

How does the model of Inquiry-Based Science Education work in the kindergarten: The case of biology

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ABSTRACT

This paper reports on seven case studies that were carried out in the context of the “Fibonacci” project and have to do with implementing inquiry-based didactic sequences of biology in kindergarten classes. The aim is to shed light on the teaching and learning practices that may be activated in a non-traditional educational setting such as the one of IBSE and the extent to which they actually are. The classes that took part were run by teachers who received IBSE-training as members of the local “Fibonacci” network. These classes were observed by us with the “IBSE diagnostic tool” that has been developed in the context of the project. The analysis of our data shows that the participating teachers were successful in activating most of the teaching practices that are required for building on children’s ideas, some of those required for supporting children’s investigations and all of those required for prompting children to communicate their ideas. On the contrary, teachers appeared to have significant difficulties in activating the teaching practices that have to do with the crucial phase of conclusions. Finally, children showed difficulties in the phases of investigation and conclusions - particularly in learning practices such as making/testing predictions or interpreting results - that haven’t been adequately prompted by the teachers.

KEY WORDS

Inquiry-Based Science Education, biology in early childhood education, teaching practices in kindergarten, learning practices in kindergarten

RÉSUMÉ

Cet article rend compte des sept études de cas qui ont été réalisées dans le cadre du projet "Fibonacci" et concerne la mise en œuvre des séquences didactiques de biologie basées sur le questionnement dans des classes d'écoles maternelles. L'objectif est d'élucider les pratiques d'enseignement et d'apprentissage qui peuvent être activées dans un cadre pédagogique non traditionnel comme celui de l'enseignement des sciences fondé sur l'investigation et la mesure dans lesquelles elles ont été faites. Les enseignants des classes participantes ont reçu une formation sur l'enseignement des sciences fondé sur l'investigation en tant que membres du réseau local «Fibonacci». Nous avons observé ces classes avec «l'outil de diagnostic d'enseignement des sciences fondé sur l'investigation» développé dans le cadre du projet. L'analyse de nos données montre que les enseignants participants ont réussi à activer la plupart des méthodes requises pour s'appuyer sur les idées des enfants, certaines des méthodes requises pour soutenir leurs enquêtes et toutes celles requises pour les inciter à communiquer leurs idées. Au contraire, les enseignants ont eu des difficultés importantes à mettre sur pied les pratiques pédagogiques concernant la phase cruciale des conclusions. Enfin, les enfants ont présenté des difficultés dans les phases d'enquêtes et de conclusions -en particulier dans les pratiques d'apprentissage comme la fabrication/le test des prévisions ou l'interprétation des résultats- qui n'ont pas été suffisamment motivées par les enseignants.

MOTS-CLÉS

Enseignement des sciences fondé sur l'investigation, biologie à l'école maternelle, les pratiques d'enseignement à l'école maternelle, les pratiques d'apprentissage à l'école maternelle

INTRODUCTION

The improvement of science education continues to be sought under the influence of the idea that science informs many aspects of contemporary life of citizens and in this respect science is a cultural good. However, research has shown in many cases that science concepts are difficult to access and not always interesting to many students. The introduction of scientific inquiry in the classroom has been suggested as a way to deal with the above. In fact, several science education organizations in USA (NRC,

2012), Europe (La main à la pâte, 2000; Charpak, Léna, & Quéré, 2005; Osborne & Dillon 2008; Worth, Duque & Saltiel, 2009), and Australia (Goodrum, Hackling & Rennie, 2001; Tytler 2003, 2007), as well as international committees and associations (European Commission, 2007; Inter Academies Panel, 2006) have tried to introduce innovative, inquiry-based science education (IBSE) curricula. The latter are recently considered as worth-funding by the European commission (i.e. Pollen project, Fibonacci project).

Inquiry in science education is an old idea (for history and rationale of inquiry-based pedagogy see the article “Inquiry-based learning in science and mathematics” by W. Harlen in this issue). The importance of interaction of learners with materials stems from the Piagetian view of learning. This idea has been combined with the Vygotskian view of teacher - pupil interaction (Vygotsky, 1978) and the Ausubel’s theory of meaningful learning (Ausubel, Novak & Hanesian, 1978). Many projects in the past have dealt with the design of educational materials and situations that would develop knowledge – “scientific content” – in parallel with the development of “skills” associated to the scientific method that is used for the construction of knowledge (Lawson, 1995; Harlen, 1996, 2010). Inquiry based teaching approaches rely on the assumption that students will benefit if they try to find solutions to scientific problems encountered in everyday life, by asking questions, thinking of possible explanations, conducting investigations and drawing conclusions (Krajcik et al., 2000; Linn et al., 2003).

The IBSE model that was recently disseminated through the European project Fibonacci (Fibonacci project <http://www.fibonacci-project.eu/>) is set in the framework of social constructivism (Driver et al., 1994) and assumes that the understanding of scientific concepts is facilitated through inquiry, while the ultimate outcome of inquiry enhances the joy of learning and favours the development of curiosity and creativity. Being engaged in the process of investigation, students can also develop their reasoning skills by collaboratively formulating and evaluating possible explanations about the phenomenon they investigate. This may require from them to challenge their related preconceptions and realize the need to elaborate them and reach a new consensus about what is valid or not. The key elements of the IBSE model are the following: (a) experience as a key element for learning scientific concepts, (b) meaningful understanding of the problem of inquiry by pupils, (c) development of basic scientific skills like “observation”, (d) development of reasoning / argumentation, (e) use of secondary resources, and (f) promotion of collaboration. These actually require specific pedagogical strategies that concern (a) leading pupils to the design of experimental tests, (b) leading pupils to the analysis of data and to the formulation of conclusions, and (c) evaluating the newly acquired knowledge of pupils in relation to the scientific knowledge.

An important issue is how effective inquiry-based teaching actually is, with regard to students’ scientific understanding and reasoning. There have been research studies that attempt to measure the effect of inquiry-based science instruction on learners’

achievement. Minner et al. (2010) reported their results from reviewing 138 research studies concerning the impact of inquiry science instruction on K-12 student conceptual learning. In the studies of their review which were mainly carried out in USA, there was a clear positive trend in favour of inquiry-based instructional practices that promote students' active involvement in investigating and drawing conclusions. In other words, it was clear that student-centered, inquiry-based learning environments are *more likely* to enhance conceptual understanding compared to teacher-centered ones.

Marx et al. (2004) have reported a three-year longitudinal study which showed that inquiry-based science teaching seems to enhance the achievement of *low* achievers in science. Moreover, Gibson and Chase (2002) examined the long-term impact of an IBS program on middle school students' attitudes toward science and found that the positive attitudes that had been developed were also maintained and combined with a higher interest in science.

The IBSE model has also been implemented and studied with much younger learners. Samarapungavan, Mantzicopoulos and Patrick (2008) and have developed a Science Literacy Project (SLP) for kindergarten students and they found that intervention students demonstrated a functional understanding of scientific inquiry processes and of important life science concepts during their investigations. Students that attended six science units during the school year showed significant science learning gains, as well as an enhanced functional understanding of scientific inquiry (Samarapungavan, Mantzicopoulos & Patrick, 2011). In another study, Patrick, Mantzicopoulos and Samarapungavan (2009), present findings concerning the motivation of kindergarten students for science. They actually show that SLP children, regardless of their sex, have greater motivation for science than children having only the regular science sessions. On the contrary, in regular classrooms there is a sex-related difference with boys appearing to like science more than girls.

Although it is rather obvious that students' practices are closely related to the practices of their teachers, there seems to be less research on the latter. Fitzgerald, Dawson and Hackling (2013) reported on effective science teaching on the basis of classroom observations and teachers' interviews. Their research questions concern teachers' beliefs about their science teaching and the learning of their students, as well as the effect that these beliefs may have on the way they implement inquiry in their classrooms. Science teaching consists of elements that dynamically interact with each other, rendering its effectiveness situated in particular contexts.

Delclaux and Saltiel (2013) have interviewed and also observed teachers in their classrooms, in order to evaluate teacher support strategies provided by pilot centers for implementing IBSE in French primary schools. Their ultimate objective was to provide information concerning professional development strategies used in the "*La main à la pâte*" project that was implemented in France. According to their findings,

the educational resources that have been provided to the teachers were essential and useful, but not enough. In order to be able to effectively use these resources, teachers need to have a background on IBSE. In fact, there seems to be a need for long and continuous teacher support both with pedagogical and scientific emphasis for changing teacher practices. One interesting conclusion emerging from this work is that the most effective teacher support was provided by persons with *pedagogical* instead of scientific training, showing that science students that are used by some professional development centers are not sufficient to provide the support needed. On the contrary, experienced teachers and teacher trainers are likely to be more knowledgeable in this respect.

Nevertheless, we need to have more research evidence about how teachers actually deal with the demanding task of implementing IBSE in real classrooms from kindergarten to high-school and how their students react. Although qualitative in nature, studies of classroom practice might benefit significantly from the use of an observation tool that would monitor the actions of both teachers and their students. This could make possible to compare different contexts of implementing IBSE with regard to their educational effectiveness. The Fibonacci class-observation tool (see “IBSE diagnostic tool”) that was developed for the evaluation of IBSE in the classroom provides the opportunity to check whether a series of inquiry teaching and learning practices are actually taking place.

This paper is particularly concerned with kindergarten teachers and students and thus employs the kindergarten version of the Fibonacci observation tool. Our focus is set on giving insights on the implementation of the IBSE model in the Greek Kindergarten, which hosts children of 4-6 years of age. Studying how teachers and students act when working with IBSE was carried out in biological learning environments that we have designed according to the IBSE principles. Our objectives and research questions are presented below in more detail.

Objectives & Research Questions

The objective of the paper is to shed light on the ways that kindergarten teachers and pupils may act in the context of inquiry-based didactic sequences that have to do with biological topics. In other words, we aim at highlighting the teaching and learning practices that may be activated in a non-traditional educational setting such as the one of IBSE and the extent to which they actually are. So, the questions we address here are following:

- “What might be the actual role of kindergarten teachers while implementing an inquiry-based didactic sequence in the context of biology?”. More specifically, “Which of the inquiry teaching practices may be more difficult for them to activate?”.
- “What might be the actual role of kindergarteners while taking part in an inquiry-

based didactic sequence in the context of biology?”. More specifically, “Which of the inquiry learning practices may be more difficult for them to activate?”.

The answers to these questions are considered as useful for informing teacher training, among other things.

METHODS

This paper reports on seven case studies that were carried out in the context of the Fibonacci project during the last two years. In fact, it attempts to provide a synopsis of what has been done and found in a series of kindergarten classes in the area of Patras. The classes were run by teachers of the local training network, who implemented the following inquiry-based didactic sequences: (a) “Life Cycle of Plants” (*LCP*), (b) “Growth Factors of Plants” (*GFP*), and (c) “Decomposition & Recycling” (*DR*). Our data were gathered through observing these classes with the “IBSE diagnostic tool” that has been developed in the context of the project with the aim of monitoring the actual performance of the teaching and learning practices which are expected to be performed while working with the IBSE model.

Participants

Schools

The six classes from which we collected our data during the school years 2011-2012 and 2012-2013 belonged to the following schools:

- 2011-2012: 1st Kindergarten of Vrachneika (*LCP*), 16th Kindergarten of Patras (*GFP*), 1st kindergarten of Vrachneika (*DR*), 21st Kindergarten of Patras (*DR*).
- 2012-2013: Laboratory school of University of Patras (*LCP* & *GFP*), 37th Kindergarten of Patras (*DR*).

So, here we are concerned with: 3 classes that implemented the *DR* sequence, 1 class that implemented the *LCP* sequence, 1 class that implemented the *GFP* sequence and finally, 1 class that implemented both the *LCP* and the *GFP* sequence.

The six classes belonged to “Fibonacci-schools” that are situated in and around Patras, namely in urban or semi-urban areas. Their contribution to our research had been approved by the Ministry of Education and the local educational authorities, but it actually happened due to the good will of the teachers.

Pupils

The total number of pupils who took part in the seven case studies that were carried out in our six classes was 111. 55 of them were boys and 56 girls. Moreover, 64 of them were 5-6 years old, while 47 of them were 4-5. More specifically:

- 1st Kindergarten of Vrachneika (*LCP*). 20 pupils, 10 boys & 10 girls, 11 age 5-6 & 9 age 4-5,

- 16th Kindergarten of Patras (GFP). 15 pupils, 6 boys & 9 girls, 10 age 5-6 & 5 age 4-5,
- 1st kindergarten of Vrachneika (DR). 19 pupils, 11 boys & 8 girls, 11 age 5-6 & 8 age 4-5,
- 21st Kindergarten of Patras (DR). 23 pupils, 11 boys & 12 girls, 15 age 5-6 & 8 age 4-5,
- Laboratory school of the University of Patras (LCP), (GFP). 17 pupils, 9 boys & 8 girls, 6 age 5-6 & 11 age 4-5,
- 37th Kindergarten of Patras (DR). 17 pupils, 8 boys & 9 girls, 11 age 5-6 & 6 age 4-5.

All parents were informed about the case studies that were planned to be performed in their children's classes in the context of the Fibonacci project and no objections were raised.

Teachers

The participating teachers had several years of teaching experience, ranging from 6 to 22, while their experience regarding inquiry teaching had to do with their training in the context of the Fibonacci project for either 1 or 2 years. More specifically, the years of teaching and inquiry teaching experience of the teachers who run our six classes are the following:

- 22 years of teaching experience & 2 years of inquiry teaching experience,
- 11 years of teaching experience & 1 year of inquiry teaching experience,
- 16 years of teaching experience & 2 years of inquiry teaching experience,
- 22 years of teaching experience & 2 years of inquiry teaching experience
- 7,5 years of teaching experience & 2 years of inquiry teaching experience,
- 6 years of teaching experience & 1 year of inquiry teaching experience.

The teachers attended (a) a 4-hour seminar about the theory and practice of IBSE

TABLE 1

Summary of the participants' profile					
	Schools	Pupils (N)	Years of teaching experience	Years of inquiry teaching experience	Didactic sequence
S1	1st Kindergarten of Vrachneika	20	22	2	LCP
S2	16th Kindergarten of Patras	15	11	1	GFP
S3	1st kindergarten of Vrachneika	19	16	2	DR
S4	21st Kindergarten of Patras	23	22	2	DR
S5	Lab School of UPatras	17	7, 5	2	LCP & GFP
S6	37th Kindergarten of Patras	17	6	1	DR

in general, and (b) 3-hour seminars about each of the didactic sequences they were expected to implement in their classes (“Life Cycle of Plants (LCP), “Growth factors of plants” (GFP), “Decomposition and recycling” (DR)). In addition, they attended reflection meetings during the implementation phase and they had the opportunity of close communication with us. As already mentioned, the teachers’ participation in the cases studies was voluntary. The profile of them and their classes is summarized in Table I.

Didactic sequences

The three didactic sequences, which were used in the case studies we summarize here and are briefly presented in this section, have been designed by us within the theoretical framework of social constructivism according to the IBSE model. Their learning objectives have to do with both the biological topic in question and the inquiry process itself. The formulation of the content-bound objectives has been informed by research evidence about young children’s naïve ideas (Osborne, Wadsworth & Black, 1992; Hickling & Gelman, 1995; Leach et al., 1996; Hatzinikita, Koulaidis & Zogza, 1999; Ergazaki, Zogza & Grekou, 2009), while the formulation of the process-bound objectives has been informed by the IBSE model. All the educational activities that are part of our sequences are organized around a central question. Each activity is completed not only by answering the central question that it is meant to explore, but also by leading to a new question which is the central one for the activity that follows. Finally, the didactic sequences are accompanied by pre- and post-tests for the evaluation of their effectiveness.

“Life Cycle of Plants” (LCP)

The LCP didactic sequence includes 4 educational activities and aims (a) at helping young children to understand the life cycle of flowering plants as a continuous process, and (b) at giving them the opportunity to get familiar with the inquiry process while being actively engaged in their own learning. So, at the end of the LCP sequence, the children are expected to have performed a shift from a linear to a circular representation of the relationship between a seed and a plant and to have practiced inquiry through empirical tests, systematic observation and use of secondary sources. A brief overview of the LCP didactic sequence might be the following:

Educational Activity 1: “A basket full of fruits, tomatoes and peppers”

Question to be explored: Why plants make fruits?

Way of exploration: Observing fruits, locating their seeds, discussing.

Educational Activity 2: “A little girl, a pomegranate plant and a jealous friend”

Question to be explored: Why plants make seeds?

Way of exploration: Educational scenario and problem-solving through observing, discussing and using secondary sources.

Educational Activity 3: “The seed gives a plant & the plant gives a seed & this goes on”

Question to be explored: Does the seed give a plant and the plant give a seed?

Way of exploration: Putting cards in sequence, creating a collage, discussing.

Educational Activity 4: “Is it really like this? Let’s find it out by ourselves!” (Observation: once a week for two months).

Question to be explored: What can we do in order to find out if *actually* the seed gives a plant and the plant gives a seed?

Way of exploration: planting seeds, taking care of the growing plants, observing their growth and production of fruits, locating their seeds.

“Growth factors of plants” (GFP)

The GFP didactic sequence includes 13 educational activities and aims (a) at helping young children to enhance their understanding about water and light as necessary factors for plant growth, and (b) at giving them the opportunity to get familiar with the inquiry process while being actively engaged in their own learning. So, at the end of the GFP sequence, the children are expected to have built satisfactory grounds for the idea that plants depend upon environmental factors such as water and light for their growth, and to have practiced inquiry through experiments that involve testing of hypotheses and systematic observation. A brief overview of the GFP didactic sequence might be the following:

Educational Activity 1: “Let’s think!”

Question to be explored: What does a plant need in order to grow?

Way of exploration: Brainstorming (gathering students’ ideas and picking up the one about water for study).

Educational Activity 2: “The watered and non-watered plant”

Question to be explored: What can we do in order to find out that plants need water for growing up?

Way of exploration: Designing the investigation, stating predictions about its results and starting its performance.

Educational Activity 3-6: “Observing the watered and non-watered plant”

Question to be explored: How does each plant look like this week compared to how it looked like the previous week?

Way of exploration: Observing, taking measurements of the plant height, recording the results, keeping the conditions required for going on with the experiment.

Educational Activity 7: “Concluding about water as a factor for plant growth”

Question to be explored: What are the conclusions from this investigation about whether plants need or not water for growing?

Way of exploration: Whole class discussions based on students’ results, drawing.

Educational Activity 8: “The plant in the light and the plant in the dark”

Question to be explored: What can we do in order to find out that plants need light for growing up?

Way of exploration: Designing the investigation, stating predictions about its results and starting its performance.

Educational Activity 9-12: “Observing the plant in the light and the plant in the dark”

Question to be explored: How does each plant look like this week compared to how it looked like the previous week?

Way of exploration: Observing, taking measurements of the plant height, recording the results, keeping the conditions required for going on with the experiment.

Educational Activity 13: “Concluding about light as a factor for plant growth”

Question to be explored: What are the conclusions from this investigation about whether plants need or not light for growing up?

Way of exploration: Whole class discussions based on students’ results, drawing.

“Decomposition & Recycling” (DR)

The DR didactic sequence is divided in two parts: the first has to do with decomposition as a biological process and includes 8 educational activities, while the second has to do with recycling as an everyday practice and includes 4 educational activities. The sequence has been designed with the aim of helping young children to (a) understand that house garbage can be sorted out in two main categories according to their material (natural or artificial) and also realize through an empirical investigation that the garbage of the two categories have different fate when buried in the soil due to the action of very small animals, (b) learn about the different garbage bins and the “journey” of the garbage from them to the dump or the recycling factory, and (c) understand recycling and re-use of materials as a way to protect the environment and adjust their everyday behavior accordingly.

So, at the end of the DR sequence, the children are expected (a) to have integrated recycling in their everyday routine as a consequence of a meaningful understanding of the different fate of natural and artificial materials in the soil due to tiny living organisms that are able to break down only the former, and (b) to have practiced inquiry through empirical tests, systematic observation and use of secondary sources. A brief overview of the DR didactic sequence might be the following:

Part A: Decomposition

Educational Activity 1: “The garbage bin of our class & the 2 groups of garbage”

Question to be explored: What do we throw into our garbage bin? Are there any groups of garbage?

Way of exploration: Observing the contents of the garbage bin, categorizing them by appealing to whether they are made of natural or artificial materials.

Educational Activity 2: “Let’s think”

Question to be explored: What may happen to our garbage when buried into the soil?

Way of exploration: Brain-storming (discussing predictions).

Educational Activity 3: “The fate of the different groups of garbage into the soil”

Question to be explored: What can we do to find out whether our predictions were right?

Way of exploration: Designing & starting the empirical testing of the predictions.

Educational Activities 4-7: “Observing and comparing the changes”

Questions to be explored: How does the garbage of the different groups look like this week? Are there any changes from the last week? Do these changes agree with our predictions?

Way of exploration: observing the results of the empirical testing, keeping records and discussing them, maintaining the appropriate conditions (i.e. soil humidity) for continuing the empirical testing.

Educational Activity 8: “Conclusions about the fate of different groups of garbage in soil”

Question to be explored: Why is that? Introducing the idea of decomposers

Way of exploration: Discussing and interpreting the results; telling a story and using it as a framework to discuss the idea of decomposers & develop the target reasoning.

Part B: Recycling

Educational Activity 9: “The two groups of garbage & the 2 types of garbage bins”

Question to be explored: Are all the garbage bins the same? Why do we have two types of them? What do we throw in the green bins and what in the blue ones?

Way of exploration: Locating different garbage bins around school; using secondary sources (photos); discussing.

Educational Activity 10: “The journey of the garbage of the blue bin”

Question to be explored: Where does the garbage-man take the blue-bin garbage?

Way of exploration: Using secondary sources (telling a story or presenting it in a puppet-show).

Educational Activity 11: “Let’s make our own bins for the class garbage”

Question to be explored: Is it difficult to separate our own garbage every day?

Way of exploration: Creating garbage-bins for the classroom and start recycling

Educational Activity 12: “Creative re-use of materials”

Question to be explored: What else can we do with the garbage that is not eaten by the small soil animals?

Way of exploration: Creating new objects from old ones, using them to play (i.e. puppet-show), discussing about the value of re-using things.

Data collection

Our data were gathered with the “IBSE diagnostic tool - for kindergarten” that has been developed in the context of the Fibonacci project (Bergman et al., 2012), with the aim of monitoring the actual performance of the teaching and learning practices which are expected to be performed while working with the IBSE model. The tool can be found at <http://www.fibonacci-project.eu/> (“Resources for Implementing Inquiry” – “Companion Resources” – “Tools for Enhancing Inquiry in Science Education”). In order to be easy to handle, the tool has been organized into three sections: (1) Interview with the teacher, (2) “Teacher-Child Interactions”, and (3) “Children’s Activities”. More specifically:

The section “*Interview with the teacher*” serves for obtaining information about the observer, the observed session (topic, objectives and teacher’s preparation for it), the observed class, the pupils and the teacher.

The section “*Teacher-Child interactions*” is structured in 4 parts:

“*Building on children’s ideas*” (3 items):

- 1a. Teacher (T) asks questions requiring Children (Ch) to give their existing ideas
- 1b. T helps Ch to formulate their ideas clearly
- 1c. T provides Ch with positive feedback on how to review or take their ideas further

“*Supporting children’s investigation*” (4 items):

- 2a. T encourages Ch to ask questions
- 2b. T involves Ch in planning an investigation
- 2c. T encourages Ch to make predictions
- 2d. T encourages Ch to check their results

“*Guiding children to conclusions*” (4 items):

- 3a. T asks Ch to compare their findings with their predictions
- 3b. T asks Ch to state their conclusions
- 3c. T asks Ch to give reasons or explanations for what they found
- 3d. T helps Ch to identify new or remaining questions

“*Guiding children to share ideas*” (3 items):

- 4a. T encourages Ch to make a group drawing, poster or model of what they have produced
- 4b. T takes notice of the Ch’s ideas and encourages Ch to do the same
- 4c. T encourages Ch to listen to each other

TABLE 2

Part of the “IBSE diagnostic tool”				
Diagnostic Tool for CPD Providers – Kindergarten				
Section B: Children’s Activities				
	Items <i>(T = teacher; Ch = children)</i>	Explanations and examples	Evaluation <i>(Circle your choice)</i>	Complementary information <i>(Where necessary, provide evidence to explain or qualify your evaluation)</i>
5. Carrying out an investigation	5c. Ch take part in planning an investigation	Ch do not need to propose their own plan but comment on the teacher’s proposed plan or adapt it during the investigation.		
	5d. Ch make predictions based on their ideas	They give a reason for what they predict, even if it is inaccurate, showing that it is not just a guess.		
	5e. Ch carry out their own investigations gathering data by using methods and sources appropriate to their inquiry question	Ch are active in collecting and using evidence themselves, not observing someone else doing this.		
	5f. The data gathered by Ch enable them to test their hypotheses /predictions	The appropriate data may be observations, simple measurements, or information from books.		
	5g. Ch consider their results in relation to the inquiry question	In discussion with others and the T, Ch use the observed evidence to answer the inquiry question.		
	5h. Ch try to give explanations of their results	Ch give possible reasons for what they found or how the results can be explained based on their previous experience and knowledge.		

Data analysis

The first step of our analysis was to use the collected data from each of the six classes we studied in order to construct separate tables for each part of the last two sections of the tool. The columns of these tables depicted the educational activities (EA) of the didactic sequence implemented by the specific class, while the rows depicted the items, namely the teaching or learning practices of the section's part in question. For example, Table 3, which has to do with the DR sequence and its implementation in school 6, shows what happened with the teaching practices that are described by the items la-lc of the first part ("Building on students' ideas") of the second section ("Teacher-Child interactions") of the tool. More specifically, it shows whether the teaching practices of the items la-lc were activated (see ✓), were *not* activated (see X), or *could not* really be activated (see NA/Not Applicable) in each of the 12 educational activities of the DR sequence.

TABLE 3

Teacher's practices for "Building on children's ideas" in the DR sequence (School 6)													
BUILDING ON STUDENTS' IDEAS ↓ DR sequence: School 6	EAI	EA2	EA3	EA4	EA5	EA6	EA7	EA8	EA9	EA10	EAI1	EAI2	Mean proportion of items
la Tasks qs requiring Ch to give their existing ideas	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA	1
lb T helps Ch to formulate their ideas clearly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA	1
lc T provides Ch with positive feedback on how to review or take their ideas further	X	✓	✓	X	X	X	X	X	X	X	NA	NA	0,2

The last column of the table provides each item's mean proportion in the didactic sequence as a whole. In other words, it shows the number of the educational activities of the sequence where the teacher *did* come up with the teaching strategy in question, divided by the number of all the educational activities of the sequence where the teacher *could* have come up with it. After the first step of the analysis was completed, we proceeded with calculating a mean proportion of each item for *all* the classes that took part in our 7 case studies. If a teaching strategy appears with a mean proportion equal to "1", it means that the participating teachers activated this practice in every single educational activity of the sequences that this was possible. Namely, they were fully successful regarding the teaching practice in question. On the contrary, if a teach-

ing strategy appears with a mean proportion equal to “0,5”, it means that the participating teachers did not activate this practice in half of the educational activities they were expected to. In other words, they acted rather poorly with regard to the teaching practice in question. It is noted that we consider the mean proportion of a teaching practice to be “low”, “moderate” and “high” when they have values ranging from “0 to 0,50”, “0,51 to 0,75” and “0,76 to 1”, respectively. The same is valid for the learning practices of the children, the mean proportion of which were calculated in a similar way.

FINDINGS

Findings about the first research question

Teaching practices for “Building on students’ ideas”

The analysis of the data regarding the part “*Building on students’ ideas*” of the section “*Teacher-Child interactions*”, gave rise to the following table that provides (a) the mean proportion of each relevant teaching practice in each of our seven case studies, and (b) the overall mean proportion of each relevant teaching practice.

TABLE 4

Mean proportions of the teaching practices for “Building on students’ ideas”									
BUILDING ON STUDENTS’ IDEAS	DR			LCP		GFP		Mean proportion per teaching practice	
	S3	S4	S6	S1	S5	S2	S5		
Ia. Teacher (T) asks questions requiring Children (Ch) to give their existing ideas									HIGH
Ib. T helps Ch to formulate their ideas clearly						0,54		0,93	HIGH
Ic. T provides Ch with positive feedback on how to review or take their ideas further			0,2 <i>Low</i>		0,75	0,23 <i>Low</i>	0,69	0,68	MODERATE

As shown in Table 4, the teachers that took part in our seven case studies were successful in activating most of the teaching practices that are required for building on the ideas of the children. The practice that seems to have raised some difficulties concerns “providing feedback to students for reviewing and taking their ideas further”. Its overall mean proportion is moderate, while the partial mean proportions of it in two out of the seven cases studies we performed is low (DR: S6 & GFP: S2). Both teachers that did not

manage to activate this practice satisfactorily had only one year of inquiry teaching experience and not too many years of teaching experience in general (6 and 11, respectively).

Teaching practices for “Supporting children’s investigation”

Table 5 shows the mean proportion of each teaching practice for “*Supporting children’s investigations*” in each of our seven case studies, as well as the *overall* mean proportion of each relevant teaching practice.

TABLE 5

Mean proportions of the teaching practices for “Supporting children’s’ investigations”									
SUPPORTING CHILDREN’S INVESTIGATIONS	DR			LCP		GFP		Mean proportion per teaching practice	
	S3	S4	S6	S1	S5	S2	S5		
2a. T encourages Ch to ask questions	0	0	1	0,25	1	1	0	0,46	LOW
2b. T involves Ch in planning an investigation	0,5	0,5	1	1	1	1	1	0,85	HIGH
2c. T encourages Ch to make predictions	1 <i>Low</i>	1 <i>Low</i>	0,2 <i>Low</i>	1 <i>Low</i>	0,75	1	0,3 <i>Low</i>	0,61	MODERATE
2d. T encourages Ch to check their results	1	1	1	0,33 <i>Low</i>	0,33 <i>Low</i>	1	0,88	0,79	HIGH

It seems that the participating teachers were successful in activating two out of the four teaching practices that concern supporting children’s investigations. The practice that seems to have raised the most difficulties has to do with “encouraging children to ask questions”. Its overall mean proportion is low, with the partial mean proportions of it in three out of the seven cases studies being 0 (DR: S3, DR: S4, GFP: S5). Another moderately problematic practice for the teachers seemed to be “encouraging children to make predictions”: in four out of the seven case studies, the teachers activated this practice in only half of the educational activities they could, while in one even less than that. Finally, the teachers that implemented the LCP sequence appeared not very keen on encouraging children to check their results (S1, S5: low), although the overall mean proportion of this teaching practice is actually moderate.

Teaching practices for “Guiding children to conclusions”

Table 6 shows the mean proportion of each teaching practice for “*Guiding children to conclusions*” in each of our seven case studies, as well as the *overall* mean proportion of each relevant teaching practice.

TABLE 6

Mean proportions of the teaching practices for “Guiding children to conclusions”

GUIDING CHILDREN TO CONCLUSIONS	DR			LCP		GFP		Mean proportion per teaching practice	
	S3	S4	S6	S1	S5	S2	S5		
3a. T asks Ch to compare their findings with their predictions	0	0,83	0	0	1	0	1	0,4	LOW
3b. T asks Ch to state their conclusions	1	1	0	0	0	0,66	1	0,38	LOW
3c. T asks Ch to give reasons or explanations for what they found	0,83	1	0,83	0 <i>Low</i>	0 <i>Low</i>	0,11	1	0,53	MODERATE
3d. T helps Ch to identify new or remaining questions	0	0,5	0	0,5	1	0,1	0,6	0,38	LOW

As shown in Table 6, the phase of conclusions seems to raise difficulties for the teachers. Three out of the four teaching practices here appear with low overall proportion, while the proportion of the remaining practice (3c) is *slightly* moderate. More specifically, the problematic practices concern “asking children to compare their findings with their predictions”, “asking children to state their conclusions”, and “helping children to identify new or remaining questions”, and they were activated in less than half of the educational activities in which it was possible to be activated. It is rather obvious that teaching practices like these are of key importance for the implementation of the IBSE model. Finally, the practice that was moderately activated has to do with “asking children to give reasons or explanations for what they found”. It is noted that in two out of the seven case studies this practice was not activated at all.

Teaching practices for “Guiding children to share ideas”

Table 7 shows the mean proportion of each teaching practice for “Guiding children to share ideas” in each of our seven case studies, as well as the *overall* mean proportion of each relevant teaching practice.

As shown in Table 7, the teachers were successful in activating all the teaching practices that concern prompting children to communicate their ideas. The practice with the lower - but still high - mean proportion was “encouraging children to listen to each other”, since in two out of the seven case studies it was activated rather poorly (LCP-S1 & GFP-S2).

TABLE 7

Mean proportions of the teaching practices for “Guiding children to share ideas”									
GUIDING CHILDREN TO CONCLUSIONS	DR			LCP		GFP		Mean proportion per teaching practice	
	S3	S4	S6	SI	S5	S2	S5		
4a. T encourages Ch to make a group drawing, poster or model of what they have produced	0,66	0,66	I	I	I	I	I	0,9	HIGH
4b. T takes notice of the Ch's ideas and encourages Ch to do the same	0,87	0,75	I	0,75	I	0,54	I	0,84	HIGH
4c. T encourages Ch to listen to each other	0,87	I	I	0,25 <i>Low</i>	I	0,16 <i>Low</i>	I	0,76	HIGH

Findings about the second research question

Learning practices for “Carrying out an investigation”

The analysis of the data regarding the part “*Carrying out an investigation*” of the section “*Children’s actions*”, gave rise to the following table that shows the mean proportion of each relevant learning practice in each of our seven case studies, as well as the *overall* mean proportion of each relevant learning practice.

TABLE 8

Mean proportions of the teaching practices for “Carrying out an investigation”									
CARRYING OUT AN INVESTIGATION	DR			LCP		GFP		Mean proportion per learning practice	
	S3	S4	S6	SI	S5	S2	S5		
5a. Ch pursue qs which they have identified as their own even if introduced by T	I	I	I	I	I	0,38	0,92	0,9	HIGH
5b. Ch give possible replies (hypotheses) concerning the central question	I	I	0,5	I	I	0,5	I	0,85	HIGH
5c. Ch take part in planning an investigation	0,5	0,5	I	I	0,5	I	I	0,78	HIGH
5d. Ch make predictions based on their ideas	0,5	0,5	0,5	0,66	I	0,15	0,77	0,58	MODERATE

TABLE 8

Mean proportions of the teaching practices for “Carrying out an investigation”									
CARRYING OUT AN INVESTIGATION	DR			LCP		GFP		Mean proportion per learning practice	
	S3	S4	S6	S1	S5	S2	S5		
5e. Ch carry out their own investigations gathering data using methods and sources appropriate to their inquiry question	1	1	1	1	1	0,92	1	0,98	HIGH
5f. The data gathered by Ch enable them to test their prediction	0,83	0,83	1	0	1	0	1	0,66	MODERATE
5g. Ch consider their results in relation to the inquiry question	0,5	1	0	0	0	0,11	1	0,37	LOW
5h. Ch try to give explanations of their results	0,83	1	0,83	0	0	0,10	1	0,53	MODERATE

As shown in Table 8, children did it very well with half of the learning practices that are integrated in carrying out an investigation, since their overall mean proportion appears to be high. Moreover, the three learning practices that were moderately activated have to do with “making predictions”, “gathering data that enable them to test their predictions” and “trying to give explanations about their results”, practices that have been moderately prompted by the teachers as well. The same seems to be valid with the learning practice that has to do with “considering results in relation to the inquiry question”: the fact that it appears with a low overall mean proportion might be related with the fact that relevant *teaching* practices such as “asking to compare findings with predictions” or “asking to state conclusions” were poorly activated by the teachers.

Learning practices for “Children’s records”

Table 9 shows the mean proportion of each learning practice for “*Children’s records*” in each of our seven case studies, and the *overall* mean proportion of each learning practice of these as well.

Keeping records was one of the very successful aspects of the project as we know not only from the observation of the classes but from children’s and classroom portfolios as well (see examples in Appendix). The teachers were very effective in facilitating children to share their ideas (see the high proportions of all the relevant teaching practices in Table 7) and the children managed to respond properly. The need to pay

TABLE 9

Mean proportions of the learning practices for “Children’s records”

CHILDREN'S RECORDS	DR			LCP		GFP		Mean proportion per learning practice	
	S3	S4	S6	SI	S5	S2	S5		
6a. Ch make a simple record of what they did and found	1	1	1	0,93	0,66	0,92	1	0,93	HIGH
6b. Ch share their records of what they did and found with others during reporting to the class	0,66	0,84	1	0,66	0,66	0,46	1	0,76	HIGH

special attention to keeping records was emphasized in all the training seminars, while an additional meeting with this topic in particular was organized in the second year of the project.

DISCUSSION

In order to summarize what our case studies show about which inquiry practices raise difficulties to the teachers, we should focus on the ones with moderate or low overall mean proportions. These actually were the following.

- 1c.T provides Ch with positive feedback on how to review or take their ideas further (moderate),
- 2a.T encourages Ch to ask questions (low),
- 2c.T encourages Ch to make predictions (moderate),
- 3a.T asks Ch to compare their findings with their predictions (low),
- 3b.T asks Ch to state their conclusions (low),
- 3c.T asks Ch to give reasons or explanations for what they found (moderate),
- 3d.T helps Ch to identify new or remaining questions (low).

Starting with some of the teaching practices that were moderately activated, we note that encouraging children “to make predictions” as well as “to explain what they found” were highlighted as very important features of inquiry teaching in *both* the introductory seminar concerning the theory and practice of IBSE, *and* in all the training seminars concerning the specific didactic sequences and their implementation in the classroom. Nevertheless, it seems that it hasn’t been easy for the participating teachers to engage their students neither in making predictions about what they might find through the empirical investigation they had planned with them, nor in explaining what they finally found.

This seems to be followed by an even lower activation of practices such as requiring comparisons between predictions and findings or stating conclusions on the basis of such comparisons. The inadequate activation of these practices that appear to be of key importance, probably indicates that teachers encounter significant difficulties when trying to shift from a more traditional, teacher-centered model to a model that attempts to simulate what has been called the “scientific method” and put the students in the shoes of novice researchers who need to *actively* construct their own knowledge. The same might be suggested by the low activation of the practice that has to do with “encouraging students to ask questions”, although it should be noted that asking questions that can properly trigger empirical investigations may be rather demanding for children of preschool age. The indicated difficulties *do* need to be addressed more effectively in the context of teacher training and reflection meetings.

On the other hand, the low activation of the practice that concerns “helping children to identify new or remaining questions” is rather unexpected. The reason is that all three didactic sequences that were tested in our case studies have been designed so that each of their educational activities is completed with the emergence of a new question to be investigated in the activity that follows. A possible explanation might have to do with the fact that it may often be difficult for kindergarten teachers to follow their teaching plan all the way through a teaching session, since the children they are working with are very young and may tend to be rather impatient after some time.

On the contrary, providing meaningful feedback to the children in order to help them review or elaborate their own ideas by themselves is a very demanding teaching practice that seems to require much more than being explicitly shown how important it is. So, its moderate (rather than low) activation might be considered as a positive characteristic of the participating teachers.

Shifting to the students and the learning practices they mobilized less, we should consider that what students do may be closely bound to what (and how effectively) teachers prompt them to do. It seems that children activated only moderately practices such as making predictions based on their ideas, testing their predictions on the basis of the data they collected and trying to explain their results. This is actually rather expected because of the low activation of the *teaching* practices that could have supported children to activate these *learning* practices more often (see Table 5: 2c & Table 6: 3c). This seems to be also the case with the low activation of the learning practice that has to do with considering results in relation to the inquiry question. In other words, children cannot be expected to mobilize such a demanding practice satisfactorily if the teachers do not require them to state conclusions as often as they should.

The synopsis we attempted to provide in this paper regarding what has been done and found in the seven case studies we performed in the context of the Fibonacci

project, along with results from pre- and post-tests that haven't concerned us here, shows that the IBSE model can be implemented in kindergarten classes and actually help young children to reach a better understanding of entities and phenomena of the biological world. Nevertheless, this may be carried out more effectively if teacher trainers have in mind that certain teaching practices which have to do with the inquiry process may raise significant difficulties that need to be systematically addressed in the context of long training programs. Inquiry-based teaching and learning seems to be a rather promising educational investment that probably deserves the attention of all the stakeholders.

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APPENDIX

Children's individual recordings



Children's group recordings



Sharing findings with other groups

