have been able to demonstrate the existence of a paranormal phenomenon. The challenge was stopped after 16 years of unsuccessful tests by the team, the prize remaining unclaimed (Charpak & Broch, 2003). While ostensibly obsolete in modern societies, such magical thinking remains strong enough for many counter-intuitive experiments to generate a sensation of strangeness.

It is the case of the manipulation which consists in filling with water a can in which a visible hole has been pierced and stopping the water from flowing through the hole by closing another small non-visible hole with a finger (Novellaux, 2012), which is counter-intuitive enough for some “magicians” to use it in their shows.

We assumed that such an experiment would also appear surprising for five-year-old children. It thus provides a good situation for identifying the reactions of pupils, their ability to consider such an experiment as reproducible and their perception of magic.

Are five years old children able to consider a counter-intuitive experiment as ‘science’, and to consider their reproducibility? Do they consider this experiment as magic? In both cases, are they able to justify their position? How do they consider the necessity of testing the reproducibility of an experiment?

2. Method

2.1. Participants

The study involved 62 five to six year old children from 4 classes, belonging to two different schools from Bordeaux, in France. These schools were chosen as fairly average in France with respect to socio-economic context. The four teachers ranged from 45 to 54 years old and have a strong experience as Kindergarten teacher (between 12 and 20 years). None of them has a scientific background and during the last ten years none of them has received a continuing training in science teaching. During the scholar year, they had studied with their pupils the human body, worked on the 5 senses, they have planted grains, constructed a technical object and some of them have visited a farm or an animal inside the classroom. All these activities are included in the French Kindergarten curriculum. The pupils were taught science between 0,5 and 2h per week. All the children were interviewed in June, at the end of the scholar year.

2.2. Data collection

The students were presented with a capless bottle in which a hole had been pierced. They were first asked if it was possible to stop the water from flowing through the hole without

closing it with a finger. They were then shown that this result can be obtained by screwing the bottle's cap. They were explained that this happens because no air can enter into the bottle any longer, and thus no water can leave it, when the cap is closed. Individual interviews were realized by the children's own teachers in a quiet place. All of them used the same questions and followed the proposed order to interview the children (Table 1). A specific guideline was provided to the teacher to describe and explain the conditions required for the interview. Duration of the interviews was between 8 and 15 minutes. The interviews were by audio and transcribed for analysis.

A pilot study identified the main difficulties encountered by 5-6 years old children when dealing with the notion of the reproducibility (Blanquet, 2014) and allowed to devise relevant questionnaire. Before implementation, the questionnaire was submitted to the teachers for assuring its understanding by the children (Lederman & al., 2014). The teachers validated its formulation after minor modifications and were able to identify the purpose of the questions in terms of assessment of children's understanding of the notion of reproducibility. The questionnaire involved ten questions investigating the understanding of the notion of reproducibility and the importance of testing reproducibility both by the child himself and by others and the pupils were systematically asked to justify their answers. Question 6 relative to the possibility that the experiment may have a magical character was the only one to require an elucidation for teachers. The teachers were then interested in the answers the children may provide to this question.

Table 1. Questions asked to the children by their teacher.

English translated questions	Original French questions
1/Do you think it would work if you would do it (instead of the teacher showing the experiment)?	<i>Est-ce que tu crois que ça marcherait si c'était toi qui le faisais ?</i>
2/How could we do to know?	<i>Comment pourrait-on faire pour savoir ?</i>
3/Was it important that you also try out?	<i>Est-ce que c'était important que tu essaies aussi ?</i>
4/According to you, if I fill again the bottle with water and if you screw again the bottle's cap, will the water stop again from flowing?	<i>A ton avis, si je remplis de nouveau la bouteille d'eau et si tu recommences à visser le bouchon, est-ce que l'eau va encore s'arrêter de couler ?</i>
5/If a 9-10 years old child tells you it is not possible, what do you answer to him?	<i>Si un grand de CE2 te dit que ce n'est pas possible, qu'est-ce que tu lui réponds/dis ?</i>
6/If someone tells you that it is magic, what do you answer to him?	<i>Si quelqu'un te dit que c'est de la magie, qu'est-ce que tu lui réponds/dis ?</i>
7/Do you think that it would work if a younger child (3 years old) was trying?	<i>Est-ce que tu crois que ça marcherait/peut marcher si c'était un enfant plus petit/de PS/ de MS qui essayait ?</i>
8/Is it important that other children try out?	<i>Est-ce que c'est important que d'autres enfants essaient ?</i>
9/A child tells you that it works only because it is you. He tells you that if he tries, it will not work. What do you answer to him?	<i>Un enfant te dit que ça marche seulement/uniquement parce que c'est toi qui le fait. Il te dit que si lui le fait, ça ne marchera pas. Qu'est-ce que tu lui réponds/dis ?</i>
10/Do you think it could work if your mother was doing it at home?	<i>Est-ce que tu crois que ça marcherait/peut marcher aussi si ta maman le faisait à la maison ?</i>
11/Is it important to try out not only at school but also at	<i>Est-ce que c'est important d'essayer aussi dans ta</i>

The question 6 aimed to evaluate in which measure children make the distinction about a magical and a physical phenomenon. The realisation of performing a magical phenomenon is presumed to required specific magical skills although a physical phenomenon is presumed be reproducible by anybody : do children presumed the same and do children have a clear notion of this essential distinction between both types of phenomenon?

Previous studies (Blanquet, 2014) motivated us to distinguish the test the replicability of a phenomenon by oneself, the reproducibility by someone else, somewhere else and in a situation which involved the use of an argument of authority by a presumed more experienced person.

3. Results

The children answered all the questions and justified an average of 6 of their answers (22 children provided justifications to more than 8 answers and 10 to less than 3.

3.1. A diversity of justifications

Question 1

More than 2/3 of the children considered that the water would stop from flowing if they screwed the bottle's cap themselves, instead of the teacher (42/62, 68%), fourteen children didn't know and six thought that the water would not stop from flowing.

Nineteen children (31%) proposed a justification:

- Among them, one child used the provided explanation: *"I have understood that the air enters through the gig hole"*.
- Eleven children expressed in some way that an experiment should be reproducible to justify their answer. Five of them explained that if it had worked for the teacher, it would work for everybody (e.g. *"you did it and it's going to work for everybody"*, *"if it works with you, it can work with everybody"*) or just stated that it would work for everybody (e.g. *"because everybody can success"*). Two children explained that if they did the same thing they would get the same result (e.g. *"because if I did the same it will work too"*). Three of them assumed (e.g. *"you did it, it can also works for me"*) and one expected by induction that the result would be the same for them as for the teacher (*"If it works for you, it has maybe to work for me"*).
- One child spontaneously used the word Magic to justify: *"because I always do magic at home"*
- Six children proposed justification fully unrelated to the reproducibility (e.g. *"because I'm 5 years old"*)

Question 2

Question 2 was not directly related to the reproducibility. 25 children proposed to try out (40%) and one child expressed his surprise: *"It works, it is Magic!"*

Question 3

Forty-five children (73%) consider it important to try out, ten don't know, and seven didn't think that it was important for them to try out. Thirty-two of the children (52%) provided a justification. Only four of these justifications came from children who considered that it wasn't important to try out: three of them are not related to reproducibility (e.g. *"because it takes too much time"*, *"because I wanted to do it"*) and one refines his mind: *"it is important*

only if someone has lied or something like that’.

Among the twenty-eight other justifications:

- 1 child who has taken the initiative to try out without waiting the teacher to ask the question explained that it was important “*because I wanted to see if you were a wizard or not*”
- 3 children who didn’t know if the experiment was reproducible, or who thought that it wasn’t, explained that it allows to know the answer (e.g. “*If I hadn’t tried out, I would not have known if it worked*”, “*because if you don’t try out, you can not know the answer*”)
- Four justifications come from children who justified their answer to the question 1 by using the reproducibility of an experiment. Two of them explained that it was important to try out to check their idea: “*We try out and then we are sure*”, “*We have seen that it was working for me*”. One who thought that the experiment was reproducible by everybody noticed a parameter to be controlled to ensure it: “*because, if not ([try out], you could not succeed. If you don’t close well the cap, you could have thought you had not succeeded*”. The last one who affirmed previously “*because it is the same*” explained that it was important for him to try out “*because he didn’t know if he would succeed*”.
- 18 were not related to the test of reproducibility (e.g. “*Because I didn’t know how to do it*”, “*I will be able to show to my parents and they can say it is good*”)
- 2 children merely emphasized the necessity to try out: “*because you always have to try out*”, “*Everybody has to try out*”

Question 4

Forty-seven children considered that the same thing will happen if they re-do the experiment (76%) and forty-three justified their answer (69%). Eleven justifications came from children who *didn’t* know (5) or thought that the water will not stop flowing again (6).

- 5 justified by the fact that “*It is always the same*”
- 6 used their previous result to conclude it will work again (e.g. “*because when I had try out, it had worked*”) and among them, two use induction (e.g. “*if it has worked the first time, it will work the second time*”, “*As I have done it, it will work again and I and you did it, it makes two of us*”)
- 4 used the explanation provided to them (e.g. “*Air doesn’t enter anymore and water doesn’t flow out*”)
- 5 explained it is linked to the cap which has to be closed (e.g. “*When you close the cap, water doesn’t flow anymore*”), one being not sure of the result (“*I think it is because you have always closed the cap*”)
- 7 explained their answer by introducing a new parameter: it is the same if they do without help (1) or with two hands or with more or less water, on being not sure that changing the amount of water has an influence (e.g. “*maybe if there is more water, it will flow out*”) and two thinking it changes the result (e.g. “*There will be too much water and it doesn’t work*”)
- 4 were not sure of the replicability of the phenomenon (“*As I have already done it, maybe it’s going to work*”, “*I think it will re-do the same*”)
- Thirteen children’s justifications were out of scope (e.g. “*I want to do it again*”, “*My brother said that*”)

Question 5

Almost all the children (51/62, 82%), considered that it is possible to prevent the water from flowing out, even if an older child says so. Sixteen children (26%) argument:

- 4 proposed to show the experiment and another one propose the older child to try out

and explain *"If it doesn't work, I tell him you have to be younger"*

- 2 explained the phenomenon (e.g. *"because air can stop the water"*)
- 2 used the authority of the teacher (e.g. *"An adult has said it to me and he know better than you"*)
- 6 used the primacy of experience (e.g. *"because I have already try out"*)
- Only 1 used the reproducibility's argument to answer: *"because it is always the same"*

Question 6

Children were divided on the answer to provide to someone who affirm that it is magic. 34 children would respond to someone who says "it's magic" that it is not (55%); 20 agree it is magic and 8 don't know.

Twenty-one children (34%) provided a justification; sixteen justified it by stating that "it's not magic" and 5 that "it is magic".

- 7 used an explanation: 5 explained that the air prevented the water from flowing out and in two cases related this explanation to magic (e.g. *"Air enters and water goes out, it is magic"*); 2 provided another explanation (the cap which closes the bottle or the presence of the hole) and used it to justify that it was not magic.
- 3 associated magic with a specific tool: *"because there is no magic wand"* (No), *"my hands and a scarf make magic"* (Yes), *"at home, I don't have magic but I still have a magic wand to make magic"* (Yes).
- 6 proposed arguments relative to the supposed characteristics of a magical phenomenon to eliminate the possibility (*"because it is easy to do"*, *"because I have done it"* (2), *"because water doesn't disappear"*), by explaining *"someone has taught it to me"* or that *"it looks like magic but it is not"*. Another child, aware that the phenomenon is not magical, still precized *"well, it is rather a little bit magical"*.

Among the 20 children who proposed a justification suggesting the idea of reproducibility in the previous questions, 6 qualified the experiment as magic but only one justified this answer by the fact that *"it is fun"*. Six out of the other fourteen children justified their answer by the proposition that magic doesn't exist without some specific tool supposedly characteristics of a magical phenomenon, such as a wand.

Question 7

Forty-four children (71%) considered a child younger than themselves can observe the same result if he follows the same procedure; seven considered that the younger child would not and eleven didn't know. Forty children justified their answers (65%):

- 9 identified technical problems as a source of difficulty for the young children (closing the cap, stabilizing the bottle)
- 3 explained that a very young child (2-3 years old) would not be able to obtain the result, but one of an intermediate age (3-4 years old) would
- 4 think that young children "don't know"
- 7 were out of scope (e.g. *"Mom told me"*)
- 4 explained that the observations was possible with anybody
- 8 induced that, since the experiment was working for them or for the adults or older children, it would also work for the younger one (e.g. *"because the older can do, it means the younger also can"*, *"if it works with me, it works with younger"*)
- 3 considered the similitude of the apparatus (e.g. *"because it is the same objects"*)
- 1 explained it by the fact that the same physical process were involved: *"there will be no air and after water can not flow out"*
- 1 made the hypothesis than *"maybe it works because with us it works"*

Question 8

Forty-two children (68%) think it is important that different children try out, 5 don't know and fifteen think it is not.

Forty-four children (71%) provided a justification:

- 7 focused on the interest to know or to learn (e.g. *"everybody has to know"*)
- 6 considered it important to try out (e.g. *"You have to try out"*)
- 10 would like others to be able to do the experiment (e.g. *"For everybody to be able to do it"*)
- 2 wanted to share with parents or friends (e.g. *"To explain to my parents"*)
- 12 were out of scope (e.g. *"Mom explained to me"*, *"Water will stop flowing out"*)
- 3 insisted that it would depend on the other children's willingness to do the experiment (e.g. *"If they like to do it"*)
- 3 considered it important to check whether the experiment worked with other children or not (e.g. *"because we don't know if they can do it or not"*, *"because they try out and we see if they can succeed"*, *"to see if they can do it"*)
- 1 commented that *"if they try out and are afraid it is not going to work, they do it and it will work"*

Question 9

Fifty children (81%) considered at this stage that the experiment didn't work for them only; 10 didn't know and two affirmed that they were the only ones but didn't justify this assertion.

Thirty-eight children justified their answers:

- 15 explained the child has to try out
- 6 affirmed to the child that *"it works"*
- 4 answered out of scope (e.g. *"It is not important"*)
- 5 proposed an explanation: closing the cap is the solution (e.g. *"when you close the cap, air doesn't pass anymore"*)
- 2 who "didn't know" said that *"maybe it is going to work for you, first you have to try out"* or *"maybe it will"*
- 3 affirmed it works for everybody
- 3 reintroduced magic inside their answer: *"it is just magic but as you can do it, all the children can do it"*; *"I can do it, why don't you manage to do magic?"*; *"If it works, it is a magic trick, if I tell him, he will believe it"*

Question 10

Fifty-six children (90%) considered that, if their mother did the same experiment at home, the same thing would happen, three didn't know and three thought that the same things would not happen. Fifty-one justified their answers (82%):

- 22 answers were irrelevant (e.g. *"My Mom always do it"*)
- 12 focused on the fact that their mother is an adult, or just older
- 2 induced that if the experiment worked with them or the teacher, it would also work for their mother (e.g. *"because you did it, it works with adults"*)
- 4 focused on the similarity of the apparatus (e.g. *"if she takes the same objects, it will work"*)
- 3 considered that it would work with anybody
- 3 considered that if it worked at school, then it would also work at home and 1 affirmed that it will work anywhere
- 4 considered that it would always work

Question 11

Forty-one children (66%) considered it important to try out at home, 16 didn't think so and 5 didn't know. Forty-four children (71%) justified their answers:

- 16 answers were irrelevant (e.g. *"Because your dad also told me the same"*)

- 13 children explained that redoing it would help to remember or learn it (e.g. *“because I want to get it”*)
- 7 children wished to share the experiment with their family (e.g. *“all the family will know”*)
- 1 explained that *“it is very important, very special, very magic”*
- 2 considered it important to try out in both places
- 3 focused on the ability to do the experiment anywhere: *“we can do it everywhere”*, *“in all the buildings we can do it, wherever we want”*, *“we can do it wherever we want”*
- 2 considered it important to try out in two different places to check that it didn’t change the result: *“we can see it works”*, *“to see if it works everywhere”*, *“it is important to try out everywhere”*

3.2. Synthetic table

Table 2 synthesizes the justifications used by the children to affirm at some level the notion of reproducibility.

Table 2. Categories of answers related to the notion of reproducibility and number of answers for each category (25 children, one child can belong to more than one category).

Type of answer	Q1	Q4	Q5	Q7	Q9	Q10	Q11	Total	%
Results of the experiment independent of the person who makes the experiment (<i>“it works for everybody”</i>)	5			4	3	3		15	24%
Identification of similitude between what is proposed and what has been done (<i>“because it is similar”</i>)	2	5	1					8	13%
Results of the experiment independent of the place (<i>“it works everywhere”</i>)						3	6	9	14%
Consideration of the similitude of materials or conditions (<i>“because it is with the same objects”</i>)				3		4		7	11%
Reference to the fact it has already been try out and it works (<i>“I have already tried out and it has worked”</i>)		5						5	8%
Induction from the result of its own experience to the result of other children (<i>“If it works with me, it works with younger children”</i>)				8				8	13%
Induction from the result of the teacher to its own result (<i>“you did it, it can also work for me”</i>)	4							4	6%
Induction from the result of the teacher to the result of other adults (<i>“because you did it, it will work with adults”</i>)						2		2	<1%
Generalization from the fact that the result was similar for two different persons to everybody (<i>“as I have done it and you have done it, we are two, it will work again”</i>)		1						1	<1%
Total	11	11	1	15	3	12	6	59	

3.3. Children expressing reproducibility and its importance

Among the 62 children, only 26 were able to justify their answers by referring directly or indirectly to the notion of reproducibility for one question at least.

For twelve of them (20%), the reproducibility of an experiment is mobilized 3 to 4 times.

Nine (14%) expressed twice justifications related to reproducibility and repeated the provided explanation to justify their answer. And for five of these children, this expression appeared at the very end of the questionnaire (Q9-Q11).

Seven children call upon reproducibility just once and three of them expressed it as a mere possibility.

Only one child (with five justifications based on reproducibility) expressed an interest to try out the experiment by himself in term of checking its reproducibility (“*We were able to see it was working for me*”).

Only three children appeared able to consider that it was important to check whether it worked the same way with other children (Q8) and two appeared able to consider that it was important to check that it worked the same way in different places (Q11).

4. Discussion and conclusion

Five-year-old children appear to be able to consider a counter-intuitive experiment as reproducible. Their perception of Magic doesn't seem incompatible with the possibility to reproduce an experiment themselves and the word *magic* doesn't seem to have a strong value for them, besides being used to express that they considered doing the experiment rather fun. For one child, who spontaneously wanted to try out “*because I wanted to see if you were a wizard or not*” (Q3), the magical character of a phenomenon was associated with his own ability to reproduce it, but such an association doesn't appear clearly through the answers of the children to the question Q6.

In both cases (questions about reproducibility or about magic), less than half of them appear able to justify their position in a relevant way.

42% of them (26/62) provide an explanation integrating an element related to some level of understanding of the reproducibility of an experiment but the independence of the result to the place (14%) or the operator (24%) is seldom evocated, such as the necessity to control the conditions or the similitude of the materials (11%). Nevertheless, some of them appear able to build explanations based on the experiment they have just witnessed. The children's understanding of the interest of testing the reproducibility appears quite poor (less than 7% of answers justifying the interest of such a test) and less important for an experiment they just discover than for a well-known experience (up to 25%, Blanquet & Picholle, 2015), which corroborates previous experiments (Metz, 1995).

These first results strongly suggest that it is possible to work with 5-6 years old children on the notion of reproducibility. Moreover, the developed questionnaire based on the discovery of a new experiment appears well-understood by children. A next step will be to identify its ability to discriminate children having specifically worked on reproducibility from other children.

In this study, no special provisions were made to insure that the teachers explicitly insisted on the importance of reproducibility or even mentioned the term in front of the pupils. Further observations would be needed to establish whether an explicit work on the reproducibility of every experiment performed in the frame of scientific inquiry would allow more children to get a better grasp of the notion of reproducibility and the usefulness of its test. Nevertheless, it is common knowledge among Kindergarten teachers that young children love to perform the same activity again and again. It thus seems plausible that a mere explicit emphasis on the

usefulness of this practice might help pupils learn the concept of reproducibility in scientific experiments better.

5. References

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