Two Attainable Skills in Kindergarten : Testing reproducibility and robustness in an experiment

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TWO ATTAINABLE SKILLS IN KINDERGARTEN: TESTING REPRODUCIBILITY AND ROBUSTNESS IN AN EXPERIMENT

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Abstract: Basic elements of scientific methodology are presented as a frame of reference, and a tool to design and implement inquiry-based sequences to 64 Kindergarten teachers. Questionnaires show that teachers welcome the explicit presentation of these elements. Among these, primacy of experiment, reproducibility and robustness of an experiment are considered relevant and attainable skills for their 5-6 y.o. pupils. After implementing relevant IBSE sequences, a large majority of pupils are indeed convinced that changing the *place* of an experiment shouldn't modify its result, but don't grasp the interest of testing the reproducibility of an experiment with a different *operator*. They also appear able to properly identify and, to a certain teacher-dependant extend, to discuss the relevance of a parameter, and can be brought to test the robustness of an experiment. These results were obtained through semi-directive interviews of 68 children from 3 classes of "Grande section de maternelle" two weeks after they had hosted a workshop around an experimental sequence in a festive science event.

Keywords: Early childhood education; inquiry oriented teaching; Nature of science

INTRODUCTION

It is now generally accepted that, with adequate supervision, children as young as 5-6 y.o. can perform (pre-)scientific inquiries. In France, Inquiry-Based Science Education (IBSE) has been since 2002 the recommended method for introducing very young children (*école maternelle*) to "discovery of the world" practices. In the spirit of *La Main à la Pâte* (Charpak & al., 2005)*,* French programs promote the well-known scientific-like sequence *Proposition of an idea / Test / Conclusion* (Coquidé & Giordan, 1997). The scientific approach to experimental activities involve many skills, among which the willingness (a) to give the primacy to the experiment when in contradiction with a discourse, and (b) to check the reproducibility and (c) the robustness (Wimsatt, 2007) of the considered experiment stand out as key features.

We have previously shown that 5-6 y.o. children can be brought to claim the primacy to the experiment when appropriate (Blanquet & Picholle, 2012). The present communication deals with the reception of reproducibility and robustness constraints, first by kindergarten teachers, then by children.

To this effect, we have integrated these constraints into inquiry-based sequences (Blanquet, 2010). We have implemented such sequences directly with kindergarten teachers and through them with 5-6 y.o. children. Questionnaires and interviews have then been used to evaluate their appropriation by both populations.

PERCEPTION OF SCIENTIFIC METHODOLOGICAL SKILLS BY KINDERGARTEN TEACHERS

Method

Five basic elements of scientific methodology have been emphasised to 64 kindergarten teachers during continuing training provided by one of us: namely, primacy of experiment; reproducibility of an experiment; its robustness (i.e. a minor modification of the conditions of an experiment does not change dramatically its result, Wimsatt, 2007); navigation between specific and general formulations; navigation between the real world and its representations. The trainees' reactions to the situations provided the practitioner/researcher with opportunities to explicit these elements in context and to emphasize their significance for qualifying an activity as scientific. At the end of the training, we asked them whether they would answer an anonymous questionnaire, considering that their training contained an original approach. All of them volunteered. They were then asked about the utility of this new tool for their usual practices; if and how they would apply it; and to classify the elements of methodology from the easiest (rank 1) to the most difficult (rank 5) to implement.

An unambiguous emphasis on primacy, reproducibility & robustness

63 (98%) of these kindergarten teachers answered that they considered the tool as "very useful". 3 main uses were spontaneously offered: a frame of reference to ascertain the scientific or relevant value of their inquiries (35 answers), a guideline for the preparation of their sequences (20) and the implementation of them (21). [Figure 1]

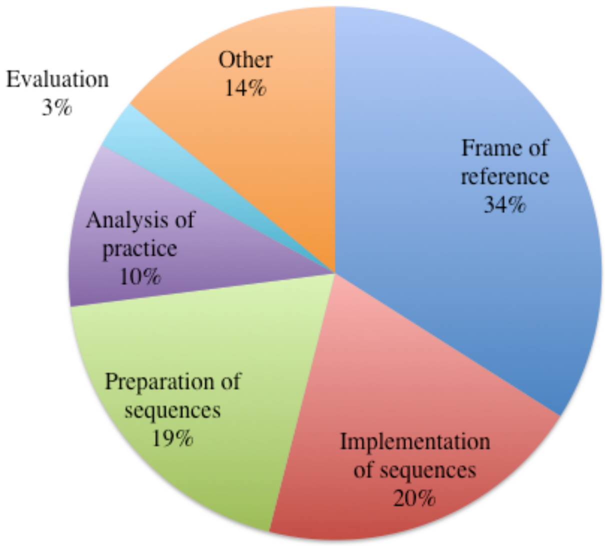

Figure 1. Relative weight of the different uses spontaneously considered by Kindergarten Teachers (100% = 104 elements of answer; an answer can incorporate several elements)

Primacy of experiment and reproducibility stood out, as they were respectively classified by 77% and 73% of the participants in either rank 1 or 2, whereas less that 10% considered them in ranks 4 or 5. Next, 80% of the answers classified robustness in either rank 2 or 3.

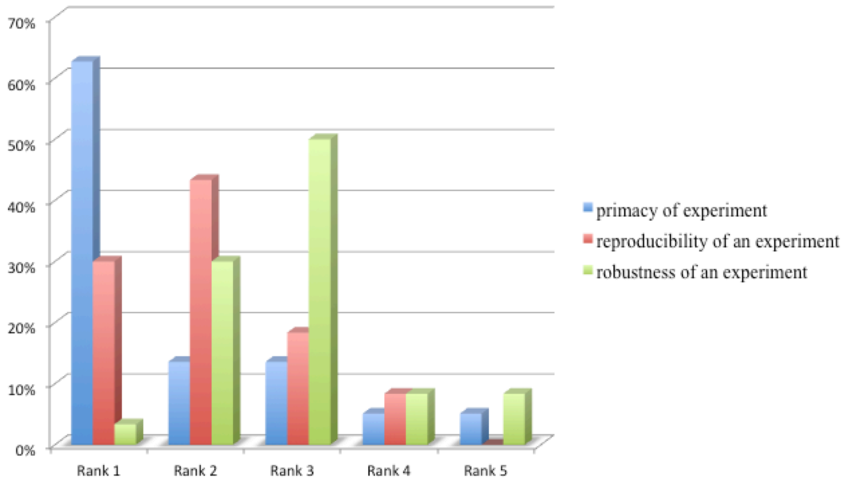

Figure 2. Relative weight of primacy of experiment (blue), reproducibility (red) and robustness (green) as classified by kindergarten teachers from the easiest (rank 1) to the most difficult (rank 5) to implement.

It thus appear that, even after a rather short introduction, reproducibility and robustness are overwhelmingly considered by kindergarten teachers as relevant and attainable skills for their 5-6 y.o. pupils.

Moreover, the explicit presentation of methodological elements appeared to help these teachers to distinguish between scientific and non-scientific activities (Picholle & Blanquet, 2016).

ACTUAL IMPLEMENTATION BY KINDERGARTEN PUPILS

Context

Several of the considered teachers rapidly reinvested these ideas during festive scientific events, as they were encouraged to. After due training in class, their 5-6 y.o. pupils proposed inquiry-based workshops to other 5-7 y.o. children. We were able to follow three such classes, involving 68 children overall. All three implementations allowed the test of both reproducibility and robustness, although through different modalities:

— The first one implemented an experimental inquiry about the capacity of various containers, by transferring liquids between them. The robustness of this experiment was checked through the use of liquids of various colours, a supposedly irrelevant parameter.

— The second class' workshop involved building hourglasses, then trying to compare and adjust their durations. A differently coloured sand was used in a reference hourglass.

— The third class investigated the best material to build a snow globe. The children used different recipients without checking the relevance of this parameter.

During inquiries children worked by small groups and shared their results. In each class, all children performed the experiment and got the same results. During this event, they relied on reproducibility to establish the results with their schoolmates.

The three teachers independently decided not to discuss explicitly the significance of reproducibility and robustness with their pupils.

Method

We designed a semi-directive questionnaire and interviewed the children by pairs, in their schools, two weeks after the scientific event (June 2013). The questions were contextualized to help the children understand them, after a preparatory study helped us to optimize the formulations of the questions and adjust them to the language abilities of children. All the interviews were audio and video recorded and transcribed for analysis (Blanquet, 2014). [Raw transcriptions are available to interested researchers upon simple mail request to E. B.]

Results about reproducibility

Table 3 synthetises the results about reproducibility. In all classes, a large majority of pupils (30/35 pairs, or 85%) are convinced that changing the *place* where an experiment takes place doesn't modify its result; 23/35 pairs justified their answer. On the other hand, the independence of the result regarding the *operator* is not obvious for 17/35 pairs (38% of the children), and only 11/35 justified their answer. The interest for a same person to redo an experiment is only perceived by a few children (9/35, 25%).

Table 3. Synthesis of the answers of 68 pupils (35 interviews) regarding the notion of reproducibility of an experiment. The data indicate the number of interviews in which a typical answer or a close equivalent appears. Left: Probe questions (translated from the French original, in italics). Second column from the left: typical answers. Last three columns: Number of occurrence of the answer (or a close equivalent), by class. The answers allowing the interviewer to validate the skill are underlined.

Probe (questions involving reproducibility)	**Typology of pupil's answers**	**Number of occurrences**		
		Transfilling (11 gp.)	**Hour-glass (12 gp.)**	**Snow-Globe (12 gp.)**
Deux enfants différents font la même chose sur ton atelier ; est-ce qu'ils peuvent trouver des choses différentes ? Can two different children find different results if they do the same thing on your workshop?	Do not know		3	2
	Yes	3	2	4
	No, without justification	8	5	1
	No: "do the same thing, get the same result!"		4	7
	Other	1		2
Ils te disent qu'ils trouvent des choses différentes : que fais-tu ? They tell you that they found different results. What will you do?	Do not know	3		
	"I say they made a mistake"		1	2
	Ask them to try again.		1	2
	Other	1		1
Un enfant sur le jardin des sciences te dit que ce qu'il a fait marche sur le jardin des sciences parce que c'est un jardin des sciences mais que dans sa classe cela ne marchera pas. Que lui réponds-tu ? During the science fair, a child insists that what he has done there happened because it was	Assure him it would work the same way.	2	5	
	Assure him it would work the same way, since I've myself done it in my classroom			3
	Assure him it would work the same way anywhere.	7	5	8
	Other	1 Try to find an explanation		1 ("You have to believe us")

a science fair, but wouldn't work in his own classroom. What will you answer to him?	Do not know		1	2
Cela sert-il à quelque chose de refaire plusieurs fois la même chose d'après toi ? A quoi cela sert-il de refaire plusieurs fois la même chose d'après toi ? According to you, is there any point in redoing several times the same thing? To what end would one do several times the same thing?	There's no point.	5	2	8
	We redo "to find out"	3	2	1
	We redo "to better keep it in mind"	1	5	1
	We redo "to be on the safe side"		2	3
	We redo "to be more certain"		2	1

Results about robustness

Table 4 synthetises the results about robustness. Most children are able to properly identify the relevance of a parameter (100% for the first and third classes and 83% for the second class). The usefulness of testing the robustness is however mainly perceived after a specific work in the classroom (first class), and by less than half of the concerned children. Without a specific work, only 4/48 (8%) children were able to identify its methodological interest.

Table 4. Synthesis of the 3 classes' answers regarding the relevance of parameters for an experiment. (same conventions as for table 3.)

Probe (questions involving robustness)	**Typology of pupil's Answers**	**Number of occurrences**		
		Transfilling (11 gp.)	**Hour-glass (12 gp.)**	**Snow-Globe (12 gp.)**
En classe/sur le jardin des sciences, vous avez changé le [paramètre indifférent dont la non pertinence a été vérifiée en classe]. Pourquoi ? In the classroom/ during the event, you have modified [*irrelevant parameter which relevance was tested in class*]. Why did you do that?	To follow a demand from the teacher	1	X (non adapted question)	
	For the pleasure of trying out different things	2	X	
	To see if the result is modified	5	X	2
	Specifically called by the investigation		X	11
	Do not know	3	X	2
A quoi cela sert-il d'essayer avec des [éléments dont un paramètre non pertinent connu varie] différents ? Why is it useful to try out with [*variation of an irrelevant parameter*]?	Do not know	1	X	X
	To see if it changes anything to the result	5	X	X

Est-ce que cela change quelque chose si au lieu d'utiliser [élément avec un paramètre indifférent non travaillé en classe] on prend [autre élément avec une variation de ce paramètre indifférent non travaillé en classe] ? Does it change anything if instead of using [*element with an irrelevant parameter not studied in class*], we use [*other element with a variation of said parameter*]?	No, identification of a new irrelevant parameter	11	10	12
	Suggest to try out to be sure	2	5	2
Est-ce que c'est important de vérifier ? Is it important to try out?	No "because we know", appeal to a generality	3		
	No			2
	Yes, without relevant justification	2	2	
	Yes, to know		6	6
	Yes, to be sure because we could make a mistake		4	3
Est-il utile de changer des choses pour voir si cela change le résultat ? Is it useful to change something to see if the result changes?	No	3	6	2
	Yes, without relevant justification		4	
	Yes, to see what happens	1	1	1
	Yes, to check that it really doesn't change			2

CONCLUSION

Explicit elements of scientific methodology appear to be welcomed by kindergarten teachers, who often admit having troubles with the somewhat ambiguous status of "Discovery of the world" activities. Primacy of experiment, reproducibility and robustness are overwhelmingly plebiscited as the most relevant methodological skills attainable by 5-6 y.o. children. When actually implemented in the classroom, these elements are adapted by the teachers and duly included in experimental sequences, but not explicitly discussed (all considered teachers, but a sample too small to generalize this result).

5-6 y.o. children thus appear mostly able to discuss relevant and irrelevant parameters in a given experiment. While they grasp the concept of reproducibility with regard to location, they do not appear to perceive the interest of checking it for various operators. Their grasp of the concept of robustness of an experiment appears to be strongly teacher-dependant.

Although further experimentations will be needed before any generalisation of these results, they strongly suggest that it is possible to work on rather sophisticated “good experimental practices” with 5-6 y.o. children, and that kindergarten children would welcome such practices. Such an early initiation would also provide the children with an easy way to build a sound, criteria-based first representation of science. Its long-term influence on their science education nevertheless remains to be studied.

REFERENCES

Blanquet, E. (2010). *Sciences à l'école côté jardin*. Nice : Somnium. [in French]

Blanquet, E. & Picholle, É. (2012). Inquiry-based analysis of early years children books: Developing skills for later science education. *ESERA Proceedings*, Lyon, France.

Blanquet, E. (2014). *La Construction de critères de scientificité pour la démarche d'investigation : une approche pragmatique pour l'enseignement de la physique à l'école primaire*. PhD Dissertation: Un. Nice and Geneva. [in French]

Charpak, G., Lena, P. & Quéré, Y. (2005). *L'Enfant et la science. L'aventure de La main à la pâte*. Paris : Odile Jacob. [in French]

Coquidé-Cantor, M. & Giordan, A. (1997). *L'Enseignement scientifique et technique à l'école maternelle*. Paris: Delagrave. [in French]

Picholle, É. & Blanquet, E. (To be published, 2016). About the scientificity of pancake-making: a criteria-based approach. *ESERA 2015 Proceedings*, Helsinki, Finland.

Wimsatt, W. C. (2007). *Re-Engineering Philosophy for Limited Beings*. Cambridge, U.S.A.: Harvard ed. Univ. Press.