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Part 15
Strand 15
Early years science education

Co-editors: Esmé Glauert & Fani Stylianidou

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INTRODUCTION TO STRAND 15

EARLY YEARS SCIENCE EDUCATION

Strand 15 focuses on Early Years Science education, for children aged between 0 and 8 years of age. This has been a field of growing interest within the science education community in recent years and encompasses a wide range of research activity related to policy and practice in early years science in preschool and primary education. This was reflected in the number of contributions and lively discussion at the 2015 ESERA conference. There were two symposia, sixteen oral paper presentations and five interactive posters, all of which had been reviewed and accepted for inclusion. From these, ten papers were submitted to be included in this e-book. Nine have met the technical requirements and are reproduced in the following pages. Their authors come from France, Germany, Greece, Japan, Poland, Sweden, and the United Kingdom. The papers explore a range of issues from different theoretical perspectives, and employ a variety of methodological approaches.

Four papers reflect a growing emphasis on classroom-based research in collaboration with teachers, and illustrate children's capacities to engage with scientific ideas, processes and procedures from the earliest years. They indicate key roles for the teacher, not only in the design of learning experiences, but also in recognizing and fostering communication in varied modes and in promoting shared meaning and understanding in the classroom community.

The research reported by *Stolpe, Frejd and Wallner* (Sweden) is focused on the very youngest children (aged 1–5) and involved 18 children and 3 teachers in a Swedish preschool. It aimed to investigate young children's meaning making in science through their engagement with scientific phenomena and communication in varied modes, not just verbally, but through gestures, embodied actions or non-verbal sounds. Data were collected through observation and audio recording. Interactions between the teacher and children were analysed using semantic relationships to identify ways in which the teacher and children constructed meaning over time. Findings illustrate ways in which the teacher and children used different modalities to communicate meaning. The concept of 'translating modalities' is introduced to characterize interactions in which something expressed in one modality (by a child) is translated into another (by the teacher), keeping the same meaning. Findings highlight the key role of the early years teacher in putting words to children's gestures and actions to enhance verbal language development and offer opportunities for shared meaning making and learning in science.

In 2014 the National Curriculum for England introduced a new area of study 'Evolution and Inheritance'. As part of a wider research project studying developmental progression in this area with pupils aged 5–11, *McGuigan and Russell* (England) worked in collaboration with four early years teachers and children to investigate young children's (aged 4–7) ideas about variation that provide an important foundation for later learning about evolution. They focused in particular on ways in which interventions involving multimodal approaches, including use of mathematical tools, might be used to enhance children's understanding. Young children tend to hold essentialist views that lead them to regard all members of the same species as identical. The paper illustrates the innovative ways in which teachers incorporated a shift in their classroom activities from mainly qualitative to increasingly quantitative observations, and how these encouraged young children's appreciation of some of the subtleties in variation within continuous traits.

McMahon et al. (England) report on a project working with 12 schools designed to examine the role of classroom talk in supporting science learning within a thematic or 'creative'

approach to curriculum planning often employed in the early years of primary education. They present examples from their analysis of series of case studies of classroom talk, drawing on a framework entitled 'sustained scientific dialogues' that they argue is central to creative pedagogies and reflects the kinds of talk the project was seeking to develop. Their paper provides rich illustration of the varied nature of classroom talk and the potential for 'meaningful and scientific' learning to take place within a thematic, creative curriculum context.

Finally in the context of widespread emphasis on inquiry based approaches to early years science, *Blanquet and Picholle* (France) present findings from their evaluation of a new tool developed to support the design and implementation of inquiry-based activities to promote young children's (aged 5–6) understandings of the 'primacy of experiment' and the 'reproducibility and robustness of an experiment'. The tool was introduced to teachers and evaluated through a professional development programme, and then used by teachers in classroom workshops as part of a festive scientific event. Questionnaires completed by 64 teachers after training indicated they found the explicit introduction of features of scientific methodology very helpful and considered that the primacy of experiment, and reproducibility and robustness of an experiment were relevant and attainable skills for their 5 to 6 year old pupils. Interviews with 68 children from three classrooms following the workshops confirmed that young children are capable of engaging with these aspects of scientific methodology.

The next three studies set out to study particular characteristics of young children's scientific thinking and response to science activities, suggesting implications for the design of classroom experiences in early years science.

Rybska, Tunnicliffe and Sajkowska investigated children's ideas about internal earthworm anatomy, and examined the extent to which children's alternative conceptions (and their understanding of the internal structure of an animal) change as a function of age. Data through children's drawings supplemented by labeling (by the child or researcher) and interviews to support their interpretation. The analysis of their 116 drawings of Polish children at aged 5 to 10 showed that their mental model of an earthworm were not necessarily in agreement with established biological knowledge. They revealed some alternative conceptions, shared by children across ages, for example: earthworms having a vertebrate type of heart, red and white blood cells, or is a prior life stage of a butterfly. The findings offer useful suggestions to inform lessons related to earthworms that are often encountered by children in their everyday lives and play a key role in land ecosystems in Europe.

Ergazaki et al. (Greece) report on a qualitative study designed to investigate young children's spontaneous formation of categories, in particular whether they prioritise perceptual-similarity or category-membership when forming categories, as suggested in previous research, and how far their approach is coherent. They conducted individual, semi-structured interviews with 120 preschoolers (aged 4–5) in three public kindergartens. Children were presented with 18 cards, showing animals, plants and objects of different colours, and asked to (a) recognize what was shown on each card, (b) create groups with the cards, and (c) provide a justification for each group. Data analysis indicated that children used criteria of several types in order to ground their categories or they did not use any criterion at all. The criteria were coded as (1) 'appearance-related' (e.g. color, size), (2) 'biological' (e.g. animals, plants, food relationships), (3) 'ordinary' (e.g. aesthetics, usefulness for humans, context-related details), and (4) 'story-making'. Most children did not sort coherently either by perceptual-similarity or by category-membership. Nevertheless the criteria children used reveal that preschoolers have creative ways of thinking about the world that early years science education could exploit.

The third paper by Skorsetz and Welzel-Breuer reports on their study to investigate how children identified as having different ‘brain types’ respond to different learning environments. Their approach drew on the Empathizing-Systemizing (E-S) theory of Baron-Cohen (2002) that proposes every person has a ‘brain type’ and furthermore that people who have the brain type ‘systemizer’ are generally more engaged and motivated in science than people who have the brain type ‘empathiser’. Children’s brain types were determined using a questionnaire completed by their parents. They were then observed (using video recording) within two different learning environments. The paper presents findings from the first phase of the study with 25 children (aged 4–6 years) focusing on children’s attentiveness in a science environment designed to exhibit characteristics of a ‘systematizing’ approach. Analysis of data indicated periods of varied attentiveness but no significant differences were identified according to brain type.

The final two papers reflect growing attention to teacher education in early years science in line with increasing recognition of the place of science within the early years curriculum.

Tomita and Kallery report on an investigation of Japanese early years teachers’ views of factors that influence the quality of their science teaching, drawing on an approach developed by Kallery (2014), involving written assignments and a group interview. Six experienced teachers from primary school and kindergarten participated in the study. The analysis of data indicated the influence of factors associated with teacher characteristics (interest in science and views of its importance in early years science), relationships (teacher-teacher, teacher-pupil and pupil-pupil) and external factors associated with parents and their material situation (space and finance). The Japanese early years teachers identified that their most serious challenge was having sufficient science knowledge to respond to children’s interests and curiosity in science. To address this they suggested it would be fruitful to participate in a working-group where they could freely ask questions and exchange ideas and views on scientific knowledge – in preference to attending official workshops or conferences.

Finally *Kallery* presents findings from such a collaborative approach to teacher professional development. The rationale for the programme was to motivate the teachers through their involvement in an action research group, to which they could all contribute, aimed at developing and implementing curriculum activities, and thus meaningfully engaging them in their own learning. The partners in the group were a researcher in science education with a background in physics who also served as a facilitator and six in-service early-years-teachers, with many years of experience, who participated as co-designers. Their shared goal was to produce inquiry-based science activities from physics and astronomy for young children. The project involved both group work and individual teachers’ work in their own classrooms. The evaluation of the impact of the programme drew on qualitative analysis of data, combining teachers’ own reflections in their essays, with field-notes, lesson recordings and records of group-work, as a means of validating teachers’ self-reported data. Key findings reported include improvement in teachers’ ‘transformed’ knowledge of subject matter and development in their knowledge of instructional strategies and of pupils’ learning. These suggest that application of this approach, incorporating teacher involvement in action research, could contribute effectively to teachers’ professional development in early years science.

Esmé Glauert and Fani Stylianidou

EXPERT TEACHERS' VIEWS OF FACTORS INFLUENCING THEIR TEACHING QUALITY IN EARLY CHILDHOOD SCIENCE IN JAPAN

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Abstract: Kallery (2014) investigated Greek early-years-teachers' views of factors that may influence the quality of their teaching performance in science. The study revealed factors that were classified in four domains: teacher-related factors, pupil-related factors, situational factors, and initiatives for personal professional upgrading. The study also revealed that the teachers recognize their knowledge as playing a primary role in relationships among the factors. Using the same methodology as this of the Greek study (written assignments and a group interview) we carried out the above study in Japan. Six experienced teachers from primary school and kindergarten participated in the study. The analysis of data yielded factors that were categorized in the following seven domains: teacher-related factors, teacher-teacher relation factors, pupil-related factors, pupil-pupil relation factors, teacher-pupil relation factors, parent-related factors, and material-situation related factors. Although the categorization of the factors in Japan is a little different from that in Greece, the results in the two countries are very similar. Early-Years-Teachers in Japan think that the most difficult problem for them is that they do not have enough science knowledge in order to be able to respond to children's interests and curiosity in science. They also think that in order for them to overcome this problem and improve their background knowledge in science, it would be fruitful to participate in a work-group where they can freely ask questions and exchange ideas and views on scientific knowledge. Teachers also noted that they prefer the group-work than attending official workshops or conferences. Starting up such groups consisting of teachers from primary schools and kindergartens and from university staff and developing the networking of such groups will lay the foundation for early-years teachers' education in science.

Keywords: Early-years science, Early-years teachers, Science education

INTRODUCTION

Although the importance of science education in early childhood has been stressed by researchers and educators, its practice is limited and often problematic. Under this situation, Kallery (2014) conducted a small-scale investigation study of the views of six experienced primary and pre-primary teachers in Greece about factors influencing the quality of their work in science and the difficulties they face. The findings of the Greek study were categorized into four domains: teacher-related factors, pupil-related factors, situational factors, and initiatives for personal professional upgrading. The Greek teachers considered that a variety of factors can contribute either positively or negatively to their teaching, most of them relating to the teacher, while a significant number of them concern different categories of teacher knowledge. They recognised their knowledge as playing a primary role in several of these relationships. They also considered that the quality of their teaching in science can be influenced by teacher-related characteristics such as emotions, personality, motivation and attitude. Some of the situational factors that teachers are difficult to control (Kennedy, 2010) can cause resistance to the improvement of early-years science education. However Greek teachers believe that improvement of their knowledge in science, their initiative-taking and their personal work could assist them to overcome several of these situational factors.

In Japan, where the importance of science education for early childhood is also well recognized and the country is industrialized, primary and pre-primary teachers are still struggling to find out what science education in early-years should be as the number of examples of practice is small and the Japanese teachers do not have enough self-confidence to teach science (e.g., Miyashita, 2011). Although the cultural background and the educational system are different in the two countries, the situation in Japan seems to be similar to that in Greece. Therefore, aiming at understanding what the present status in Japan really is, following Kallery (2014), we collected data using the same methods. This also gave us the opportunity to make comparisons between the Greek and the Japanese cases.

METHOD

Six teachers, five female and one male, participated in the present study. Four of them had a long experience in teaching early primary classes and two of them kindergarten. All participants were from the middle-sized city of Wakayama, Japan.

Data were collected using the same methods as in the Greek study by Kallery (2014): (1) one take-home written task, (2) one questionnaire constructed by the teachers themselves, (3) one questionnaire constructed by the researcher, and (4) one group interview. The summary of the method is presented in Table 1. The detailed description of the instruments used in the study is presented in the Appendix of the present paper.

Table 1: Summary of the method

1. Take-home written task	Each participating teacher wrote answers to the question “Which factors do you believe influence the quality and effectiveness of your teaching in science?” Each teacher completed this task at home or at office individually.
2. Participating teacher-constructed questionnaire	Each participating teacher constructed a questionnaire as a means of investigating the views of other colleagues on factors that may influence the quality of their teaching in science. Each teacher completed this task at home or at office individually.
3. Researcher-constructed questionnaire	Kallery (2014) developed a questionnaire with 11 items to investigate teacher’s view of factors influencing the science education practice. Each participating teacher wrote answers to the questionnaire. Each teacher completed this task at home or at office individually.
4. Focus group interview	Teachers’ answers to the individual questionnaire and the views of all the participants were extensively discussed. The first author conducted the interview session.

This method developed by Kallery (2014) provided valuable data on factors which the teachers consider to have an important influence on science teaching. Prior to the commencement of the study, the first author of the present work discussed the study and the methodology with Kallery (private communication) in the summer of 2014. In the written tasks teachers were encouraged to point out as many factors as possible and to freely express

their views. In the group interview, teachers' answers to the written tasks and the views of all the participants were extensively discussed as all sources of data were analyzed prior to the interview.

The data from all sources were qualitatively analyzed and the findings were integrated. More specifically, initially, the data were repeatedly read and the most striking and ultimately most important aspects were isolated. These data were then unitized; i.e. units of information (phrases, sentences or paragraphs), which later served as the basis for defining categories, were identified. In the second level of analysis, a constant comparison technique was used to sort units of information into internally homogeneous categories. At the third level, the categories were organized into domains (Strauss & Corbin, 1990).

RESULTS

The findings of the present study were classified into the seven domains presented below. Representative examples of teachers' answers for each of the categories are given.

(1) Teacher-related factors, such as:

- Teacher's interests in science
 - ✓ *It is necessary for teachers to have a will and be interested in natural phenomena, and that teachers enjoy and investigate natural phenomena with pupils.*
 - ✓ *If teachers become interested in something, they try to learn more about it.*
 - ✓ *The teacher can understand the phenomena using a combination of their daily life experiences and their knowledge.*
- Teacher's understanding the importance of science education in early childhood
 - ✓ *The teacher must appreciate children's interest, awareness, and feelings.*
 - ✓ *Activity which looks like science education is not always science education. The thing is the teachers to understand the importance of science education in early years.*
 - ✓ *Whether the teacher recognizes that science education in early childhood is important will constitute the base for primary school science education.*

(2) Teacher-teacher relation factors, such as:

- Team-work among teachers
 - ✓ *Whether the school has an atmosphere to encourage the team work.*
- Having colleagues and seniors to consult
 - ✓ *Whether the teacher has colleagues to consult with about science education.*
 - ✓ *Whether the teacher has a friendly connection with other staff at school.*

(3) Pupil-related factors, such as:

- Children's scientific knowledge
 - ✓ *Whether children have enough knowledge, experience, interest, and curiosity to enjoy the science class.*
- Various experiences in their everyday life
 - ✓ *Whether children have enough science-related experiences in their childhood.*

(4) Pupil-pupil relation factors, such as:

- Whether they are friendly with each other
 - ✓ *Whether children can speak with each other freely.*
- Whether they accept each other in the class
 - ✓ *Whether children get interested in other's awareness and actions.*

(5) Teacher-pupil relation factors, such as:

- Whether teacher catch children's awareness and questions
 - ✓ *Whether children are or are not accepted by adults when they ask their own questions.*

- ✓ *The teacher has to encourage children to become more interested in what they wonder about in their daily lives.*
 - Whether teacher can find scientific values in them
 - ✓ *How the teacher connects children's awareness to the scientific learning; it is the teacher's sense of science education.*
- (6) Parent-related factors, such as:
- Parents' cooperation to school education policy
 - ✓ *Parents' poor attitude to science education.*
 - Parents' trust in school
 - ✓ *If you get a claim from a parent after the activity using mud, like 'My daughter's gym suit got muddy, so stop muddy activity,' what will you do?*
 - ✓ *If you get a claim from a parent after the activity in the school field, like 'My son hates mosquitos, so stop activity in school field,' what will you do?*
- (7) Situational factors including:
- Space factors
 - ✓ *The school's natural environment is not rich; however the teachers try to convey science to children.*
 - ✓ *Number of teachers per certain number of children is small.*
 - Financial factors
 - ✓ *Not enough budget to develop instructional materials*
 - ✓ *Not enough budget for improving kindergarten's physical conditions such as natural environment, area, and room*
 - ✓ *It is difficult to improve school curriculum.*

It is interesting to note that both primary school and kindergarten teachers provided similar answers to the questions. However, while primary school teachers referred to teacher's interests in science and teacher-parent factors more frequently than kindergarten teachers, the kindergarten teachers referred more frequently to teacher-pupil relation factors and to the issue about continuity between kindergarten and primary education.

Although we categorized Japanese data into seven domains, the factors and their coverage are similar to those found by the Greek study (Kallery, 2014). The teacher-related factors in the Greek study correspond to those of domains (1), (2) and (5) of the study in Japan, the pupil-related factors correspond to factors of domain (3), (4), and (5), the situational factors correspond to (6) and (7) and initiatives for personal professional upgrading are included in domains (1) and (2) of the Japan study. The teachers pointed out that especially in domains (1) and (5) are included basic factors that could affect the others although all factors are related to each other. They also mentioned that "teacher's understandings about the importance of science education for early childhood" and "whether teacher can find scientific values in children's awareness and questions" are the most important views in reflecting their own educational activities. They said that domain (2) can help strengthen domain (1). They also said that domain (3), (4), and (5) can be strengthened by the abilities and characteristics included in the domain (1) where teachers' pedagogical content knowledge is essential. Factors in domains (6) and (7) could present difficulties in the improvement of the quality of science education and are what the teachers can-not control and manage. However teachers said that they try to do their best despite the various limitations.

The teachers in Japan also believe that their performance has been affected by their own education and everyday experiences in school, findings which are also very similar to those of the Greek study. Japanese teachers also mentioned that the absence of systematic and appropriate for the early-years teachers' science education in their university studies results in

absence of self-confidence in science. All of the above results are similar to those obtained by the study in Greece.

One thing that Japanese teachers frequently mentioned was the so-called “monster parents” problem in early childhood science education. The “monster parents” characterization refers to parents who express unreasonable requests or complaints to the school. Examples are provided in the “parents’ trust in school” category in the parent-related factor domain. Further investigation is needed to see whether this is common in other countries as well or specifically in Japan.

Some Japanese teachers noted that at beginning of their careers they felt that a pure science-oriented university education would not seem to be useful for the early-years teacher. However after many years of experience, the teachers realised the importance of subject knowledge in science. The conversation between Ms. H and Ms. K presented in the focus group interview reflects the teachers considering the science knowledge as an important part of their knowledge for teaching.

Ms. H: I always wonder why a butterfly comes and goes every day in the same direction in my classroom. The other day, classmates threw out a butterfly. Children said the butterfly wanted to see our classroom once a day, but it does not seem probable to me. I think the butterfly is not always the butterfly we threw out. Rather than that, always the same direction, it is so impressive question to me.

Ms. K: It is the butterfly’s road. The butterfly flies through the safe path they find. Wait and see today. You will find the safe path.

Ms. H: Really? I will admire the safe road with children!

Ms. K also introduced us another exciting science class of her practice.

Ms. K: When I had a class about the spider, I talked that a spider has eight legs. Children said, “Is it really so?” Then I replied, “OK, let’s confirm it. Catch spiders and see their legs!” After the lunch time and during the classroom cleaning time, children were searching for spiders. They knew well where spiders frequently were; inside the cleaning tool holder, below the umbrella stand. To tell the truth, I hate the appearance of the spider, but I inspected the number of legs. It was so surprising! Some spiders do not seem to have eight legs. Some had seven. It might be we just miscounted them, or the spider was injured. Anyway, the textbook description only is not impressive to children.

DISCUSSION AND CONCLUSIONS

Juxtaposing the results of the studies in Greece and Japan can be gathered that early-years teachers in both countries consider knowledge in science to have key role in early-years science education and in realising the scientific values of children’s awareness and questions in science. The teachers demonstrated a common understanding about what good science teaching in early childhood is; they noted that the teachers should be interested in arousing children’s interest in natural phenomena, guide the development of their skills and assist the scientific interpretation of their experiences. The six experienced early-years teachers in Japan who have a good level of pedagogical knowledge are eager to develop their knowledge in science as well. Teachers’ comments about the absence of education on how much important the science knowledge is in real practice and how the science knowledge relates to and connects to the pedagogical content knowledge in their university studies urge the reconsideration of the curriculum of the teacher training system in Japan. Teachers’ suggestions for a fruitful participation in working groups with other teachers and university specialists are in line with the approach followed by Kallery (2014) in Greece. This approach has many advantages such as that teachers can think together practical ideas suitable for various occasions, avoid expenses by commuting to distant places in order to attend formal training sessions which also tend to be overloaded with scientific information instead of

sharing the collective knowledge and experiences. Starting up such group and developing the networking of the groups will lay the foundation for early-years teachers' education in science.

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APPENDIX

Instruments

Take home written task

Which factors do you believe influence the quality and effectiveness of your teaching in science? As these factors are formed by your personal views and ideas as well as by your classroom experiences, please provide a description and elaborate briefly on them where possible to make them clearer.

Teacher constructed questionnaire

Please construct a questionnaire which you would use to investigate the factors that early childhood teachers of science believe may influence the quality of their teaching of science.

Individual questionnaire

1. Do you think that the factors that you reported in your written task are related to each other? More specifically which of these factors do you believe influence others factors and in what way?
2. Do you believe that these factors have been affected by your own education? How so?
3. Are there any affective factors mentioned in your written task? What are these affective factors and how would you describe them?
4. Do you think that teacher's creativity is a factor that can contribute to the quality of her teaching in science? If so, how do you think it contributes?
5. In the case of implementing predesigned science activities in the classroom, how do you think that teacher's creativity can contribute?
6. Do you think that some of the factors you reported in the written task depend on the teacher's knowledge? If so, which types of teachers' knowledge?
7. Do you think that some of the factors you mentioned in the written task are topic dependent, i.e. are related to the science topic you are teaching?

8. Do you think that teacher's knowledge of how to praise children is a factor that could influence the quality of your teaching in science? Was this mentioned in your written task?
9. Are there factors that are outside your control that can influence the quality of your teaching of science? If so, what are these factors?
10. a) Has the development of any instructional materials, or your participation in any research activities related to your work, influenced the quality of your teaching of science? If so, what were these activities and how did it influence your teaching?
b) If you had the opportunity to participate in a work group seeking involvement in professional development activities, which factors do you think could have a positive influence on your teaching of science? For example, your participation in the development of instruction materials, your participation in the research activities related to your work. Please mention whatever else you feel or believe may influence you.
11. Do you have any other comments on what factors may influence the quality of your teaching of science?

Focus group interview

Questions will be formed by the interviewer on the basis of results coming from the preliminary analysis of the written task. Are similar to the individual questionnaire and will generate discussion from the participants.

HOW DO PRESCHOOLERS SPONTANEOUSLY FORM CATEGORIES?

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Abstract: Categorization lies at the bottom of scientific thinking and its development. Relevant research is mostly driven by a twofold debate about whether children prioritize perceptual-similarity or category-membership when forming categories. Nevertheless, young children's reasoning may involve much more than this dichotomy implies. It seems reasonable then, to explore how children categorize spontaneously. This paper reports on a qualitative case study that aims at highlighting preschoolers' ability to (a) put entities together in order to form categories of their own, and (b) recognize new entities as exemplars of specific categories already given to them. Here we discuss the first. Conducting individual, semi-structured interviews with 120 preschoolers (age 4-5.5) of 3 public kindergartens of Patras, we traced what criteria preschoolers use to spontaneously categorize different entities and whether they use them coherently. Children were presented with 18 cards (6 animals, 6 plants and 6 objects, of 5 different colors). Then, they were required to (a) recognize what was shown on each card, (b) create groups with the cards, and (c) provide a justification for each group. Our data analysis within 'NVivo' qualitative data analysis software, showed that students used criteria of several types in order to ground their categories or they did not use any criterion at all. The criteria were coded as (1) 'appearance-related' (e.g. color, size), (2) 'biological' (e.g. animals, plants, food relationships), (3) 'ordinary' (e.g. aesthetics, usefulness for humans, context-related details), and (4) 'story-making'. Most children did not sort coherently either by perceptual-similarity or by category-membership. Nevertheless, some of the biological, most of the ordinary and all of the story-making criteria they used, reveal that preschoolers have creative ways of thinking about the world that science education could exploit.

Keywords: Preschoolers; categorization criteria; scientific thinking; reasoning skills; biology education.

INTRODUCTION

Categorizing lies at the rock bottom of scientific thinking. It helps us build taxonomic systems, attribute properties, articulate theories about the world (Carey, 1985; Markman, 1989). How do we categorize then? According to *empiricists*, we are born into a stream of sense data, which we daily learn to assemble into categories (Prinz, 2002; Shapiro, 2004). According to *nativists* on the other hand, we come to the world already equipped with some basic, category-membership intuitions (Carey, 2009; Fodor, 2008). The ontological debate above is linked with the epistemological dilemma of whether we prioritize *perceptual-similarity* or *category-membership* in our early attempts to form categories.

When empirical studies tried to investigate the above dilemma however, they found that whereas adults seem to rely *more* on category-membership, children do not *just* evoke *category-membership* or *perceptual-similarity* criteria. They may use both in the same task; they may use either or both incoherently; and what's more they may build mixed categories as well, most of them being *thematic* (Inhelder & Piaget, 1964; Murphy, 2002). In a *free-sorting task*, for example, when children are asked to make groups with many items, among which a pet-dog, a toy-dog, a pig, a leash and a plate, they may mix and match the items in all possible ways; some may put the pet-dog in the same group with the toy-dog, probably relying on

appearance; some may put it with the pig, probably relying on category-membership; yet others would put the pet-dog in the same group with the leash and perhaps other items as well, thus forming a *thematic* category (Murphy, 2002). However, it also became evident that while *free-sorting tasks* mostly evoke mixed and thematic groupings, *triad tasks* can better explore the *perceptual-similarity vs category-membership* distinction. In a *triad task*, informants are presented with a target entity and two test entities (one of similar appearance and one of the same category with the target) and they are asked which of the two test entities they would pair with the target one (Murphy, 2002).

Even with triad tasks however, the results are inconclusive. In some studies, young children seem to draw upon the perceptual properties (Fisher, 2011; Gelman & Markman, 1986). For example, 3-5 year old children presented with an open, red umbrella and asked to group it either with a closed umbrella (a test-item of the same category) or with a red mushroom (a test-item of similar appearance) were found to draw upon perceptual-similarity for creating their 2-item groups (Fisher, 2011). In other studies though, children seem to shift their focus from perceptual-similarity to category-membership when asked to attribute properties (Carey, 1985; Heyman & Gelman, 2000). For example, 4-10 year-old children, who knew that real monkeys breathe, eat and reproduce, did not attribute these properties to toy-monkeys despite how similar they looked with the real ones (Carey, 1985). Even 4-year olds, when provided with the information that certain non-similar looking entities belonged to the same category (dinosaurs), they used this information to claim that they may share non-visible properties (identical heart-shape) regardless their dissimilar external appearance (Gelman & Markman, 1986).

So, the debate about whether we prioritize *perceptual-similarity or category-membership* when we categorize is still on. Leaving it aside however, we would rather concentrate on the *educational* aspect of category formation. Besides, up to now, the most prevailing interpretation of the difference among children's and adults' performance in sorting tasks draws upon education (Murphy, 2002). Education, and more specifically science education, seems responsible for the shift to more taxonomic criteria. Science education aims at helping children apply category-based criteria coherently and use category-membership terminology correctly. On the other hand, children seem to categorize using many kinds of criteria; *perceptual*, *category-based* and many others under the umbrella-term *thematic*. If we want to develop learning environments that help children move from their current state towards a more scientific, category-based reasoning then, we should further explore children's free associations when performing categorization tasks. Even the so-called *thematic* criteria should be looked into in more detail.

In order to do this, we need data-gathering techniques that will not obscure children's spontaneous reasoning. Triad tasks are mostly concerned with tracing the dominance of perceptual or taxonomic criteria in children's minds. Their narratives and instructions do not leave much space for the emergence of other types of criteria that are possibly meaningful for young children. It seems reasonable then, to explore how children categorize *spontaneously*.

Thus, we decided to study preschoolers' ability to (a) put entities together in order to form categories of their own, and (b) recognize entities as exemplars of specific categories already given to them. Our focus here is particularly set on the first one; namely, on the criteria upon which young children may spontaneously perform categorization of different entities, and on how coherent the use of their own criteria may be. The research questions we address are the following:

- (1) 'What kind of criteria do preschoolers use in order to spontaneously categorize different entities?'
- (2) 'Do preschoolers use their categorization criteria coherently or not?'

METHODS

The overview of the study

This paper reports on the 1st part of a qualitative case study, which addresses the two questions presented above. The informants were 120 preschoolers (65 girls/55 boys, age 4-5.5), attending three public kindergartens in Patras during the academic year 2013-2014. The schools were situated in different semi-urban areas of medium/high socio-economic status and were selected due to the teachers' wish to facilitate our study. Children were already familiar with educational interactions and according to their teachers they had not been engaged in formal learning activities about categorization up to that point. Tracing children's reasoning was performed through individual, semi-structured interviews; these were conducted by the authors in quiet places of children's schools and lasted approximately 20 minutes each. Children had the opportunity to meet the interviewers before the interview-phase; they got familiar with them and sometimes they got even excited about giving their first interview. So, their own assent for participating was provided along with their parents' informed consent.

The interview protocol

The interview protocol included 3 tasks. Here we will only discuss the first one. Children were presented with 18 cards, which depicted 6 animals, 6 plants and 6 objects of 5 different colors. The depicted entities were the following:

- Animals: frog, fish, pig, bird, snail, snake.
- Plants: bush, wheat-plant, almond-plant, daisy-plant, 'naked' tree, cypress.
- Objects: bag, umbrella, pacifier, sock, broom, chair.

The colors were green, yellow, pink, white, and brown; each of them was the color of at least 3 card entities, an animal, a plant and an object.

Children were required to (a) recognize what was shown on each card, (b) create groups with the cards, and (c) provide a justification for each group they created. The way they were asked was the following: *'Let's see the cards. What do the card-drawings depict? Can you make groups with them? Why did you make these groups? What do the cards in this group have in common?'*

The analytic procedure

The tape-recorded interviews were transcribed and prepared for coding within 'NVivo' qualitative data analysis software. Coding children's responses to the sorting task resulted in a series of main categories, which correspond to the types of criteria children used. Coding was independently performed by two authors and the inter-rater reliability was satisfactory (Cohen's kappa: 0.90). Moreover, in order to explore whether the use of criteria was coherent, semi-coherent or incoherent, we created relevant 'NVivo-attributes' and assigned them to children's interviews accordingly. When children used the same criterion for *all* of their groups, their interviews were labeled with the attribute 'Coherent Use of Criteria'. The label 'Semi-coherent Use of Criteria' was attributed to interviews in which (a) children used the same criterion for *all but one or two* of their groups, or (b) they used the same criterion for all their groups but left some entities *ungrouped*. And finally, when children used different criteria for each of their groups, their interviews were labeled with the attribute 'Incoherent Use of Criteria'.

RESULTS

Our data analysis within ‘NVivo’ showed that children used criteria of several types in order to justify their groups (RQ1), while most of the times the use of these criteria was not coherent (RQ2). The findings for each research question are presented below in more detail.

Results about RQ1

Children formed groups with the card entities they were given by appealing to four main categories of criteria (‘appearance-related criteria’, ‘biological criteria’, ‘ordinary criteria’ and ‘story-making criteria’), or by not appealing to any criterion at all (‘no criteria’). A closer look at each category will provide a better insight into children’s reasoning.

The **‘appearance-related criteria’** are *perceptual-similarity* criteria of different kinds. They refer to external, visible features of the card entities, such as ‘color’, ‘size’ or ‘other details’. In children’s words:

- *‘The umbrella goes with the wheat-plant because they are yellow’* (‘color’)
- *‘The pig and the fish are in the same group because they are small’* (‘size’)
- *Look, they all have lines going downwards... The wood in the umbrella, the wheat-plant, the chair here [pointing to chair-legs], the broom, the snail [pointing to the antennas] and the tree here’* (‘other details’)

The **‘biological criteria’** involve ideas about the biological world. Some of them, such as ‘animals’, ‘plants’ and ‘objects’, appeal to category-membership. Others, like ‘food relationships’ or sharing the same ‘habitat’, ‘movement type’, ‘life-cycle facts’ and ‘typical body features’, involve more thematic relations. In children’s words:

- *‘This’ll be the group of animals: snail, fish, frog, snake, pig, bird’* (‘animals’)
- *‘Cypress, tree, almond-plant: together cause they’re all trees’* (‘plants’)
- *‘Chair, bag, sock, broom, pacifier, umbrella... things’* (‘objects’)
- *‘These go together because the bird eats the fish’* (‘food relationships’)
- *‘The fish and frog go together because they live in the water’* (‘habitat’)
- *‘The snake with the snail cause they crawl on the ground’* (‘movement type’)
- *‘I put this tree (points to the ‘naked’ tree) with this tree (points to the almond-plant) because this is in the winter...it has no leaves and flowers...in the spring it becomes like this’; ‘The daisy-plant and the almond-plant are in the same group because they make flowers in spring’* (‘life-cycle facts’)
- *‘The fish and pig make a group together because they both have eyes’* (‘typical body features’).

The **‘ordinary criteria’** relate to a range of ideas encountered in everyday life: ‘aesthetics’, ‘usefulness for humans’, ‘pattern’, ‘pair absence’, ‘material’ and ‘context-related details’.

These are also thematic criteria of various kinds. In children’s words:

- *‘I put them in the same group because they look nice together’* (‘aesthetics’)
- *‘The wheat-plant gives us food and the umbrella keeps us dry in rain’* (‘usefulness for humans’)
- *‘I put them this way to have triads’* (‘pattern’)

- *'Bag, snake, umbrella, and bird together: no cars to put with the bag, no road to put with the snake, no rain to put with the umbrella, no sky to put with the bird' ('pair absence')*
- *'Broom with chair because they are made of wood' ('material')*
- *'Pigs are in the farm and wheat-plants are also in the farm'; 'Chair and bag are school-stuff, we use them at school'; 'The fish goes with the umbrella because the fish lives in the water and the umbrella protects us from water'; 'Snake and broom together because when the snake is dead they get it somewhere else with the broom' ('context-related details')*

The **'story-making criteria'** are also thematic. They involve ideas that allow entities to become the building blocks of imaginary stories. In children's words:

- *'The pig and the frog go together because if the pig jumps 3 times like the frog, it will become a frog too'*
- *'The bush and the bag. I put them together. A little boy threw the bag behind the bush because he did not want to go to school.'*

Children drew more frequently upon 'appearance-related criteria' and less frequently upon 'story-making' ones; 'biological' and 'ordinary' criteria were somewhere in between; finally, they were also times that some children could not provide any justification for their groups ('no criteria'). Table 1 summarizes the times of appearance of the *sorting criteria categories* in children's responses, as well as the number of children who drew upon them to justify their groups.

Table 1. The frequency of the sorting criteria categories.

Categories of criteria	Times of appearance	Number of children (N=120)
'Appearance-related criteria'	330	74
'Biological criteria'	150	76
'Ordinary criteria'	95	60
'Story-making criteria'	41	22
'No criteria'	37	25

Results about RQ2

Most children did not activate a unique, coherent criterion throughout the sorting task. If for example they *did* activate the color-criterion *coherently*, they would end up with a variety of color-groups, so that all the available objects would belong to one of them. Contrariwise, children seemed to activate different criteria for making their different groups. So, most of them came up with several groups, each formed with a different criterion: a *color-group* next to a *habitat-group*, next to an *aesthetics-group* etc. Nevertheless, some children *did* sort coherently. The criteria they used in a coherent way were the 'color' criterion and the distinction between 'animals', 'plants' and 'objects' ('A-P-O' distinction) (Table 2).

Table 2. Coherent use of specific sorting criteria.

Coherently-used criteria	Number of children	Percentage of children
‘Color’	21/120	17.5%
‘A-P-O’- distinction	11/120	9.2%

Moreover, there were a few children who used the above criteria in an *almost* coherent way, namely (a) for all their groups except one or two, or (b) for all their groups but some card entities remained ungrouped (Table 3).

Table 3. Almost coherent use of specific sorting criteria.

Almost Coherently-used criteria	Number of children	Percentage of children
‘Color’	12/120	10%
‘A-P-O’- distinction	6/120	5%

DISCUSSION

Our findings cannot take issue with the ontological aspects of the empiricist - nativist debate. Preschoolers are old enough to draw upon beliefs they have acquired through learning processes. The epistemological conclusions of our study though, show that *perceptual-similarity* (‘appearance related criteria’) and *category-membership* (‘animals’, ‘plants’ and ‘objects’, *i.e.* the ‘A-P-O’- distinction) were *both* among the criteria preschoolers used when performing our sorting task. It’s worth noting that, whenever we found *coherent* or *almost coherent* criteria, they were of one of these two sorts; children used coherently either ‘color’ from the ‘appearance-related criteria’ or the ‘A-P-O’- distinction from the ‘biological criteria’.

However, most of children’s spontaneous sortings resisted the *perceptual-similarity versus category-membership* dichotomy. Most children did not sort coherently either by perceptual-similarity or by category-membership, but rather relied on different kinds of *thematic* criteria. The term thematic has been mostly used as an umbrella-term to describe whatever did not fit the *perceptual-similarity vs category-membership* dichotomy (Murphy, 2002). As Markman (1989) has pointed out yet, thematic relations highlight important pieces of knowledge about what things go together, how objects are used in various events, what items can be expected in different situations, and children, like adults, draw upon them to form categories. As soon as we look at children’s spontaneous sortings without the dichotomy-blindfolds, a vast variety of criteria emerge, revealing types of reasoning and pieces of knowledge that science education could exploit in order to support children’s shift to more taxonomic criteria within appropriately designed learning environments.

The different thematic criteria children use then, can give us fruitful insight. For instance, appealing to ‘context-related details’ of certain entities, *i.e.* appealing to the fact that we typically find them in the same location or that we use them at the same time or in the same way, indicates children’s ability to combine learnt information in creative ways in order to ‘solve’ a ‘sorting problem’. In fact, the whole category of ‘ordinary’ criteria could provide some promising background for the development of scientific thinking. Moreover, some biological criteria are also quasi-thematic revealing children’s grasp of several relations within the biological world. Children’s ‘biological toolkit’ includes knowledge about food

relationships, shared habitat, movement type or typical body features, and indicates a remarkable potential to reason about biological entities. Their toolkit also includes the ‘APO-distinction’, only just emerging as a coherent category-membership device.

In summary, young children managed to perform a sorting task adequately by drawing upon prior knowledge, understanding and imagination. They also appeared ready to *start* reasoning in coherent ways on the basis of certain biological criteria. So, it is probably time for their systematic engagement in a long-term development of solid taxonomic categories about the natural world in appropriately designed learning environments. Such learning environments should be informed by children’s spontaneous ideas; this way they could facilitate the shift from perceptual and thematic sortings to taxonomic ones and help children develop sound taxonomic reasoning for later science education.

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SYSTEMIZING AND EMPATHIZING: RESEARCH ON EARLY YEARS SCIENCE EDUCATION AND BRAIN TYPES

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Abstract: Main goal of the study is to find out how pre-school children act and react in different learning environments. An approach for explaining differences in the motivation for science is the Empathizing-Systemizing (E-S)-Theory (Baron-Cohen, 2002). It says that every person has a so called “brain type”. People who have the brain type “systemizer” are generally more engaged in science and motivated to do science than people who are stronger in empathizing (Zeyer et al., 2013).

Tested children will be observed within two different, according to the brain type characteristics designed, learning environments to investigate potential different behavior. Thus, our main research question is: What kind of attentiveness related reactions do tested empathizing and systemizing preschool children show towards a specific “systemizing” and a specific “empathizing” approach?

In this study the brain types of 4 to 6 year old pre-school children were determined with a 55 item EQ-SQ-questionnaire (Auyeung et al., 2009) that we translated into German. In terms of a design-based research approach (Collective, 2003) the tested children will be observed while acting within two different scientific learning environments.

Until June 2015 the parents of 25 children filled out the EQ-SQ-Questionnaire und the children were videotaped while acting in a systematic scientific learning environment. For the questionnaire, Cronbach’s alpha coefficients were calculated und showed high coefficients for empathy items ($\alpha=0.81$) as well as for systemizing items ($\alpha=0.61$). Within this small population a normal distribution can be shown (as Auyeung et al., 2009): 1 EE, 8 E, 7 B, 8 S and 1 ES. We analyzed the videotapes using a category based system with focus on the children’s perspective and discovered that so far the children with the same brain type shows various periods of attentiveness but not significant variant between the different brain types.

Keywords: early years science, video based research, design based research

INTRODUCTION

Science for all

An interesting approach for explaining differences in the motivation for science is the Empathizing-Systemizing (E-S)-Theory (Baron-Cohen, 2002). It says that every person has a so called “brain type”. People who have the brain type “systemizer” are generally more engaged in science than people who are stronger in empathizing. Focusing the problem that “science for all” (Aikenhead, 2001, p. 3) is wanted (in order to overcome the lack of people who are interested in studying and doing science) and not a “swing away from science” (Zeyer et. al., 2013, p. 1047), what often is observed, we have to motivate also empathizers for science. But, the problem to be solved is how to realize that.

According to the E-S-Theory, individual’s brains should correlate to a type between two dimensions: the empathizing and the systemizing. “Systemizing is the drive to analyze or construct systems” (Baron-Cohen, 2009, p. 71). The goal of this dimension is “to identify

rules that determine a system” (Zeyer et al., 2013, p. 1048) and to “predict how that system will behave” (Baron-Cohen, 2009, p. 71). “Empathizing is the drive to identify another person’s emotions and thoughts and to respond to these with an appropriate emotion” (Auyeung et al., 2009). In the majority of cases people shift between the two dimensions (Baron-Cohen, 2009, p. 72).

With a questionnaire the measure of the peculiarity of these dimensions – called EQ and SQ – can be determined. Baron-Cohen (2009) identified five different brain types: Extreme E, E, Balanced, S und Extreme S. Billington et al. (2007) found that the brain type seems to be a better predictor than gender, concerning the individual motivation to study science. Through an empirical cross-cultural study Zeyer et al. (2013) added the finding that only systemizing has an impact on motivation to study science. The questionnaire used here (and which can be found in the section “Appendix”) was adapted and validated for 4 to 11 year old children by Auyeung et al. (2009). Just like adults, children could be allocated to brain types. From that, Zeyer et al. (2012) concluded that people with an empathizing or a systemizing cognitive style need different approaches to science because, due to their brain types, they are not similarly motivated in this field of education. In order to motivate empathizing children for science they suggest to reorganize the lessons or the learning environments. They recommend first-person-perspectives and context-based-approaches, i.e. approaches with an individual relatedness. Topics that include these aspects could be e.g. health and environment. Furthermore, the teaching should be attached didactically-methodologically, such as field trips, collaborative projects and fostering autonomy (Zeyer et al., 2013, p. 1062).

Early Years Science and Motivation

In German kindergarten the pre-school teachers often prepare learning environments which are oriented at their own experience with science lessons. These approaches are more or less structured in their procedure and content.

Within this study, it will be investigated whether there are differences in the motivation of pre-school children with respect to the degree of the structuring in scientific learning environments. We pursue the question, whether tested empathizing children can be motivated to do science if it is prepared in different ways for them.

At the common practice, different approaches to science for kindergartens are existing. Seeing the child as “protagonist of its own development”, while adopting its knowledge like a scientist by “being self-actuating”, is one of the approaches (Schäfer, 2011, p. 27). Fthenakis (2009) sees the child as an active part of its own educational process in co-construction with others. Lück (2003) proposes children to construct their new knowledge – e.g. in a pre-structured series of experiments and a subsequent interpretation. Finally, we assume that fictions and the identification with protagonists should better motivate empathizers to do science. These different approaches will guide us for the design of two different types of learning environments with respect to the needs of the different brain types.

Main goal of this study is to find out how motivated pre-school children with different brain types appear within different learning environments. Tested (to their brain type) children will be observed within two different, according to the brain type characteristics designed, learning environments in order to investigate potential different behavior.

Knowing that motivation is an internal condition that elicits, leads and maintains the children’s behavior (Glynn & Koballa, 2006, p. 25) we have to find observable behavior because we also know that “motivation cannot be observed directly” (Barth, 2010). Laevers (2007) identified in the “Leuven Scale of Active Engagement in Learning” different signs of motivation. These are bodily posture, attentiveness, endurance, accuracy, responsiveness and contentment (Laevers, 2007). In the first step we will focus on the attentiveness.

Our research questions are:

What kind of attentiveness related reactions do tested empathizing and systemizing pre-school children show towards a rather specific “systemizing” and a specific “empathizing” approach?

At first the children participate the more structured setting. So our specific research question is: Do the empathizing and systemizing children show different behavior concerning their attentiveness in a more systematic learning environment?

One possible empirically observable behavior is the period of time that children are attentive in a learning environment. Hütter (2010) argues: “Attentiveness is the door for learning. Who wants to learn, has to focus his attention, therefor to reduce the importance of other stimuli such as his neighbor, the mobile phone, the teacher’s earring, the passing bus etc. Only the learner decides to be concentrated” (Hütter, 2010; cited in Richter, 2015).

If we assume that someone is motivated when he or she follows attentively in a situation, the children’s attention should be shortened in learning environments that are not according to their brain type.

METHOD

Based on the E-S-Theory we developed a rather “systemizing” and a rather “empathizing” learning environment on the same topic for kindergarten children. We translated the EQ-SQ-Child questionnaire into German and will apply it to about 100 pre-school children.

In terms of a design-based research approach (Collective, 2003), one part of the mixed groups will participate in the “systemizing” approach; the other part will participate in the “empathizing” approach. The children’s behavior will be observed (video-recording) carefully. First, we will film 50 tested pre-school children. The same procedure will be performed with the “empathizing” approach in year two of the project.

The videotapes will be the basis for an empirical analysis (Mayring, 2008). We will start by putting the focus on the children’s attention. At first, we inductively developed categories with the focus on the children’s viewing direction. A more qualitative analysis should follow.

RESULTS

The EQ-SQ-Questionnaire

By now, the first 25 children of the population have been investigated. The internal consistency of the results has been tested. Cronbach’s alpha coefficients were calculated and showed high coefficients for empathy items ($\alpha=0.81$) as well as for systemizing items ($\alpha=0.61$). Within this group we found a normal distribution: 1 EE, 8 E, 7 B, 8 S and 1 ES. This result is in accordance to the literature data of Auyeung et al. (2009). Thus, we can conclude that the translated questionnaire should be valid and reliable.

The results show – in comparison with the distribution of values in the original study – that as presented in Figure 1 the extreme values (EE=Extreme Empathizer und ES=Extreme Systemizer) were not acquired in our Pilot Study I.

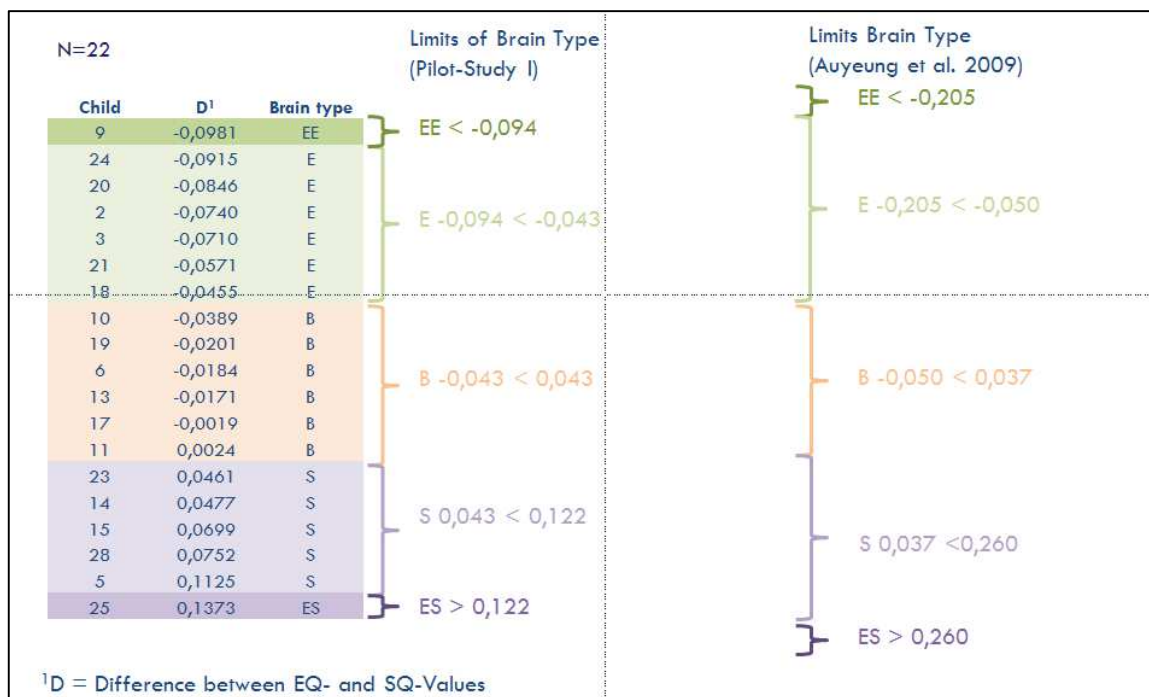


Figure 1. Classification of Brain Type in Pilot Study I

Development of Learning Environment

For the first setting – the rather systematic one – we screened the literature and singled out described systemizing characteristics. We chose an experiment which was delineated by Lück (2007) and titled as “What is absorbent?” Thereby, the children follow a sketched manual and compare the different absorbing traits of super-absorber crystals in diapers with cotton wool and aluminum foil.

The selected learning environment represents a lot of described systemizing characteristics such as dealing with manuals and sorting of things (here: to line up the three materials in order of their degree of absorbency). We found a student who already had a pre-school teacher education to perform the setting.

To ensure the setting will proceed as similar as possible we compiled a so called “script” with determined activity instruction and talk. After a pretest in one kindergarten the script was revised.

For the study, children with tested brain type participated the learning environment in groups of four. During their activities, they were videotaped using two camcorders from different perspectives. Until now, the systematic setting was implemented with 22 pre-school children from age 5 to 6 in three different kindergartens in the area Heidelberg.

Data Analysis

The two videotapes of each setting were inset in the evaluation software program “Videograph” (Rimmele, 2012) und synchronized. Inductively we developed eight observation categories with the focus on the children’s viewing directions:

1. Towards Preschool Teacher
2. Towards other Children

3. At the Experimentation Material
4. Towards the Observer/into the Camera
5. Around
6. Material, that is not relevant right now
7. Indistinguishable
8. Any other business

In the following step we summarized the fourth, fifth and sixth code to a new category “Distraction/Attentiveness”.

After the evaluation of the videotapes focusing the children’s viewing directions, we compared the two children with the extreme brain types (child 9= EE and child 25=ES). Looking at the direct relation (shown in Table 1) it was seen that there are differences in the duration time of viewing in different directions. The extreme empathizing child looks 8,18 % at other children. On the contrary, the extreme systemizing child looks at this direction only 4,29 % of the whole time. Also the new code “Distraction/Attentiveness” displays a difference in the viewing time (child 9=12,16% and child 25=7,99%). The empathizing child seems to be longer distracted than the systemizing child. These results match our hypothesis.

Child	Brain type	Towards Preschool Teacher	Towards other children	At the Experimentation Material	Towards Observer/camera	Around	Material that is not relevant right now	Indistinguishable	Any other business	Distraction Attentiveness
S-9	EE	14,84%	8,18%	58,29%	1,99%	0,47%	9,70%	6,31%	0,23%	12,16%
S-25	ES	18,42%	4,29%	65,93%	3,01%	4,52%	0,46%	3,36%	0,00%	7,99%

Table 1. Comparison of Children with Extreme Brain Types

Nevertheless, the summarized mean of the three groups (empathizing, balanced and systemizing children) still shows that there are no significant differences in the behavior concerning their attentiveness. At this point, more data and deeper analyses are needed to clarify the results.

DISCUSSION AND FIRST CONCLUSIONS

We assume that these dissenting results can have diverse reasons. So, possible bias of parents’ answers in the questionnaire items maybe one of those, because of emphasis on the empathetic qualities of one’s own child. In consequence, we decided to apply the EQ-SQ-Child Questionnaire to the kindergarten teachers as well.

Another reason could be that there are some parts in the setting that are more empathetic than planned: e. g. the organization of the children in small groups, or the teacher’s behavior towards the children.

In addition to that, it could be that the children may show different behavior in their attentiveness and in the quality of their activity. Thus, we decided to code the videotapes using the assignment of “Leuven Involvement Scale for Young Children” (Laevers, 2007) according to the next research question: To what extent does the quality of activity

(engagement) of empathizing or systemizing children differ within the different learning environments?

At the actual stage, the basis for further the video-analyses is prepared. At the end of the whole study there will be empirical data from more than 100 children – their brain types and their time of attention in different learning environments – and about the quality of the children’s activities. So we will be able to compare the scientific learning environments concerning “motivation” (in terms of paying attention) of systemizers and empathizers.

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APPENDIX

EQ-SQ-Child Questionnaire

Please complete by ticking the appropriate box for each statement

		Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1.	My child likes to look after other people.				
2.	My child often doesn't understand why some things upset other people so much.				
3.	My child doesn't mind if things in the house are not in their proper place.				
4.	My child would not cry or get upset if a character in a film died.				
5.	My child enjoys arranging things precisely (e.g. flowers, books, music collections).				
6.	My child is quick to notice when people are joking.				
7.	My child enjoys cutting up worms, or pulling the legs off insects.				
8.	My child is interested in the different members of a specific animal category (e.g. dinosaurs, insects, etc.).				
9.	My child has stolen something they wanted from their sibling or friend.				
10.	My child is interested in different types of vehicles (e.g. types of trains, cars, planes, etc.).				
11.	My child does not spend large amounts of time lining things up in a particular order (e.g. toy soldiers, animals, cars).				
12.	If they had to build a Lego or Meccano model, my child would follow an instruction sheet rather than "ploughing straight in".				
13.	My child has trouble forming friendships.				
14.	When playing with other children, my child spontaneously takes turns and shares toys.				
15.	My child prefers to read or listen to fiction rather than non-fiction.				
		Definitely	Slightly	Slightly	Definitely

		Agree	Agree	Disagree	Disagree
16.	My child's bedroom is usually messy rather than organized.				
17.	My child can be blunt giving their opinions, even when these may upset someone.				
18.	My child would enjoy looking after a pet.				
19.	My child likes to collect things (e.g. stickers, trading cards, etc.).				
20.	My child is often rude or impolite without realizing it.				
21.	My child knows how to mix paints to produce different colors.				
22.	My child would not notice if something in the house had been moved or changed.				
23.	My child has been in trouble for physical bullying.				
24.	My child enjoys physical activities with set rules (e.g. martial arts, gymnastics, ballet, etc.).				
25.	My child can easily figure out the controls of the video or DVD player.				
26.	At school, when my child understands something they can easily explain it clearly to others.				
27.	My child would find it difficult to list their top 5 songs or films in order.				
28.	My child has one or two close friends, as well as several other friends.				
29.	My child quickly grasps patterns in numbers in math.				
30.	My child listens to others' opinions, even when different from their own.				
31.	My child shows concern when others are upset.				
32.	My child is not interested in understanding the workings of machines (e.g. cameras, traffic lights, the TV, etc.).				
33.	My child can seem so preoccupied with their own thoughts that they don't notice others getting bored.				
34.	My child enjoys games that have strict rules (e.g. chess, dominos, etc.).				
35.	My child gets annoyed when things aren't done on time.				
36.	My child blames other children for things that they themselves have done.				
37.	My child gets very upset if they see an animal in pain.				
38.	My child knows the differences between the latest models of games-consoles (e.g. X-box, Playstation, Playstation 2 etc.) or other gadgets.				
39.	My child remembers large amounts of information about a topic that interests them (e.g. flags of the world, football teams, pop groups, etc.).				
		Definitely	Slightly	Slightly	Definitely

		Agree	Agree	Disagree	Disagree
40.	My child sometimes pushes or pinches someone if they are annoying them.				
41.	My child is interested in following the route on a map on a journey.				
42.	My child can easily tell when another person wants to enter into conversation with them.				
43.	My child is good at negotiating for what they want.				
44.	My child likes to create lists of things (e.g. favorite toys, TV programs, etc.).				
45.	My child would worry about how another child would feel if they weren't invited to a party.				
46.	My child likes to spend time mastering particular aspects of their favorite activities (e.g. skate-board or yo-yo tricks, football or ballet moves).				
47.	My child finds using computers difficult.				
48.	My child gets upset at seeing others crying or in pain.				
49.	If they had a sticker album, my child would not be satisfied until it was completed.				
50.	My child enjoys events with organized routines (e.g. brownies, cubs, beavers, etc.).				
51.	My child is not bothered about knowing the exact timings of the day's plans.				
52.	My child likes to help new children integrate in class.				
53.	My child has been in trouble for name-calling or teasing.				
54.	My child would not enjoy working to complete a puzzle (e.g. crossword, jigsaw, word-search).				
55.	My child tends to resort to physical aggression to get what they want.				

(In: Auyeung et al., 2009, p. 11)

TRANSLATING MODALITIES: PRESCHOOL TEACHERS' WORK WITH CHILDREN'S MEANING MAKING IN SCIENCE

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ABSTRACT

Children in preschool encounter sensations in their daily activities that could be interpreted as scientific phenomena. As part of these encounters, social interaction and meaning making are important elements in making science available to the children. Children in preschool rely on multimodal communication since they have not yet developed a verbal language. Therefore, this study aims at taking a multimodal perspective to investigate meaning making in science in a preschool setting. Data was collected using observations and audio recordings from one Swedish preschool with 18 children between 1-5 years old and three preschool teachers. Data was analyzed using semantic relationships. However, these relationships were investigated not only within verbal utterances, but in gestures and embodied activities as well. The results show that the preschool teacher verbalizes children's embodied actions and gestures. In doing so, the teacher not only offers words for children's activities, but also makes the activities, and participants' meaning making, explicit to all children in the group. Hence, the teacher is *translating modalities*. Furthermore, this study shows the importance of attending a multimodal perspective in preschool settings. If attention is only given to children's verbal output, there is a risk of underestimating their competence in emergent science meaning making. Instead, a multimodal perspective reveals children's competent meaning making in interaction.

Key words: meaning making, multimodality, preschool, science education

INTRODUCTION

Children encounter what could be called science, or scientific phenomena, almost on a daily basis in their everyday activities both at home and in preschool. They see condensed water drops on a cold glass, experience the pendulum effect of a swing, and realize that there are different flowers and birds. However, when do these occurrences become scientific phenomena? We would argue that science is constructed in social context, through interaction. From this perspective, doing science is about making meaning in a social context in relation to scientific phenomena. Or at least, it could be argued that the experiences children have during their time at preschool could be seen as the first seeds for later scientific knowledge.

Science in preschool

In Sweden, science is part of the curricula for preschool (children aged 1-5 years). Even though preschool is voluntary, it is part of the school system in Sweden and a majority of Swedish children attend this school form. According to the curricula, preschool promotes development and learning, and a lifelong desire to learn for all children. However, the

foundation for learning in a preschool setting is play. Teaching in preschool is not organized as classroom activities, but rather in playful settings where interaction between children, and between children and teachers, is essential. Preschool teachers play a central role in focusing child attention towards specific phenomena (Pramling & Pramling Samuelsson, 2001), and providing opportunities for children to explore, ask questions, and observe, enabling them to discover new things about the world (Howitt, Upson, & Simon, 2011).

Klaar and Öhman (2012) have, for example, shown that a preschooler explores friction while playing on a slippery slope. Robert (22 months old) is trying to reach the top of an icy hill to be able to slide down the hill on his sledge. However, as he reaches the top, he slowly starts to slide backwards, whereby he bends his knees, puts one hand on the ground and takes small steps. In changing his way of approaching the slippery slope, Robert is able to reach the top. Klaar and Öhman (2012) conclude that learning could be seen as a practical and physical meaning making rather than being conceptual or verbal. As this particular example shows, Robert's activity could be seen as an embodied experience that could be later used as a building stone in learning about friction.

Larsson (2013) also shows that preschool children are in contact with the phenomenon of friction during their play. However, even though the children spontaneously explore and talk about friction, Larsson (2013) shows that the teachers focus more on the social aspects of children's actions and intentions, rather than on the content. Larsson argues that there is a risk that children's actions are not viewed as signs of competence. Content knowledge and pedagogical content knowledge is seen as necessary for the teachers to be able to create space for children's exploration.

These studies indicate that embodied action play an important role in children's emergent learning about science. However, there are also indications that it is important for children to have a competent teacher to interact with in their meaning making. Children in preschool differ extensively in their communicative repertoire, from children that have almost no language at all to children who communicate using a wide range of semiotic resources. Since children express themselves not only verbally, but also through gestures, embodied actions, and non-verbal sounds, we would argue that it is important to take a multimodal perspective on children's meaning making in preschool. Traditionally, many studies on science teaching and learning only take verbal language into account. This approach gives a limited view of children's meaning-making process.

Multimodality and meaning making

After all, studying human interaction is to study the utilization of different sign systems, or modalities, for example speech, gestures (such as pointing), prosody, and use of physical materials (Goodwin, 2000; Goodwin & Goodwin, 2013; Jewitt, Kress, Ogborn, & Tsatsarelis, 2001). As such, analysis of this practice rests on identifying where participants understanding of one another originates, where the heart of the communication lies. Here, Enfield (2011) distinguishes between fine-grained *semiotic dimensions*, wherein one can distinguish between e.g. the speed, angle, and pressure of a certain gesture, and *sensory modalities*, i.e. basic physiological modes of input. The analysis in the present paper rests on the latter, wherein participants' talk, gaze, movement, and manipulation of physical material are considered.

Mercer views the combination of these modalities as "getting things done" (2004, p. 138), a person's communicative abilities to make meaning. In our daily lives we rarely rely merely

on talk for our communication, we also combine this with gestures, gaze and prosody. However, before becoming verbally proficient, young children rely to a higher degree than their older peers on embodied actions, prosody, and pointing for their communication with the surrounding world (Enfield, 2011). As such, a multimodal perspective is important in the analysis of interaction including young children.

In their study of very young children's multimodal interaction, Lerner, Zimmerman, and Kidwell (2011) show how a toddler, Laura, interacts with her caregiver using a combination of gestures, vocal expressions, and gaze. Their analysis demonstrates how the caregiver responds to Laura's communicative efforts with verbal responses, showing an understanding of an expressed desire from Laura. This can be viewed as a shift between modalities, with the purpose of establishing a joint understanding of the previous utterance (through a three-part sequence), between two participants.

Building on this view of multimodal expressions, this paper investigates the use of different modalities, for example the relation between embodied actions and verbal utterances, as a way of making meaning in science in a preschool setting.

Aim and research questions

The aim of this study is to investigate multimodal meaning making in science in social interaction in a preschool setting.

More specifically, the following research questions have been posed:

1. How are relations between different modalities done in preschool meaning making in science?
2. In what way does a multimodal perspective contribute to the understanding of meaning making in preschool science?

METHOD

The data in this study was collected in a preschool located in the central parts of a middle-sized city in Sweden. Three preschool teachers work with 18 children between 1-5 years old. One of the preschool teachers, Caroline, was responsible for science and mathematics. All children in the study have their parents' consent to participate in the study and the children were informed about the study before participating. The preschool teacher also agreed to participate in the study. All names have been changed due to ethical reasons.

Data collection

The data were collected through observations, using field notes, audio recordings and photographic documentation with a digital camera. In total, the data consist of 12 h 20 min of observations distributed over seven occasions. During the time of observations, the first author had the role of participating observer. The researcher observed activities both indoors and outdoors and all observations were made before lunch, since this is the time when most children are present and the more planned activities took place. The days that were chosen for observation were those where the preschool teachers intended to teach science and mathematics. The researcher took detailed field notes describing activities, what the children made, their gestures etc. The researcher never interrupted the ongoing activities.

Data analysis

The audio recordings were transcribed and incorporated into field notes making up one document. Photographs were also inserted to give a rich picture of what happened during the episodes.

The first step of the analysis was to roughly organize the extended field note document in activities that had the potential to be about science in a broad sense, and activities that did not include science content. In the more fine grained analysis of these science episodes, the interaction between the children and the preschool teacher was coded using semantic relationships (Lemke, 1990). Semantic relationship denotes to when several ways of expressing something refers to the same scientific meaning. Originally, semantic relationship were used in order to analyze texts – written or verbal excerpts (Lemke, 1990). However, in this study we infer ‘text’ in a broader sense, including other semantic resources, in line with Fredlund (2013). Using this approach, speech, embodied actions, and manipulation of objects were all seen as potential carriers of semantic relationships, when relevant for the participant interaction. The extended field notes were analyzed by searching for different semantic relationships. This means that we looked for when the same scientific meaning was expressed using different words or different semantic resources. This approach made it possible to see in what way the teacher and the children constructed and co-constructed meaning of science in interaction over time.

RESULTS

The children and teacher construct meaning of scientific content throughout the activities. Verbal language together with the use of artefacts, such as pictures, blocks, written stories, were used to communicate about content. In the following, one particular example has been chosen to illustrate in what way the participants use different modalities, or semantic resources, to communicate about earthworms, their characteristics and their behaviour. In the following, the interpretation of what is said or communicated in the interaction is informed by the participants’ following turn (Goodwin, 2000, 2013; Goodwin & Goodwin, 2013). This implicates that the researchers’ interpretation of one participant’s turn can be validated through the response in the next turn.

Caroline has gathered all the children in a circle on the floor. She tells the children that they are going to make a worm world, which is a plastic terrarium that you fill with dust, sand and leaves. Thereafter, you put earthworms into the terrarium and after a few days you can study how the worms are making tunnels in the dust and how they are dragging down the leaves from the top layer. The children tumble around on the floor, and talk loudly and excitedly, and some of the older children reminisce about when they made the worm world the last time. Caroline and the children talk about worms; what they eat, where they could be found, that they have no eyes and are not able to see, but that they are very sensible to vibrations in the ground. They also sing a song about a worm named Kurt, who is made of paper, with hair and eyes. In the following excerpt, they are leaving the subject of earthworms for a while to eat some fruit before going outside to set up the worm world. However, the children show that they are not ready to leave the worms yet.

- 1 Erik: [Erik lies down on the floor and crawls towards Caroline]
- 2 Caroline: [Turns to the whole group] Now I think Erik became an earthworm,
- 3 actually.
- 4 C: [Turns to Erik] Here you go Erik, what kind of fruit would you like?

- 5 C: [Turns to the other children:] Now you have to move aside because
6 there is an earthworm crawling on the floor.
- 7 C: [Turns to Erik:] Maybe you would like a leaf instead?
- 8 E: No.
- 9 C: [C holds out the fruit basket, but when Erik does not reach for a fruit, C
10 notices that Erik has his eyes closed] No, of course you're not looking, you
11 don't have any eyes. And you don't hear anything either when you are a
12 worm.
- 13 E: Yes, I'm a worm.
- 14 C: But you can feel instead. Then I take your hand here, there, then you
15 felt that you got a fruit. [Caroline takes Erik's hand and puts a fruit in
16 it]
- 17 C: Then we shall see. [Turns to Noelia] Noelia, what kind of fruit would
18 you like?
- 19 N: [Noelia crawls towards the fruit basket with her eyes closed].
- 20 C: Then we have the next earthworm crawling.
- 21 C: What kind of fruit would you like?
- 22 N: Pear.
- 23 C: Pear.
- 24 N: I could hear.
- 25 C: Yes could hear, indeed. Here you go. [Hands the fruit to Noelia]. Then
26 you can crawl back to your spot.

In the beginning of this excerpt, Erik is crawling across the carpet (Line 1). Caroline comments on Erik's movement and thereby makes a connection to the just ended discussion about worms (Lines 2-3: "Now I think that Erik became an earthworm, actually"). In doing so, Caroline acknowledges his action and interprets it as Erik being an earthworm. However, when Caroline tells the other children to move aside, because "there is an earthworm crawling on the floor" (Line 6), she puts into words the semantic relationship that this is a behavior typical for earthworms. In doing so, Caroline translates meaning from embodied action to verbal utterance. Furthermore, she addresses the whole group with her utterance, thus giving the rest of the group the opportunity to share her interpretation. Caroline addresses Erik as a child, but when she talks to the other children about Erik, she talks about him as if he was an earthworm.

Caroline also continues this role-play when asking if Erik wants leaves instead of fruit (Line 7). In this line, she takes the opportunity to recapture the semantic relationship that worms eat leaves, something they have previously addressed. Erik responds with a "No" (Line 8) and Caroline holds out the fruit basket to him. However, when Caroline notices that Erik is not taking any fruit, she looks at him and realizes that he has his eyes closed (Line 9-10). Again, Caroline verbalizes her interpretation of what Erik is doing, namely that he cannot see anything since (as a worm) he does not have any eyes (Line 10-11). Furthermore, she adds another characteristic of earthworms, the fact that they cannot hear (Line 11-12). In doing so, she once more explicates her interpretation that Erik is playing an earthworm, which he also confirms (Line 13: "Yes, I'm a worm"). Thus, when Caroline notices that Erik has his eyes closed (Line 9-10), she makes a verbal translation of his embodied actions, which makes these actions accessible to the rest of the group.

Caroline adds to Erik's play as she comments that Erik, when he is an earthworm, "does not hear" (Line 11-12), but that he could instead use his sense of touch (Line 14). Caroline adds to this utterance by taking Erik's hand and putting a fruit in it (Line 15-16). In doing so, Caroline assists Erik in using his sense of touch, thereby translating a verbal modality into an embodied, encouraging Erik to use his sense of touch.

In the following lines, we may see indications for shared meaning as Noëlia, who is next in turn to get a fruit, imitates Erik's behavior. Noëlia crawls towards the fruit basket with her eyes closed (Line 19). Caroline again interprets this as an attempt to imitate an earthworm. She verbalizes her interpretation, making it explicit to all the children (Line 20). When Caroline asks which fruit Noelia wants (Line 21), Noëlia answers "Pear" (Line 22). Then, Noëlia herself points out that she was able to hear Caroline's question (Line 24). In doing so, Noëlia states her awareness that it is not typical for an earthworm to be able to hear. Caroline confirms this by adding "indeed" (Line 25), which signals that this was indeed rather unusual for an earthworm. Caroline then continues the play as she prompts Noëlia to "crawl back to [her] spot" (Line 25-26).

This episode continues, as all children have received their fruits, are eating, and are talking enthusiastically about the worms, their characteristics, and later what clothes they are going to wear as they go outside.

DISCUSSION AND CONCLUSIONS

This study investigates meaning making of science in an ordinary Swedish preschool. The results show that the teacher and the children use different modalities to express the same semantic relationships. Talk, embodied actions and gestures complement each other to make meaning of the behavior and characters of an earthworm. Erik and Noëlia express the crawling of the earthworm (Line 1 and Line 19) by using their bodies, actually laying down on the floor and crawling over the carpet. In both these cases, Caroline puts into words Erik's and Noëlia's actions. In this way, Caroline phrases the semantic relationship of how an earthworm is moving – it crawls. In contrast to Mercer (2004), who states that a person combines several modalities to make meaning, the present study shows that different persons (the teacher and the children) use different modalities to communicate the same meaning. We introduce the concept *translating modalities*, as a way of describing what Caroline is doing here. She offers a verbal output (Line 6: "there is an earthworm crawling on the floor" and Line 20 "Then we have the next earthworm crawling"). In doing so, she introduces words important for emergent science learning and she also offers this meaning making to all present children. In other words, the teacher translates the children's embodied actions into verbal utterances.

This type of translation is also seen when Caroline discovers that Erik has his eyes closed (Line 10). He is then playing an earthworm and Caroline puts into words (Lines 10-11) the character of the earthworm that Erik performs with his embodied actions.

The results also show that Caroline suggests embodied experiences for uttered words. When Caroline introduces the fact that earthworms have a sense of touch (Lines 14-15: "But you can feel instead. Then I take your hand here, there, then you felt that you got a fruit.") she also encourages Erik to experience this himself, as he has his eyes closed, and she guides his hand to grab a fruit from the basket. We suggest that Caroline in this example translates verbal language into children's embodied experiences and the use of several senses.

Thus, *translating modalities* is defined as when something expressed in one modality – or semiotic resource – is translated into another modality, keeping a similar meaning. Translating modalities is an interactive meaning-making process. This means that the aim of translating between modalities is to seek common understanding. Children use a broad repertoire of semiotic resources as they have still not yet developed a verbal language

(Enfield, 2011). We suggest that translating modalities could be a way for teachers to enhance children's verbal language development, by putting words to children's gestures.

We would argue that when the teacher translates between different modalities she offers opportunities for learning science. This highlights the importance of the teacher's role in science learning for preschool children. In contrast to Larsson (2013), this study shows a teacher that interprets children's actions as potential science content. Caroline could have interpreted children's crawling on the carpet as a disciplinary offence, but instead she sees the competence of the children in relation to the previous topic. To be able to see this, the teacher does not only have to have sufficient content and pedagogical content knowledge (Larsson, 2013), but also have to be aware that children do not always express their science knowledge in words. Even though the teacher's role is to guide child attention to important science content (Pramling & Pramling Samuelsson, 2001), it is also evident that the teacher's awareness of multimodality can help them to see children's emergent meaning making in science.

Furthermore, in putting words to children's embodied actions, Caroline offers a verbal language for the children's spontaneous activities. In doing so, she also highlights the activities and connects them to the characteristics of the earthworms for the other children in the group. In other terms, Caroline *promotes shared meaning* (Scott, 1998) as she makes her interpretation publicly accessible to the other children. By translating between modalities the teacher makes scientific content available to all the children.

In answering the first research question, characterizing the interaction of meaning making in science in preschool, some light have also been shed on our second question. The second question deals with the contribution of a multimodal perspective for meaning making in science.

Our results indicate that semantic relationships could be carried by different semiotic resources, or modalities, as stated in earlier research (Fredlund, 2013). In a preschool setting, where not all children have developed a verbal language, it is of even greater importance to study not only the uttered words, but also to take into account gestures, embodied actions and gaze.

It is interesting to note that if only the spoken words are taken into account, the children only say a few things during the excerpt above. Erik says "No." (Line 8) and "Yes, I'm a worm" (Line 13) and Noëlia says "Pear." (Line 22) and "I could hear." (Line 24). The science content is not visible merely by looking at these few spoken lines. However, taking an interactional multimodal perspective on the activities in preschool reveals a much richer picture of the meaning making process going on together with the teacher. As we can see from the results, the children use other modalities than verbal language to express their understanding of emerging science content. Thereby, we suggest that embodied actions contribute to meaning making in science. It is important to not only look at verbal language as we are trying to understand children's conceptions of science.

Even though this is a small-scale study, we argue that the results and the ensuing analysis are of great interest for teaching and learning in a preschool setting. Caroline's interaction with the children in approaching a science content gives new insight into how children could be seen, not only as passive recipients, but as active meaning-making individuals in social interaction, using different modalities to communicate an emergent science content.

However, the children do not become competent actors by themselves, but through the support that Caroline gives their engagement through translating between modalities.

Furthermore, we want to highlight the importance of more studies in preschool taking a multimodal perspective. These studies could help inform and guide preschool teachers in how to notice and interpret preschoolers' actions and activities as exploring and making meaning in emerging science.

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CHILDREN'S IDEAS ABOUT INTERNAL STRUCTURE OF AN EARTHWORM

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Abstract: Finding out about children's ideas about biological phenomena is an important area of biological education research. One method of gathering data about children's conceptions is through analysis of their drawings. Drawings are one of type of representation; they can be viewed as expressed models, generated from mental models – the personal cognitive representations held by individual subjects. Such investigations, especially when supplemented with the labeling of the parts by the child herself, or by an adult for the younger children and cross-referenced through interview may provide information about the way children picture their surrounding world and its other living things. Earthworms are a common annelid that play an important role in many land ecosystems in Europe. They are adequately prevalent to be within reach of the daily experience of children and teachers. 116 drawings of Polish children at age 5 (N=36), 7(N=38) and 10(N=42) were analyzed. The ideas of the children of what is inside an earthworm were categorized using a rubric scale to analyze children's perceptions of what is inside the human body. This task was difficult for many children, particularly as many of them perceive earthworms as not very nice or an offputting/disgusting animal. The goal of the study was to investigate children's ideas about internal earthworm anatomy, and to examine the extent to which pupils' alternative conceptions (and their understanding of the internal structure of an animal) change as a function of age. The results show that the mental model of an earthworm held by these learners is not necessarily in agreement with established biological knowledge. The mental models expressed revealed some alternative conceptions, shared by children across age, for example: earthworms having a vertebrate type of heart, red and white blood cells, or is a prior life stage of a butterfly.

Keywords: earthworm, mental model, drawings.

INTRODUCTION

Children observe, ask questions, are interested in the world that surrounds them and also possess mental models of, among others, biological objects. Mental models are personal cognitive representations held by individuals, formed through the interpretation of experiences and also through the processing of information acquired from the surrounding environment, including through education.

Identifying and interpreting children's ideas about biological phenomena is an important area of biological education research, receiving increasing attention. One method of gathering data about these understandings of children is an analysis of their drawings. Such investigations, especially when supplemented with the labeling of the parts indicated by the child, or by an adult on behalf of younger children, and an interview, may provide information about the way children picture their surrounding world and its other living organisms. Drawings are one type

of representation that can be viewed as expressed models which are generated from mental models – the personal cognitive representations held by individual subjects (Gilbert & Boulter, 2000).

Earthworm

Earthworms are a common annelid, which play an important role in many land ecosystems in Europe. They process large pieces of organic matter into humus thus improving soil fertility; they are involved in the formation of pore structures in the soil (Edwards & Bohlen, 1996; Groffman & Bohlen, 1999). Earthworms form the base of many food chains. The most desirable way to maintain or increase worm populations in the soil is to avoid the application of chemicals, including fertilizers (Edwards & Bohlen, 1996).

Although earthworms play an important role in ecosystems, they are often perceived as disgusting animals and, perhaps because of this, they are underappreciated. This attitude holds, not only for children (Prokop et al. 2011) but also for adults – including pre-service biology teachers (Tomazic, 2011; Olatunji et al. 2007). As Kaiser and Fuhrer (2003) noticed, knowledge about our environment is one of the major factors that influence ecological behavior. Pooley and O'Connor (2000) added that, besides knowledge, people's feelings and beliefs about the environment also influence their attitudes towards it. So we may assume that children's knowledge and beliefs affect their behavior and serve as strong predictors of their pro-environmental attitudes.

Earthworms receive little attention in the primary science curriculum. One reason for this might be that interactions between organisms and other constituents of an ecosystem might be considered too complex to address in the early years. We take the view that biological organisms that are accessible to human experience can play an important role in familiarizing children with the important role of biological processes and also some aspects of the dynamic interactions that sustain ecosystems.

The goal of the study

The aim of this study was to investigate children's ideas about internal earthworm anatomy, and to examine the extent to which pupils' understandings and alternative conceptions of the internal structure of an animal change as a function of age.

In order to find out children's ideas about earthworms and their internal structure, 116 children were asked to draw what is inside this animal. These drawings of Polish children at age 5 (N=36), 7 (N=38) and 10 (N=42) were analyzed. The children's ideas of the internal anatomy of an earthworm were categorized using a rubric scale similar to the one used previously by, eg. Tunnicliffe and Reiss (2001), to analyze what is inside the human body.

METHOD

The researchers worked with three age groups, at age 5 (kindergarten, 36 children), age 7 (first class of primary school, 38 children) and age 10 (fourth class of primary school, 42 children), using a method similar to the one used in investigations made by Rybska, Tunnicliffe and Sajkowska (2014) while searching for children's ideas about the internal structure of snails. Altogether, 116 drawings were gathered and analyzed. Both the kindergarten and primary school are located in Poznan (west part of Poland). Ethical considerations were discussed and approved by the principals of the schools. Children were motivated to draw by showing a live specimen of an earthworm. Then they were asked to close their eyes and think what was inside this living animal. Children were provided individually with an A4 sheet of paper, pencils and crayons. Interviewers made notes on what

could be observed during the time that children were drawing and the pupils' answers during or immediately after the drawing activity. Children drew for approximately 20 minutes. The fieldwork was conducted in their whole group/class setting. In each case, a researcher interviewed a child whilst they were drawing. Special attention was given to labelling by the researcher of what children thought they drew (especially for younger ones who were not able to label the picture, themselves). The children were also asked to mark their age and gender on the drawing (for the younger participants this was also done by a researcher). Interviews were carried out just after the drawing activity and pupils' words were written down on the same day that the drawing activity took place.

Data analysis

After collection, the drawings were numbered and coded according to the age and gender of the children. Afterwards each drawing was scored. Two people carried out this process, first scoring them separately. The rubric scale used was based on the scale proposed by Reiss and Tunnicliffe (2001) and modified for drawings of the earthworm (see Table 1). It was adjusted to measure children's understanding about the internal structure of earthworms. The "artistic" value of the drawings was not taken into consideration in this research. Also, no notice was taken into consideration of the age or gender of the child, during the scoring of the drawings.

Table 1. The rubric scale used to allocate a grade to the drawings.

Level	Source of knowledge / Characteristic of an Earthworm's anatomy
0	Nothing inside but we know it is earthworm/ child indicated there was something inside
1	No representation of internal structure / earthworm placed in its environment
2	One or more internal organs placed at random
3	One internal organ in appropriate position
4	Two or more organs in appropriate position
5	One organ system indicated
6	Two or more major organs systems indicated
7	Comprehensive representation with four or more organ systems indicated

Data were entered into Minitab and Excel for analysis. One-way ANOVA test was used for statistical analysis (STATISTICA ver.10) tests were performed for detecting differences between levels and age groups, distinguishing categories and structures and age groups and population structures.

RESULTS

The participating children drew rich drawings with interesting information. In each age group the most often scored level was 2 (one or more internal organs placed at random) with 65% frequency (for 5 years old it was 75%, for 7 years old 68% and for 10 years old 55%). None of the drawing of 5 years old child scored higher than 2 level. Higher scores were presented at drawings made by 7 and 10 years old pupils, where we could observe whole organs system drawn. The most

frequent organ systems presented at analyzed data were circulatory (at 7 year old group it was 6% and in 10 year old 14%) and digestive system (at 7 year old group it was 6% and in 10 year old 17%). Only in group of 10 years old were drawing which scored 6 level – 6% of the group. Children understanding of organ systems seems to be poor.

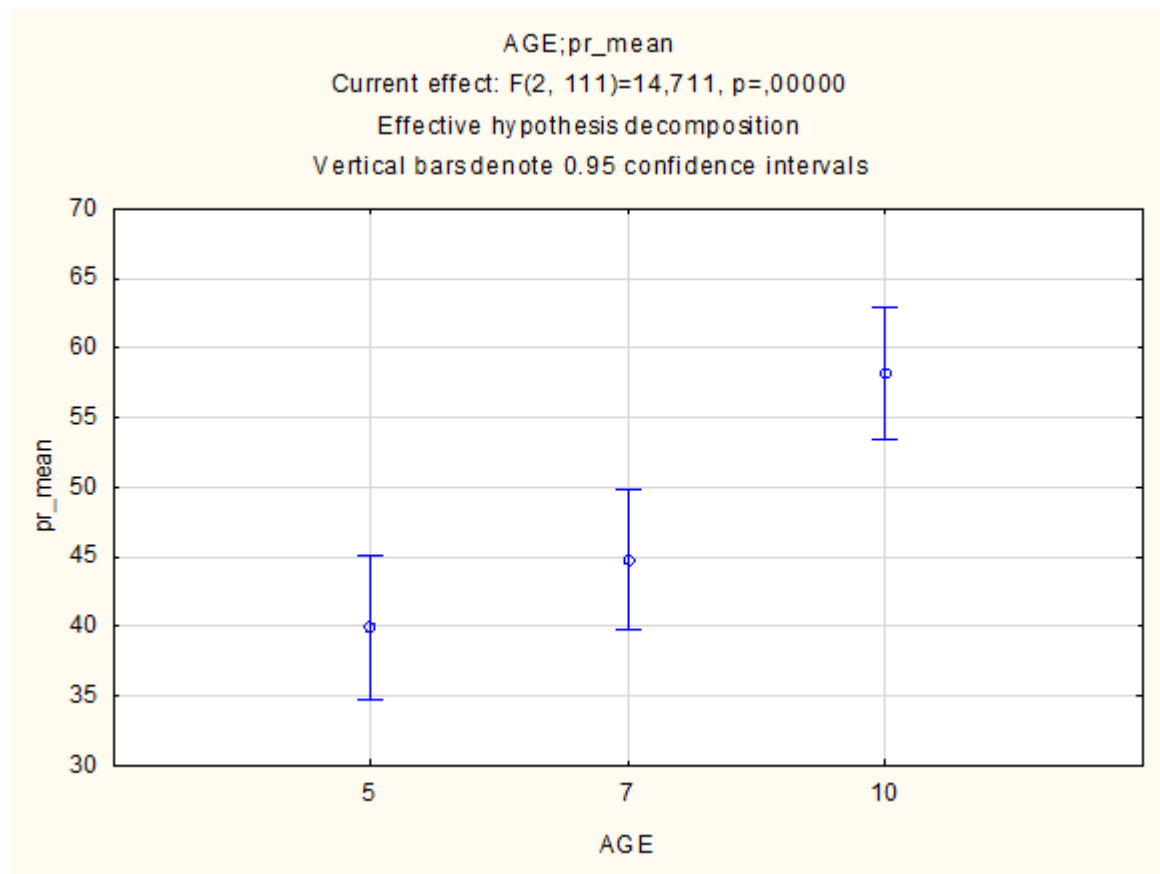


Figure1. Differences in mean scores of level of representation of organ systems with respect to children's age differences.

The most frequent organ drawn was a heart (it appeared on 81% of all pictures). Next, were elements of a digestive system (33%) and the brain (24%). There were very few drawings with muscles, or elements of a urinary system. Elements of a reproductive system appeared only in the third age group (10 years old).

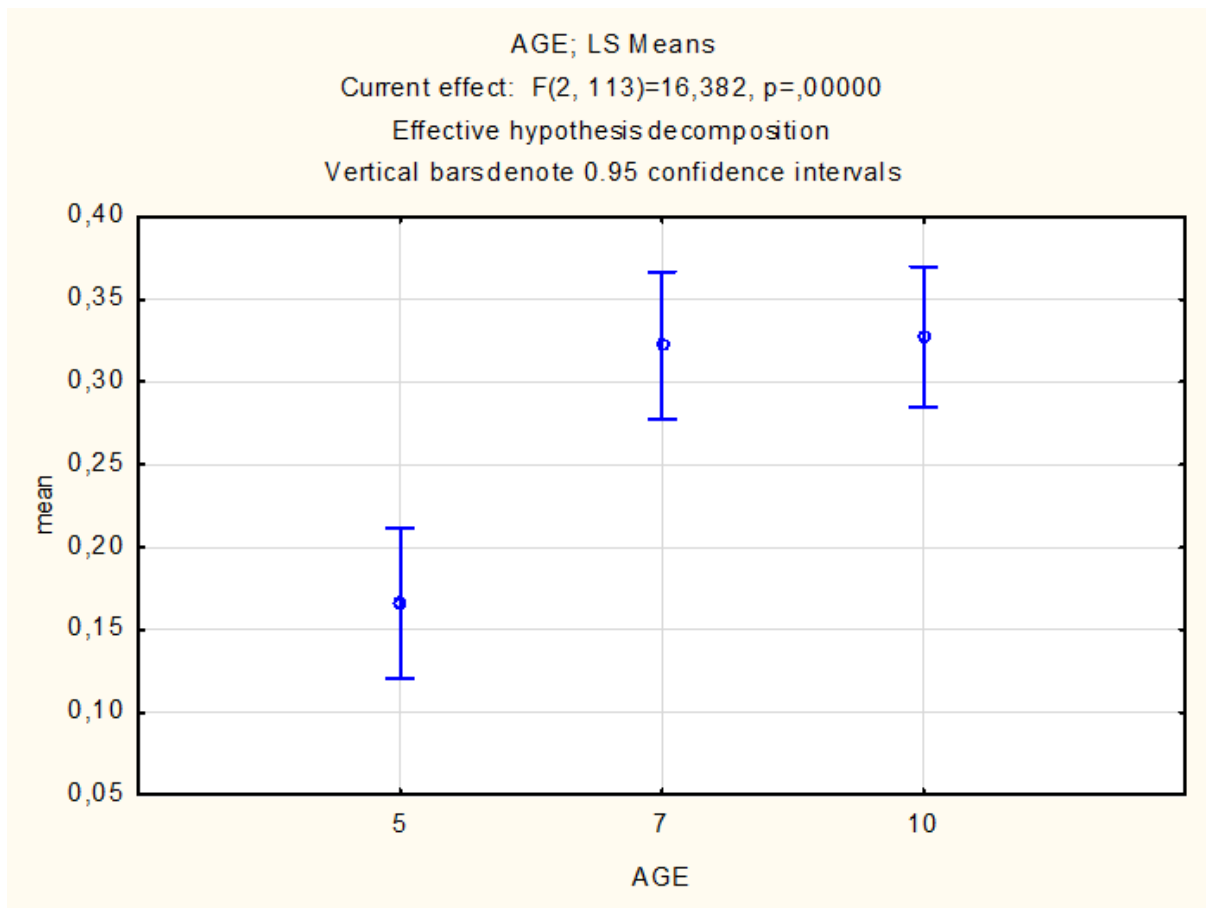


Figure2. Differences in mean scores of representation of particular organ systems with respect to children's age differences.

Illustrative drawings with corresponding labels are shown below (Fig.3-5).

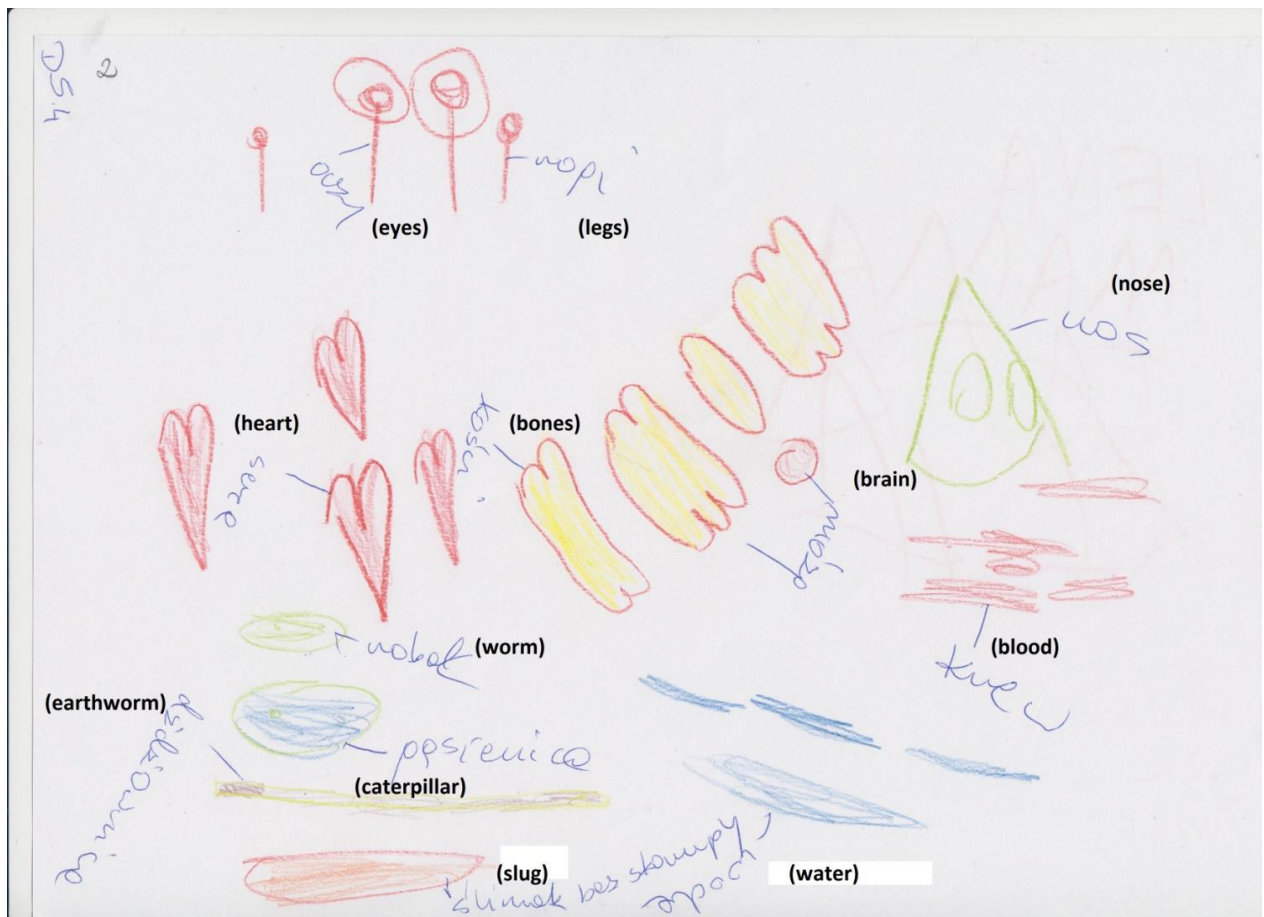


Figure3. Drawing of a 5 year-old child, which was scored as level 2, (One or more internal organs placed at random).

Based on the drawings we interpreted the existence of some interesting conceptions that, to our knowledge, have not been documented in the research literature before:

- Earthworm is a prior life stage of a butterfly (26%).
- Earthworms have a vertebrate type of heart (81%).
- Circulatory systems consist of water veins and blood veins (24%).
- The main role of an earthworm is to eat soil.
- Earthworms belong to invertebrates but it might have bones and spinal cord inside.
- It might change at some point of its life cycle into a snail/slug.

The percentages appearing in parentheses indicate the prevalence of these conceptions, in children's drawings.

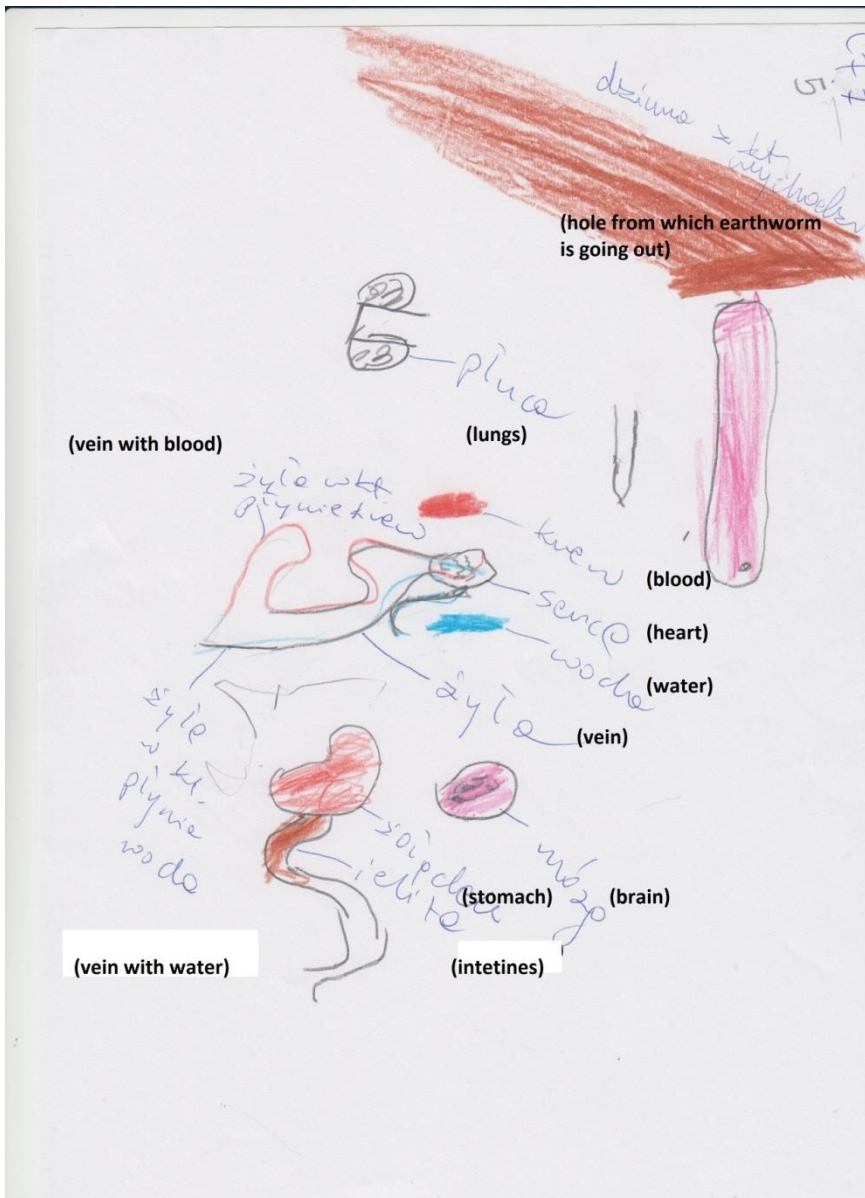


Figure 4. Drawing of a 7 year old child, which was scored as level 5 (one organ system indicated correctly).

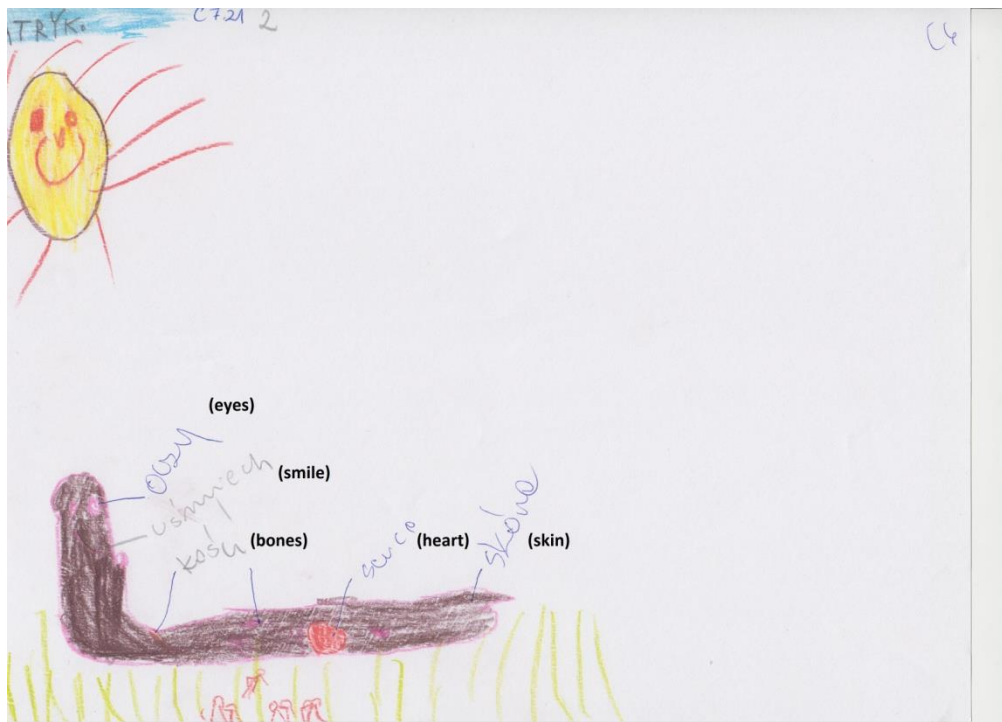


Figure5. Drawing of a 7 year old child, which was scored as level 2, (One or more internal organs placed at random).

DISCUSSION

Our results indicate that the mental model of an earthworm held by these learners is not necessarily in agreement with established biological knowledge. The mental model expressed revealed some alternative conceptions, shared by children across ages, for example: earthworms having a vertebrate type of heart, red and white blood cells, or is a prior life stage of a butterfly.

Children's understanding about organ systems seems to be poor. The most frequent level achieved on drawings was level 2 - one or more internal organs placed at random. Similar results was received by Rybska and co-authors (2014) while investigating children's conceptions about snail internal anatomy with that difference, that the knowledge of circulatory system in presented research was better. What is worth highlighting here is the fact that most children who drawn circulatory system were explaining that it consists of two systems – water and blood system. This finding is quite important because it erase from the way circulatory system is pictured in textbooks – with red and blue colors, and children seeing blue seems to connect it to the water (since we have to have water inside the body).

The most frequent drawn organ was heart – which is in agreement with other research done by Reiss and Tunnicliffe (2001), Rybska, Sajkowska and Tunnicliffe (2014) and Prokop and Fančovičová (2006), who showed that the most common human internal organs drawn by the children were heart or bones.

Children's mental models of an earthworm in presented research is quite complex. It shows some hints or suggestions that teachers might use in order to design their future lessons about this common annelid. Student's mental models are often constructed when a given task requires from students more general approach (Kattmann, 2001).

Conclusions and Educational Implications

- Formal education has a positive effect on students' knowledge: conceptions change with age. However we observed a tendency amongst the older children to always tend to use the human body as a template.
- The younger children tend to think that an earthworm has to differ from the human; for example it might possess 5 hearts or a home inside its body.

We consider that primary science teaching should introduce this commonly found invertebrate in classes more often so that children can gradually learn that different types of animals have a differing structure, internally and externally, and some differ from the mammalian pattern.

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CREATIVE PEDAGOGIES IN EARLY YEARS SCIENCE: THEMATIC PLANNING AND SUSTAINED SCIENTIFIC DIALOGUES

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Abstract:

This paper draws on the ‘See the Science’ Project funded by the Primary Science Teaching Trust that took place in South West England in 2012-13. It aims to illuminate the process of transforming a curriculum document into a valuable learning experience for children through the use of classroom talk. The project was grounded in concerns that the increased use of thematic, ‘creative’ curricula in England was leading to a loss of scientific learning for children in the early years (five to seven year olds). It presents our findings that in the context of the twelve primary schools with which we worked, the type of curriculum used (e.g. thematic, cross-curricular) had less impact on teaching than we anticipated, whereas the teacher’s immediate responsiveness to children’s ideas and interests and their development of a repertoire of different forms of talk for different purposes in learning science was crucial. A framework emerged to characterise the form of talk we aimed to develop; *sustained scientific dialogues*, encompassing the essence of sustained, shared thinking in the early years (Siraj-Blatchford et al., 2008) with a science focus and drawing on characteristics of dialogic talk (Mortimer and Scott 2003; Alexander, 2008). Through the development of case studies using qualitative approaches including transcription and analysis of classroom talk we examine how teachers developed their practice and we argue that *sustained scientific dialogues* play a key role in the development of creative pedagogies. Three cases presented here are representative of the typical project findings: one inexperienced teacher developed talk that was more sustained and two experienced teachers developed talk that was more dialogic, the latter exemplifying how this maintained a strong science focus. The fourth case shows how an early years teacher with a strong dialogic pedagogy expanded his repertoire to include more authoritative episodes focussed on scientific knowledge.

Keywords: early years, primary, thematic, creative, dialogic

INTRODUCTION

The *See the Science* project funded by the Primary Science Teaching Trust involved primary school teachers working with university research staff to secure and strengthen the place of science within a thematic, ‘creative curriculum’ and to enhance children’s learning by improving the quality of classroom talk between teacher and pupil. This paper aims to explore:

- How science learning is identified and developed within a thematic or ‘creative curriculum’ framework;
- The challenges of promoting and implementing primary school teachers’ *sustained scientific dialogues* with children.

Seeing the Science within a Thematic Curriculum

Our concern is for the future of science teaching of the highest quality within educational practices that are increasingly moving away from a traditional subject focus on science as more thematic, ‘creative’ and child-centred approaches to curriculum design continue to emerge, develop and be championed in England and elsewhere. In England two major

reviews of curriculum design for children aged 5-11 proposed curricula which are not arranged around traditional subject structures (Alexander, 2010; Rose, 2009). Although the current National Curriculum for England (DfE, 2013) (for children aged 5 and upwards) has set aside such recommendations and put in place a subject-based curriculum, many schools are not obliged to teach this curriculum and have opted to adopt alternative versions that exploit the potential of thematic learning. There is also a strong international trend in this direction: The authors of the International Primary Curriculum (Fieldwork Education, 2013), (claimed to be in use in 80 countries) purports to be a highly successful thematic, creative curriculum for 3-11 year olds, Altinyelken (2010) reports on the implementation of 'thematic curriculum' in Uganda and McCulloch (2011) reports on 5 high performing school systems (including Finland & Australia) where schools are 'increasingly taking a rigorous thematic approach...' (p27). Although the thematic approach is believed to have considerable benefits in situating knowledge within a meaningful, motivating context, we were concerned that where teachers may have multiple objectives for classroom activity the distinctive contribution of science to children's learning may disappear (Davies, 2011).

Creative curriculum is often used interchangeably with 'thematic' or 'cross-curricular' when discussing the school curriculum. Curriculum design has been a highly contentious issue in the UK since the inception of the National Curriculum in 1988 (Alexander, 2010). The debate is often characterised as a dichotomous struggle between realists purporting that subjects should be the fundamental units of the school curriculum, challenged by pragmatic and progressive philosophies that champion student-centred curricula claimed to engage learners and contextualise knowledge and skills (Ornstein & Hunkins, 1998; Alexander, 2010). However, as Alexander (2010) argues, subject disciplines and thematic teaching are not mutually exclusive. Subjects, he asserts, can be integrated, connected or combined through classroom activity, yet remain as subjects. A curriculum organised in a way that does not exploit connections between subjects, is, arguably, a poor alternative.

Curriculum transformation through classroom talk

Siraj Blatchford et al (2002) distinguish between 'pedagogical framing' and 'pedagogical interventions'; curricula become uniquely developed, interpreted and transformed by teachers and their students. Teachers will draw on knowledge of subjects, of learners and of their own roles, strengths and limitations, to make a unique blend of educative experiences and practices. It is this transformation that we take to mean 'creative curriculum' development. We acknowledge that such practice is, for teachers, a high-risk strategy requiring self-confidence and an investment of time and energy (Jeffrey & Craft, 2004).

How teachers talk with children plays a key role in this creative process of curriculum transformation. Dialogues between children and adults that have shown Sustained Shared Thinking (SST); a practice that embodies the value of responding to children's ideas and interests through talk, have been found to be a common feature of early years practice leading to higher outcomes (Siraj-Blatchford et al., 2008). Similarly, a principle of 'dialogic' talk is that it is 'genuinely reciprocal' (Alexander, 2008), and in the context of science this means teachers working with both children's ideas and scientific ideas together in classroom talk (Mortimer and Scott, 2003). The assumption of the *See the Science* Project was that the way teachers develop such dialogues will be informed by their understandings of science and its relationship with other subject areas. We invited practitioners to consider how they could develop the scientific aspect of their talk with children within a thematic curriculum.

As the English curriculum is undergoing a period of change this project was well placed to explore the possibilities for and challenges of developing sustained dialogues within different forms of curriculum planning. As schools have been encouraged to adopt a 'creative curriculum', often based on thematic topics rather than subject focussed planning teachers have been working to adopt 'creative pedagogies' in which children's ideas and interests

inform the content and processes of teaching and learning. Although it is used widely in educational discourse in the UK, there is no single consensus what the term ‘creative curriculum’ means in practice and the model of curriculum and of pedagogy that underpins it is under-researched (Davies et al., 2014). We will discuss some ways in which teachers have attempted to construct a creative curriculum through their planning and talk with children within the *See the Science* project.

Dialogic and creative pedagogies

A ‘transmission model’ of communication, in which information is simply coded by a sender and decoded by the receiver, is a common view of the purpose and process of schooling and is often associated with classroom talk is overly dominated by ‘Initiation-Response-Evaluation (IRE) triads (Sinclair and Coulthard, 1975). An alternative to the transmission view of talk, suggests that texts (both spoken and written) fulfil two functions: to convey meanings adequately, and to generate new meanings (Wertsch, 1991; 74). The first requires the codes of the speaker and listener to coincide – it requires univocality, the second involves multivoicedness. Unlike the Vygotskian use of the term dialogic, which focuses on the development of shared understandings through language (Vygotsky, 1978), Bakhtin’s use of ‘dialogic’ values the differences in meanings between any participants in creating a ‘multivocal’ discourse that is in tension with the ‘univocal’ discourse imposed by powerful groups within society (Bakhtin, 1981) This multivocality is a source of creativity as new meanings are generated (Wegerif, 2008).

The Cambridge Primary Review (Alexander, 2010) advocates pedagogy of both cultural induction and exploration, this dual view of the purpose of education as both the appropriation of cultural knowledge and its transformation is central to our view of creative pedagogies for science education. Science is about being imaginative and creative; about generating ideas, as well rigorous testing leading to (tentative) verification of concepts. When science is understood as a tentative, changing knowledge, then engaging in that discourse requires simultaneously working with the existing ideas and seeking to change them. Thus we position dialogic talk as an important element of creative pedagogies.

Working with teachers to understand the theoretical model in practice, Mortimer and Scott (2003) argue that moving between univocal and multivocal discourses by using different communicative approaches that include both dialogic and authoritative elements in science lessons is fundamental to supporting children’s appropriation of scientific concepts and suggest that in most cases this requires an increased use of dialogic talk in classrooms. This is how dialogic talk can support univocal outcome of shared understanding of existing science concepts. Extending this, we advocate a repertoire of talk to support multivocal as well as univocal outcomes (McMahon, 2012). Alexander also provides indicators of dialogic talk in the classroom, arguing that the key features are that is collective, supportive, cumulative, purposeful, and reciprocal and suggesting that the cumulative feature in which ideas build upon each other through sustained chains of utterances is particularly challenging to achieve.

Sustained Scientific Dialogues

Teachers and researchers discussed literature on classroom talk and experiences of practice in terms of our views of the aims of science education within a thematic curriculum as the *See the Science* project progressed. We developed a framework (summarised in Table 1 below) to characterise and reflect on the form of talk we wanted to develop, coining the term *sustained scientific dialogues* (SSD) as encompassing the essence of sustained, shared thinking in the early years (Siraj-Blatchford et al., 2008) with a science focus and drawing on features of dialogic talk from Mortimer and Scott (2003) and Alexander (2008).

METHOD

The *See the Science* project combined research with professional development as university tutors worked collaboratively with teachers to reflect on practice and how it can be developed. By developing narratives based on cases situated in a diverse range of contexts we were able to generate rich accounts of the complexities of teaching that engages with the tacit knowledge of the teachers and we intend will resonate with readers (Stake, 1995). The use of multiple case studies increases the external validity as findings can be compared across the cases (Yin, 2003).

Case studies were developed with twelve teachers in six primary schools in three different environments; rural village, city centre and city suburbs. The schools were self-selecting in response to an open invitation to approximately 250 schools within the university teaching partnership so we can assume that science was already important to those schools and this limits the extent to which they can be seen as representative of English schools.

The project intervention strategies over one year were: workshops on identifying science in a thematic curriculum, workshops on research into classroom talk, teacher self-audit and target setting, teachers sharing approaches to planning, audio-recording and transcription of teacher-pupil talk and reflective dialogues on transcripts.

This generated the following data sources:

- Teacher self-audit questionnaires and on-going reflections
- Samples of planning
- Audio recordings of teacher –pupil talk in three science rich lessons per teacher over the course of the project supported by observational field notes.
- Audio transcription of selected episodes
- Teacher and tutor reflection on transcripts
- Teachers' PowerPoint presentations and accompanying narratives at project end.

Analysis of the transcripts drew on elements of the literature discussed by the whole project team that, during the course of the project, emerged into the analytic framework summarised in Table 1. The first analysis was a reflective discussion between the tutor and teacher then the validity of their interpretation of the transcripts was enhanced by further analytical discussion with another teacher.

Table 1. Sustained Scientific Dialogues as the framework for analysis of transcripts

Element of SSD	Key Questions for Reflective Analysis
Sustained	Were ideas developed over several exchanges in a sustained way? (Siraj-Blatchford et al. 2008) Were there chained utterances, not limited to IRE triads? Was the development of ideas cumulative? (Alexander, 2008)
Scientific	Was the episode purposeful in terms of scientific learning? (Alexander, 2008) Did the content go beyond factual recall to conceptual and/or procedural understanding? (Wegerif, 2013)
Dialogue	What was the overall balance of pupil to teacher talk? Were children's ideas expressed and explored? Was the talk collective, & genuinely reciprocal? (Alexander, 2008) Was the communicative approach dialogic or authoritative? (Mortimer & Scott, 2003)

The time consuming nature of producing and analysing transcripts meant that selection was required. The lessons observed were planned by the teacher and so were likely to represent what they saw as their ‘best’, but possibly also ‘safest’ teaching. Episodes of audio recording were selected for transcription by the tutor in discussion with the teacher after the lesson, enabling the teachers to feel in control of this potentially exposing process. So the transcripts presented in the findings are not chosen as typical of a teacher’s practice, rather they represent their journey of professional development.

RESULTS

Framing of science within the schools’ curriculum

The project schools situated science within their curricula in different ways: most teachers (10) taught science as a distinct thread within a topic and only two had science fully integrated into a theme. None taught science as an isolated subject. Questionnaire data showed that no school made large changes to their medium term planning during the project. Some teachers reported frustration in realising their view of a creative curriculum within the constraints of whole school approaches. Most were content that their existing planning provided sufficient opportunities for science and were more interested in changing the kind of science this was and ensuring that it allowed time for discussion of questions and building on children’s ideas.

Curriculum transformation through classroom talk

During the analysis of data from the project it became clear that the teachers had limited control over the medium-term planning as all the project schools had adopted externally produced schemes of work. Whilst there were espoused notions of ‘creative’ or ‘thematic’ curriculum organisation at school level intended to make learning more relevant and effective, the impact such curricula had at the level of teacher-pupil interactions were difficult to discern. It became apparent that it was still in the teacher’s control to determine the kinds of talk that happened in the classroom and there were many opportunities (that were sometimes missed) within curriculum frameworks to develop *sustained scientific dialogues* with children. By exploring these issues with teachers we produced case studies to provoke further discussion about how to manage the delicate balance between a rigorous approach to progression in science and providing meaningful, engaging contexts for learning.

Analysis of early observations and transcripts showed few episodes of SSD and confirmed concerns in research literature on classroom interactions that many teachers dominate the talk of the classroom and use of limited three part ‘initiation, response, evaluation’ triads were the most common structure, validating this as a focus for development. Samples of teacher talk with children at the start of the project showed very few instances of dialogic talk, suggesting there is no simple relationship between practicing dialogic talk and a commitment to a ‘creative curriculum’. Teachers reflecting on transcripts of their talk led to some changes in practice as they have realised there is a difference between their espoused values and their practice.

The four cases in two schools presented here have been selected to show different ways in which the analytic framework was applied to develop practice depending on the analysis of teachers existing practice, illustrating the more typical and unusual. In the transcripts T: indicates the teacher is speaking and C1, C2 etc. indicate different children speaking.

Sam – more *sustained*

The first case represents features common to the majority of project schools as teachers strove to realise their espoused views on a creative curriculum by shifting classroom dialogues from

more authoritative to dialogic talk. This school described their curriculum as ‘creative’; science was embedded within thematic curriculum planning under the title ‘Exploring’ which encompassed a broader range of activities. In practice, science was clearly visible as a distinct lessons linked to the overall theme.

Sam, a newly qualified teacher of six to seven year olds reflected on the following episode:

T: Right. So we're going to have a race. H said we've got a start line, a finish line and a race. Now, we're going to have to get our boats from the start line to the finish line. Can you move right back behind the line please.

C1: Yes.

T: Now how do you think we could move these boats across from the start line to the finish line? H?

C2: We could umm blow them.

T: Okay. Okay. So you're waving your hands, but you're also saying we could blow on them, so to move some air were you thinking?

C2: Yes.

T: Now if we were ... if we were either creating air from blowing or moving some air, what forces would we be using to get these boats to the finish line through air?

C3: Air.

T: Oh good. So we could use the air to push the boats across couldn't we?

The content here was scientific, but limited to labelling a force as a push, and characterised by IRE triads it was neither sustained nor dialogic. Sam commented that: *‘It was a real eye opener looking at those transcripts. I hadn't realised how much I was talking and how I was leading what they were saying.’* In discussion with the tutor/researcher Sam focussed on planning classroom organization so that he could be with a small group at a time and work extending and using children's contributions in what he termed ‘learning discussion’ time.

The episode below shows children's utterances became longer and more detailed and Sam sustained exchanges with one child over several turns.

T: Okay, that's fine. Right, so C1, let's have a look shall we.

C1: He still looks like any new toy. I can see the material. It's kind of stretched. Mr Z?

T: Yes. (pause) Why do you think the material look stretched then?

C1: It's because umm I know umm ... I saw it (inaudible) it's kind of stretchy.

T: Oh wow. What great links you are making, just like the spider in our (inaudible). So how do you think the material being stretchy will help you to use it?

C1: Umm it will be useful for making clothes.

T: Yes, why is that?

C2: It's because clothes if made of material.

T: Yes.

C2: (inaudible)

T: Okay, C2, make sure you share please. Why is it important that clothes are made of material?

C2: It's because if you don't make any kind of clothes in material, you can't even make a coat anyway.

T: Yes, because we couldn't ... if we made ... if we made clothes out of metal, that would be quite difficult wouldn't it?

C2: Yes.

T: So why do you think it's important that clothes are made of soft material?

C1: Umm ... so that it won't be so kind of hard and kind of cosy.

Although the original purpose of the activity was to invite children to consider how the materials of the toys may have aged, Sam saw and took the opportunity afforded by Child 1's observation that the fabric looked stretched to encourage the children to think and express their ideas about how the properties of a material, a fabric, relates to its uses, going beyond simple recall.

Judith – more *dialogic*

Working in the same school, but in contrast to Sam, Judith was the most experienced teacher in the project. She described the curriculum as 'completely creative'. Also teaching six to seven year olds she aimed to explore: *'how children really respond to my questioning and at their interactions with myself and others, developing my own questioning confidence and extending science opportunities within a creative curriculum to have a greater understanding of how to extend children's science thinking.'*

On analysis of her transcript (below) Judith found that although she was often phrasing questions as open ended and inviting a range of different children to participate, the children were responding with brief answers. Her feedback extended the scientific ideas available to the children, but there was limited opportunity for the children to be the ones explaining ideas.

T: Who can think of anything they know that starts off as a liquid, but can also change into a solid? Anything else that might change in the same way? C1.

C1: (inaudible)

T: Water. What does water do?

T: Right, A says that water can start off as a liquid and then it can turn solid. How does it turn solid then? Do you mind if we ask somebody else just for a minute, C2?

C2: Umm ... you put it into the fridge and it turns solid.

T: Even colder than a fridge? What's even colder than a fridge? Freezer, that's right. It has to be turned somewhere ... well it has to go somewhere very cold for it to turn into what?

C3: Into a solid.

T: What is the solid called, C4? What's the solid of water called?

C4: Ice (? inaudible)

T: Ice. Well done. E, could you sit down please. Anything else that can start off as a liquid and turn into a solid? What do you think then C5?

C5: soap

T: Okay soap. Ahh let me think ... do you know, soap, could well have started off as a liquid, and then are you thinking of the hard soap? I think there must be chemicals

that when they're mixed together, like this, make the particles stick to turn that into something solid, well done. Does anyone on this table have an idea? C6?

C6: Cake.

Judith focused on extending her range of responses to children to encourage them to expand on their ideas and develop them. Recognising from other transcripts that she did this more readily in small group contexts she sought to bring more of this form of discourse to the high status whole class discussions to show she valued the children's insights (McMahon 2012). In the following episode she works on extending discussion of the children's observations of some old and decaying objects.

C1: Umm I ... (inaudible) and it was really disgusting.

T: Something disgusting? What was disgusting about it?

C1: Well ... this is ... (inaudible) disgusting.

T: It just made you think of the word disgusting did it? Somebody else, B?

C2: Umm ... I saw like the sewing bits that was like the umm ... M's (inaudible) saw like the sewing bits.

T: You could actually see the thread could you?

C2: Yes.

T: What did it look like when you look at this?

C2: It was like cross, cross and then it went like ...

T: Like that?

C2: Yes.

T: Wow. So you saw the detail of things. That's why someone like a history detective or an archaeologist or a scientist would use magnifiers because they see really closely the little detail that you can't see with your ordinary eye. Did anyone else see something that made them go, oh, I hadn't noticed that before? C?

In this episode, Judith's acceptance, expressed by repeating back or rephrasing children's ideas, and her interest, expressed by asking questions that stayed with the child's idea, and invited more contributions on the same topic, maintaining a sustained focus. Overall, the balance of talk was shifted so that the children had a greater share and the episode was more reciprocal, more dialogic. Judith maintained the scientific content by explaining how close observations relate to the work of scientists, but in this episode chose not to develop specific content on properties of materials.

In these two classrooms, having a 'creative', thematic curriculum did not of itself lead to *sustained scientific dialogues*, but reflection on features of talk in the transcripts supported the development of a repertoire that included more *sustained scientific dialogues* for both a new and experienced teacher. This striving to move from more authoritative to more dialogic talk was a feature of 9 of the 12 cases.

Julia – more *dialogic* and still *scientific*

Julia and Jae, whose work will be considered in the next section, both taught at a school which made a distinction between the curriculum planning for the youngest children (4-5) which was entirely thematic and flexible to respond to children's interests and that for the older children (6-11 years) which was in transition from being generic 'skills-led' to adopting an externally planned scheme in which science lessons were linked with a theme or topic but were clearly defined lessons.

Julia had previously taught 8 -11 year olds and wanted to develop what she saw as features of good early years pedagogy in her work with 6-7 year olds: *“I wanted to build on children’s responses, ...but I was driven by the content or plan of the lesson. [I want] to take risks [and] to think about making the science curriculum more child-led... building on from their interests and questions/thoughts.”*

Analysis of this episode in which the children sorted pictures into living and non-living reassured Julia that her following children’s lines of thought did not have to weaken the scientific content. In fact the children’s contributions extended the science as Julia recognised that these young children were more knowledgeable than she had supposed.

C1: I know how the trees, how umm plants help us to ...

T: How do they help us?

C1: They produce oxygen.

T: They do, you're quite right. Well done, they do help us; they do help produce oxygen which we breathe, well done. What's oxygen?

C1: It's what ... it's the air that we breathe in.

T: That's quite right, well done.

C2: We breathe umm ... trees breathe ... umm ... us and trees are the opposite.

T: How are we the opposite?

C2: I can't remember the other one, umm, oxygen.

T: Are you thinking about another gas called carbon dioxide, is it carbon dioxide are you thinking about?

C2: Because we breathe out carbon dioxide and breathe in oxygen and that ... and trees breathe out oxygen and breathe in ...

T: Carbon dioxide. Do you know what they do with the carbon dioxide, with that special gas, do you know what they do?

C2: Does the oxygen come from the trees and the plants or does it just come ... does it just come? Was it made or does it just come from the plants?

T: That's a good question isn't it?

This was not an isolated episode, other scientific topics of talk included the human rib cage and snail trails. This case illuminated the importance of establishing that dialogic talk can be scientific talk and not to see ‘child centred’ learning as being in opposition to scientific discourse.

Julia’s questions were understood as genuine questions explore the children’s their ideas not as questions to test them. She also gave feedback that told the children when an idea was right and in this context this affirmation did not close down the child’s talk but validated it. Rather than setting up a pattern of IRE triads led by the teacher, the child was the one initiating the new turns of the conversation. It is also notable that the focus of discussion was sustained over a large number of turns and it was cumulative in that each utterance built on the one before.

‘...I realised I needed to make the science curriculum more child-led, to allow children to explore and to encourage dialogue and discussion. Through doing this, the children were heavily involved, engaged and they felt at ease to impart their knowledge or to ask questions. This classroom talk stimulated and extended their thinking and allowed for a wide range of

scientific discussion. ...I feel I have discovered how classroom talk can lead to a greater level of engagement and how it can extend learning and depth of understanding.'

As Wegerif (2014) argues, if our aim is for children to engage with and take part in the discourse of science, some scaffolding may be required, in this case this was provided by the problem posed by Julia about classifying things as living or non-living and her questioning, but the overall dialogic purpose of the episode was maintained.

Jae – more scientific and still dialogic

An expert early years practitioner, Jae was led by children's ideas and interests during 'science rich' activities, even if that took them in an unintended and sometimes non-scientific direction. He aimed to: *'extend my repertoire of classroom talk strategies; to explore science concepts, generate new meanings, and pose genuine questions (Mortimer and Scott, 2003).'*

In the episode below in which the children were exploring plant life in the school playground, Jae made a deliberate shift to focus attention of the scientific features of plants, in this episode, the roots.

T: Shall we pull the flower up and see the roots? Ready. Oh it's a bit messy. Can you see them? Have a look ... careful look at those roots, what can you see when you look at those roots?

C1: They're brownish.

T: It is quite brownish isn't it. What else can you see?

C1: Mud.

T: Lots of mud, that's the soil.

C1: And lots of kind of strings.

T: Strings, that is the root, yes, you're right. Can you see ... yes, they look a bit like straw, C2, you're right, can you see them? Yes. What else can you tell me about the roots that you can see?

C2: Umm ... they're going round and round and in and out.

T: They are, round and round and in and out aren't they. Can you see, they're really long as well, look at this one here, look at this one. What can you tell me about this one?

C2: It's all stringy.

T: It's all stringy, yes, you're right, it is isn't it. Wow. It's going down quite far isn't it. So what other parts of the plant can you see, apart from the roots, now?

Jae introduced and reiterated the word 'roots' while drawing children's attention to the salient features of the roots. Reflection on this change from his practice Jae argued that:

'[practitioners must]...be ready to challenge children in their thinking. This is most effective in an interactive-dialogic approach which gives the children and the practitioner equal weighting in the discussion...however, [they] must always be ready to interject the correct vocabulary and scientific concepts when they arise, thus tilting the conversation towards a more interactive-authoritative slant as the children begin to gain a more scientific mind-set'

Over the course of the project Jae concluded that his repertoire of talk to support learning should include more scientific talk; *'I have really begun to tailor my repertoire towards the objectives I want the children to achieve'*. The tension inherent in Jae's thinking, and likely that of other early years science educators concerned with maintaining children's own lines of enquiry while also valuing the scientific discourse, is mirrored in the conversation between

Wegerif and Matusov (2014) about the ends and means of a dialogic education. Matusov argues that

‘...dialogic education has to be a genuine dialogue and this means that a curriculum goal cannot be specified in advance because learning in a dialogue is always emergent and unpredictable.’ (Matusov)

Whereas Wegerif counters that:

‘...dialogic education can include ‘scaffolding’ for full participation in dialogue as long as dialogue is the aim.’ (Wegerif).

DISCUSSION AND CONCLUSIONS

The *See the Science* project can be considered in terms of the finding of Stylianidou et al (2014) in nine European countries that teachers of young children failed to see the potential of dialogue in relation to creativity and underemphasised the knowledge and understanding present in policy documents. *Sustained scientific dialogues* proved to be a useful framework for conceptualising analysing and developing dialogues to support creativity and valuing scientific knowledge and understanding in a range of school curriculum contexts.

Although the place(s) of science in a thematic/creative curriculum are not clearly defined, teachers can work with this professional uncertainty and take advantage of the permission it implies to develop a pedagogy that enables meaningful and scientific learning to take place. Teachers' skills in choosing the right words and questions (or silence) at the right moment in order to establish a *sustained scientific dialogue* are key to a dialogic and creative pedagogy within a thematic/creative curriculum, i.e. where teachers enable learners to take ownership of their learning, take risks, make new connections and make new meaning.

Analysis of the English Primary science curriculum (Department for Education, 2013) reveals an emphasis on conceptual knowledge presented as facts and on limited procedural knowledge associated with methods for testing and verification, not open exploration. The importance of discussion with children to support their learning has been recognised and this presents useful justification when working with teachers, but does emphasise children ‘developing their scientific vocabulary and articulating scientific concepts clearly and precisely’ (ibid p4). This could exacerbate the existing challenge for teachers of engaging with children’s ideas through discussion to support their learning and instead move teaching in the direction of a model based on the transmission of ‘facts’. We believe learning is motivated by dissatisfaction with extant explanations and facilitated by opportunities to consider alternatives - neither process is supported explicitly by the proposals. However, there are possibilities to interpret the curriculum in ways that will build children’s capacity to engage in meaningful scientific learning.

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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]

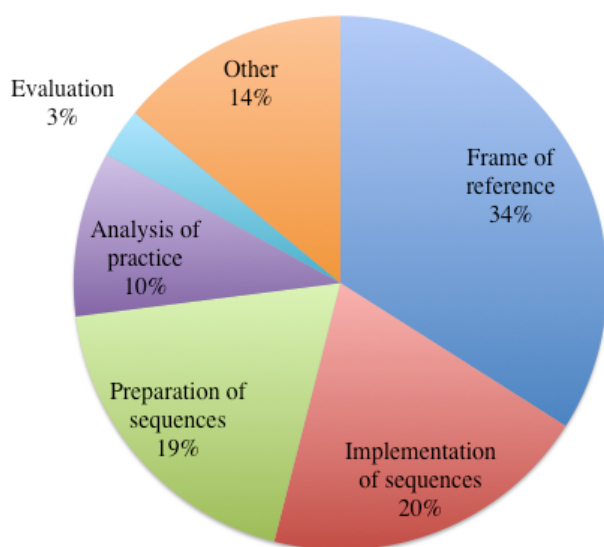


Figure 1. Relative weight of the different uses spontaneously considered by Kindergarten Teachers (100% = 104 elements of answer; an answer can incorporate several elements)

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 than 10% considered them in ranks 4 or 5. Next, 80% of the answers classified robustness in either rank 2 or 3.

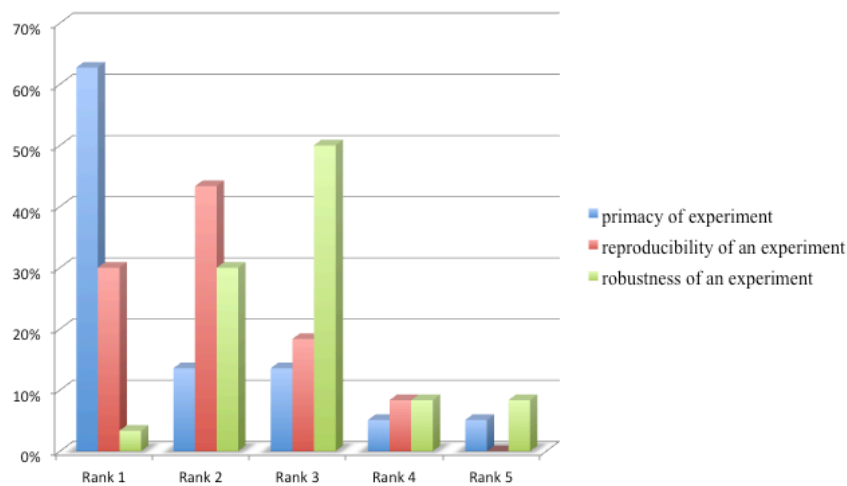


Figure 2. Relative weight of primacy of experiment (blue), reproducibility (red) and robustness (green) as classified by kindergarten teachers from the easiest (rank 1) to the most difficult (rank 5) to implement.

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 synthesises 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.)
<i>Deux enfants différents font la même chose sur ton atelier ; est-ce qu'ils peuvent trouver des choses différentes ?</i> 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	<u>8</u>	<u>5</u>	<u>1</u>
	No: "do the same thing, get the same result!"		<u>4</u>	<u>7</u>
	Other	1		2
<i>Ils te disent qu'ils trouvent des choses différentes : que fais-tu ?</i> They tell you that they found different results. What will you do?	Do not know	3		
	"I say they made a mistake"		<u>1</u>	<u>2</u>
	Ask them to try again.		<u>1</u>	<u>2</u>
	Other	1		1
<i>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 ?</i> 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.	<u>2</u>	<u>5</u>	
	Assure him it would work the same way, since I've myself done it in my classroom			<u>3</u>
	Assure him it would work the same way anywhere.	<u>7</u>	<u>5</u>	<u>8</u>
	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
<i>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 ?</i> 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"	<u>3</u>	<u>2</u>	<u>1</u>
	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"		<u>2</u>	<u>1</u>

Results about robustness

Table 4 synthesises 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.)
<i>En classe/sur le jardin des sciences, vous avez changé le [paramètre indifférent dont la non pertinence a été vérifiée en classe]. Pourquoi ?</i> 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	<u>5</u>	X	<u>2</u>
	Specifically called by the investigation		X	11
	Do not know	3	X	2
<i>A quoi cela sert-il d'essayer avec des [éléments dont un paramètre non pertinent connu varie] différents ?</i> 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	<u>5</u>	X	X

<p><i>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] ?</i></p> <p>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]?</p>	No, identification of a new irrelevant parameter	<u>11</u>	<u>10</u>	<u>12</u>
	Suggest to try out to be sure	<u>2</u>	<u>5</u>	<u>2</u>
<p><i>Est-ce que c'est important de vérifier ?</i></p> <p>Is it important to try out?</p>	No "because we know", appeal to a generality	3		
	No			2
	Yes, without relevant justification	2	2	
	Yes, to know		<u>6</u>	<u>6</u>
	Yes, to be sure because we could make a mistake		<u>4</u>	<u>3</u>
<p><i>Est-il utile de changer des choses pour voir si cela change le résultat ?</i></p> <p>Is it useful to change something to see if the result changes?</p>	No	3	6	2
	Yes, without relevant justification		4	
	Yes, to see what happens	<u>1</u>	<u>1</u>	<u>1</u>
	Yes, to check that it really doesn't change			<u>2</u>

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.

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A 'COLLABORATIVE PARTNERSHIP' PERSPECTIVE ON THE DEVELOPMENT OF ACTIVITIES FOR PROFESSIONALLY UPGRADING EARLY-YEARS-TEACHERS IN SCIENCE

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Abstract: In this paper we present a professional upgrading/development program for teachers of the early-years and explore which aspects of their knowledge and teaching in science have been affected by their participation in the program. Basic idea of the program was to motivate the teachers by making them members of an action research group aiming at developing and implementing curriculum activities to which they would contribute and thus meaningfully engaging them in their own learning. The present work used a "collaborative partnership" model for the development of the activities. In this model the collaborative notion is defined as an act of 'shared creation', partners share a goal and members bring their expertise to the partnership. Within this context, the partners were a researcher in science education with a background in physics who also served as a facilitator and six in-service early-years-teachers, with many years of experience (classroom experts). The shared goal was to produce inquiry based science activities from physics and astronomy for young children. The teachers of the present study participated as co-designers but the degree of their involvement was much lesser than this of the researcher. The procedures of the project comprised group work and individual teachers' class work. Data sources included teachers' essays, field-notes, lesson recordings and group-work records. Data were qualitatively analyzed. Data from the three latter sources were used as a means for validating teachers' self-reported data. The main results indicate improvement of teachers' "transformed" knowledge of the subject matter, development of knowledge of instructional strategies including factors related to quality of implementation of the activities, and development of knowledge of pupils. Findings suggest that the application of the approach used could contribute effectively to the professional upgrading in science of the teachers of the lower grades of education.

Keywords: Early-years' science education, In-service teacher training, Collaborative partnership in teacher professional development

BACKGROUND

The quality of early-years' science education has directly been related to teachers' competencies in science: knowledge, pedagogical skills and their abilities to synthesize them in a way that makes science more accessible to young children (Garbett, 2003).

However research has shown that qualifications in science of the teachers of the lower grades of education are quite limited. Specifically studies of early-years-teachers' knowledge background and practices in science have documented on the one hand low levels of background knowledge and alternative conceptions several of which coincide with those of children, and on the other, problematic instruction of the subject (Kallery, Psillos, & Tselfes, 2009). A subject specific study of early-years-teachers' concerns and needs in science (Kallery, 2004) revealed that these teachers face the most of their difficulties in topics related to physics and astronomy.

To approach teachers' professional needs researchers (Copley, & Padron, 1999) suggest that the emphasis should be placed on a variety of experiences especially those that are specific for their needs which have already been identified. Researchers also agree on the importance of forms of the teachers' professional upgrading that are based on collaboration and interaction and on the idea that their active participation constitutes necessary component for high quality professional development (Borko, Jacobs, & Koellner, 2010).

In view of all the above, and taking into consideration that there is a growing realization of the importance of continuous professional upgrading for teachers (Dass, 2001) as one of the most promising roads to the improvement of instruction (Sparks, 1983), an early-years teachers professional development/upgrading program in science was undertaken.

In this paper we highlight some of the salient features of the program the methodology of which has been influenced by the ideas presented above, and explore which aspects of the teachers' knowledge and teaching in science have been affected by the approach used.

More specifically the article addresses the following research questions:

- Which aspects of the teachers' knowledge of the subject for teaching were influenced by the program?
- Which aspects of the classroom/instructional practices did the teachers develop during the program?

DESIGN AND APPROACH OF THE PROGRAM

The grounds of the program were shaped by the following arguments and positions (Copley, & Padron, 1999):

- a. Teachers' professional development must move beyond the 'sit and get' model, should be ongoing and an integral part of their regular work day, should include group study, inquiry into practice, action research and consultation with peers and supervisors.
- b. Engaging teachers in scientific inquiry activities which are considered to make learning more meaningful, supports the development of teachers' more appropriate understanding of science and contributes to the development of their Pedagogical-Content-Knowledge.

A basic idea of the program was to motivate the early-years-teachers by making them members of an action research group aiming at developing and implementing curriculum activities to which they would contribute substantially and thus meaningfully engaging them into their own learning.

The present work used a 'collaborative partnership' model for the development of the activities. In this model the collaborative notion is defined as an act of 'shared creation' (Figure 1), partners share a goal and members bring their expertise to the partnership (Jones, 2008). Within this context, the partners were a researcher in science education (author of the present paper) with a background in physics who also served as a facilitator (R/F) and six in service early-years-teachers, with many years of experience (classroom experts).

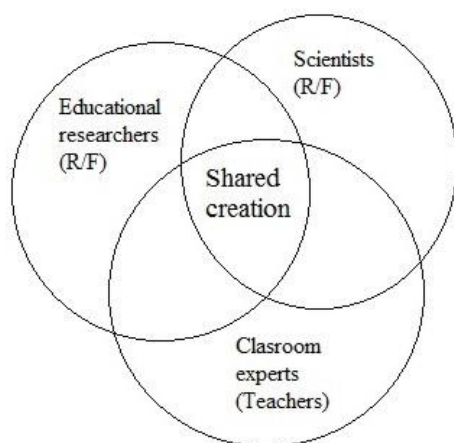


Figure 1. Shared creation: Specialties contributing to the development of the activities

The shared goal was to produce inquiry based science activities from physics and astronomy for young children. The type of participation of the teachers and the researcher were defined from a three-level scale shown in Figure 2.

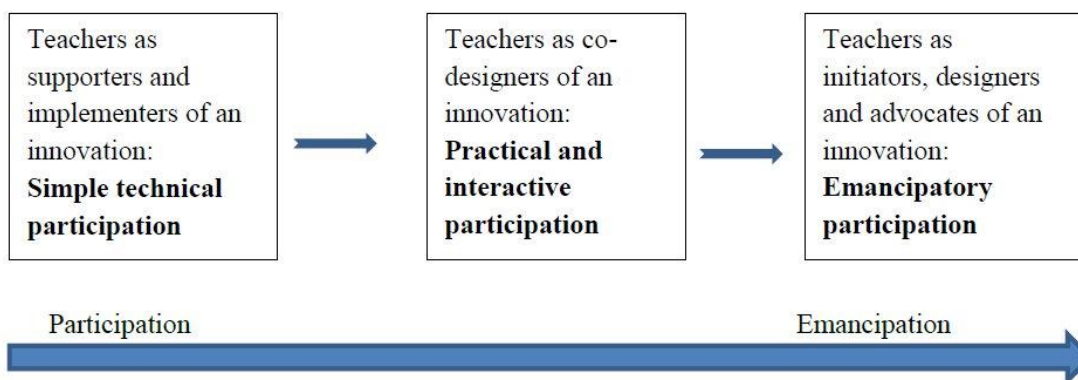


Figure 2. Types of teachers’ participation

The teachers of the present study participated as co-designers but the degree of their involvement was much lesser than this of the researcher.

The procedures of the program comprised individual teachers’ class work and group work. The work of the group proceeded as follows: the R/F designed the activities and presented them to the teachers in group meetings, where the content, the materials and the approach were analysed and discussed with regard to their appropriateness for the specific ages of the children and the context in which the activities would be implemented. Activities underwent specific teacher-suggested modifications which, as verified by the researcher, did not affect the scientificity of the content and the concepts to be introduced.

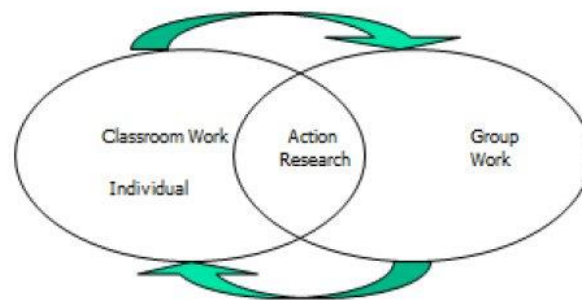


Figure 3. Group work, individual work and action research

The teachers implemented the activities and used action research processes to optimise classroom practices and to gather information, which in turn was used by the group for the revision and final shaping of the activities (Figure 3). Group work led teachers to joint decisions on handling common problems and yielded alterations to the activities as initially designed. At the end of the program teachers, in individually written essays, described their progress in all the domains in which they felt they had succeeded to make improvements.

METHOD

Data collection

Multiple sources of data were used coming both from the teachers' individual work and from group work:

- a. Classroom data (lesson recordings and field-notes)
- b. Records of the reviewing-reflecting sessions (group-work records)
- c. Teachers' complementary essays (to the R/F's notes)
- d. Teachers' self-evaluation essays

Data analysis

Data were qualitatively analyzed. The analysis used a three-level analysis system to interpret the data. Initially, the data were repeatedly read and the most striking and ultimately most important aspects were isolated. These data were then unitized; i.e. units of information (phrases, sentences or paragraphs), which later served as the basis for defining categories, were identified. In the second level of analysis, a constant comparison technique was used to sort units of information into internally homogeneous categories. At the third level, the categories were organized into themes (Strauss, & Corbin, 1990). The analysis and coding involved the author and a colleague researcher in science education. For the validation of interpretations member checks—taking data and interpretations back to people from whom they were derived and asking them if the results are plausible—were also used throughout the study (e.g. Guba, & Lincoln, 1981). Data from the three latter sources were used as a means for validating teachers' self-reported data.

RESULTS

The analysis yielded the following main themes:

1. Teachers' "transformed knowledge of the subject matter"
2. Teachers' classroom/instructional practices

3. Teachers' knowledge of pupils

Teachers' "transformed knowledge of the subject matter":

Analysis of the teachers' lesson recordings and of the reviewing-reflecting sessions revealed that the teachers improved or developed their knowledge of concepts and phenomena related to the topics of the activities (the scientific knowledge as it is simplified and appropriately reduced for the level of education in which this was used); they developed their knowledge of how to introduce/present a specific topic to the children, their ability to use analogies and to relate new knowledge to what the children already knew.

Teachers' classroom/instructional practices:

The teachers implemented the activities using inquiry approaches adjusting them to the particularities of their classroom. They had children try out the ideas they expressed during investigations and experimentations. The testing of ideas is directly linked with the use of process skills. Teachers had children use science process skills. They developed an appreciation of the importance of science process skills as a foundation for the development of understanding in science, while changing children's ideas to more scientific ones depends a lot on the ability to carry out process skills in a scientific manner (e.g. Harlen, 1996).

In the activities teachers directed children's attention to specific points which they considered crucial for their understanding, using guiding and challenging questions as well as explanatory or investigative questions (e.g. Chin, 2007; Elstgeest, 1985; Erdogan, & Campbell, 2008).

Researchers and educators consider teachers' questions a significant variable in the instructional process which characterizes the teaching style (e.g. Harlen, 1996).

Another aspect of the teaching practices that is considered as of crucial importance was the teachers' initiative for making consistent and systematic use of whole class discussions and discussions during experimental explorations throughout the intervention. This is thought to have created the potential for clarifying children's thoughts through discussion of ideas.

Teachers' knowledge of pupils:

The teachers were able to recognize children's alternative ideas and their resemblance to some of their own. They also demonstrated a significant improvement in their ability to discern whether something was appropriate for the children's cognitive level. Working together with the children in the activities the teachers also became familiar and developed an appreciation of the children's interests in specific science issues and exploited these interests during the implementation of the activities.

CONCLUSIONS AND IMPLICATIONS

This long term project designed to support early-years-teachers' professional upgrading in science resulted in successful changes. The findings indicate that the teachers improved or developed several factors related to their subject knowledge: they improved their knowledge of the concepts and phenomena they dealt with in the activities, they realized several of their alternative ideas and they modified them to more scientific ones. The teachers also oriented their teaching to inquiry based approaches providing children with opportunities to use science process skills and to take part in whole class discussions. They improved/expanded their knowledge of pupils becoming more familiar with their abilities, exploiting their interests and becoming acquainted with their ideas about the topics of the activities. Drawing on the well-known classification of teachers' knowledge developed by Shulman (1986), it can be concluded that the

teachers, during their participation in the program improved/developed several factors which compose aspects of their Pedagogical Content Knowledge, the knowledge a teacher uses to develop and implement science learning experiences (Appleton, 2005).

Two methodological components of this program that seem to have played key role in the final outcomes are worth underlining: Teachers' involvement in the development and final shaping of the activities and teachers' use of action research. As noted earlier these are considered to have supported the improvement of the teachers' subject matter knowledge and teaching strategies.

Within the limits of the present study, the findings suggest that the present programme, which was successful in improving teachers' competencies in science, presents strategies that can be effective not only for the professional upgrading of in-service early-years teachers but also for the professional development in science of pre-service teachers of the lower grades of education. The approach used in the present program could also be used for the preparation for teaching science of student-teachers during their practicum. Practicum, associated with teacher education, is one of the most critical aspects of a teacher's preparation and is widely considered the most important component in teacher education programs (e.g. Jones, 2008; Kenny, 2009).

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ESSENTIALISM VERSUS VARIATION: 'THAT'S NOT A SHEEP! SHEEP ARE WHITE!'

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Abstract: In September 2014, the science national curriculum in England introduced 'Evolution and Inheritance' as a new area of study for children aged 5-11 years. The Nuffield Foundation supported our research examining developmental learning progression in this new area. A wider study with pupils aged 5-11 years explored five sub-domains: deep time; fossils; variation; inheritance and macroevolution. The 5-11 years sample ensured the developmental perspective, but this paper focuses on the particular circumstances relating to the education of 'early years' children (4-7 years) and their understanding of just one of the sub-domains explored, variation – the trait that makes evolution by natural selection possible. Early years circumstances include the emphasis on holistic, cross-curricular practices and the direct experiential, 'hands-on' activities that are favoured prior to the more formal introduction of science. Young children tend to hold essentialist views that lead them to regard all members of the same species as identical. Teachers explored innovative ways for children to challenge their perspectives on variation through enquiries relating to themselves, other animals and plants. This paper documents how a variety of tailored interventions including mathematical tools introduced to the early years generic approaches were helpful in bringing about a shift from mainly qualitative to semi-quantitative and increasingly quantitative observations and how such activities encourage younger children's appreciation of some of the subtleties in variation within continuous traits. Such understandings serve children well as foundational concepts to their later learning about evolution. The research activities suggested starting points for formative assessment and led on to the production of effective pedagogical strategies. The authors worked collaboratively with teachers and children to explore the ideas early years children bring with them to their study of variation and to find out what targetted interventions informed by formative assessment and multimodal approaches can be developed in teachers' practices.

Key words: Early years, Evolution, Variation

INTRODUCTION

In 2014, 'Evolution and inheritance' was introduced into the National Curriculum in England as a new area of study in primary schools (5-11 years). The Nuffield Foundation supported our research examining developmental learning progression in this newly introduced area. To help ensure the manageability of the research, the domain was clustered into five interrelated themes: 'Deep time' 'Fossils' 'Variation', 'Inheritance' and 'Macroevolution'. These themes provided sufficient breadth to ensure children's access and were considered to offer manageable units of classroom activity. The full 5-11 years sample augmented the developmental perspective, but this paper focuses on the particular circumstances relating to the education of 'early years' children (4-7 years) in just one of the sub-domains explored, variation. Those early years circumstances include the emphasis on holistic, cross-curricular practices, which tend to stem from children's interests prior to the more formal introduction of 'science' as such, and the direct experiential, 'hands-on' activities that are favoured during this phase of education. Children tend to hold 'essentialist' beliefs that include a view that all living things within a species share some essential nature that makes all individuals identical,

apart from minor aberrations (Evans, 2001; Gelman and Rhodes, 2012). Children tend to focus on similarities between living things of the same species, as it is these that endow different kinds of plant or animal with their identity. These naive views are believed to emerge early in development and are acknowledged to be valuable in that they provide children with ‘constraints’ or ‘predispositions’ which give them a kick start to learn about categorizing their world (Gelman, 2003). However, these same ‘naïve understandings’ that that appear to fit with everyday experience become conceptual obstacles when children face new aspects of the world that may operate in ways that are contrary to their essentialist beliefs (Gelman, 2003; Berti et al., 2011). It was just such an essentialist reasoning that led 4- and 5-year olds who encountered black sheep during a farm visit in the current study to disbelieve that the animals could be sheep, exclaiming, ‘That’s not a sheep! Sheep are white’. While some researchers (Fischer and Yan, 2002; Samarapungavan and Wiers, 1997) argue that it is the complexity of evolutionary processes that causes difficulty for learners, others such as Evans (2008) argue that ‘An understanding of evolution does not require complex ideas that take years to acquire, such as mathematical reasoning or an understanding of genetics.’ (p. 271). According to Evans, it is essentialist beliefs that act as conceptual barriers to children’s developing understanding of evolution. Lehrer and Schauble (2012) offer a positive way forward in their suggestion that children can be encouraged to observe differences and, over the longer term, to develop the capability to think mathematically about within-species differences.

In our project, teachers were encouraged to explore variation with early years children within their usual holistic practices. The intention was to find out what might be viable following discussions and exploration in classrooms. We draw on Karmiloff-Smith’s (1995) hypothesis that during development, children’s naïve ideas that are stored implicitly become increasingly explicit through a process described as representational redescription. In our view, multimodal activities that encourage children to recode understandings across different modalities help children make their understandings known to themselves, to their peers and to supporting adults. Variation in people, other animals and plants of the same species can be experienced by children kinesthetically in their whole body actions, visually in 2-D drawings and 3-D models, speech, number and other sense modalities. Building on Lehrer and Schauble’s (2012) work, early years children in the project were introduced to mathematical tools such as sequencing, counting, measuring and aggregating data in the context of their enquiries as one of several modes designed to encourage children’s developing understanding.

The authors worked collaboratively with teachers and children to explore the research questions:

- What ideas do early years children bring with them to their study of variation?
- What targeted interventions informed by formative assessment and multimodal approaches can be developed in teachers’ practices?

Outcomes of the study included the identification of a variety of multimodal interventions that included using mathematical tools to support children’s developing understanding of variation in plants, animals and people. These strategies offered the prospect of being helpful in developing children’s awareness of within-species differences and in laying foundational understandings that might lead towards later appreciation of distributions of variation in traits in different species.

METHOD

The collaborative research evidence was collected specifically from the contributions of four early years teachers working within the wider support network of a total of eleven primary teachers. The fact of the early years work being alongside that of teachers of children up to 11

years served to highlight developmental trajectories and thus also to maximize the search for strategies to ensure early and smooth age transitions. Specialist biological knowledge was not essential to the participation of teachers in this research; participants were selected on the basis of their curiosity to explore the ideas children bring to their learning. All teachers attended three project meetings and engaged in cycles of activity that involved finding out children's ideas and developing targeted interventions aimed at helping children to develop their understanding. Explorations and interventions introduced as part of the research were undertaken within the expectations of generic early years practices. There was a focus on children's direct experiences and reflection in various ways on differences in themselves, other animals and in plants of the same species.

Data generating activities comprised a) direct experiences introduced by teachers; b) teachers' research diaries; c) researchers' observations of practice; d) teachers' insights and practices shared on a SharePoint facility and e) group meetings. Data were also drawn from researchers' observations of practice, children's outputs and teachers' records of their involvement. Fourteen researcher visits were made to the four early years settings.

A collaborative design-based research approach (DBR, Anderson and Shattuck, 2012) was adopted which recognised the complementarity of the skills of the researchers and teachers. The focus within DBR is on the development of ecologically valid material resources and approaches rather than on quantified outcomes (Schoenfeld, 2009). Our version of the DBR approach involves the agreement and seeding of initial ideas for practice; reformulation of these initial ideas in settings in ways that are tailored to the needs and interests of the children; exchange, critique and development across the group of promising emerging practices. These iterative cycles of developing practices in project settings leads to gradual refinement and identification of successful strategies. The importance of a formative assessment approach was emphasized as a key principle of practice. Within this view, teachers accepted the need to identify learners' current understanding in order to support progressive conceptual change. The teachers were to be the early years experts and the judges of the needs and capabilities of the children they taught and were therefore deemed to be key to the validation of the emerging strategies. In this way, it was ensured that all activities were viable and appropriate for the early years age group (Russell & McGuigan, 2016a).

RESULTS

Evidence of children's expectations of within-species similarities were revealed and confirmed in their initial explorations of animals, plants and themselves. These assumptions included a widespread view amongst children making farm visits of e.g., all ducks having yellow beaks or of all sheep having white woolly coats. This view led to children failing to identify the ducks they were observing with grey beaks as ducks and the black sheep as sheep. (McGuigan & Russell, 2015). In challenging these ideas, teachers provided children with opportunities to observe directly some of the differences within collections of, for example, sheep, rabbits and hens, tadpoles, stick insects and plants. Teachers and parents brought hens and rabbits into early years settings. In one setting, a local farmer brought sheep, rabbits, chicks, ducks and calves to school for children to handle and observe. Interactions which focused children's attention on some of the differences between, for example, a small number of hens, represented a shift in orientation and emphasis and contrasted with conversations which might more usually have concentrated on the similarities between animals of the same kind, their classification and naming. Raising children's awareness of the differences between the hens was relatively straightforward as, once encouraged to observe differences, children enthusiastically described the different colours, features and markings of each hen.

Superficially, at first glance, animals such as stick insects, butterfly caterpillars and eggs and tadpoles – all of which are often seen in early years settings - appear to be identical. Using

hand held digital microscopes revealed to children (4-6 years) differences in frogspawn that they) were able to comment upon in the following ways: ‘That is a different shape, not round’; ‘That’s got a white dot in it and the others are black’; ‘Some are brown and some are black.’

In one of the classes, children’s conversations as they observed frogspawn revealed expectations that the frogspawn would, ‘Eat at the same time’ and all hatch at the same time: ‘They all stick out at the same time’. Those children aware that there may be variations in hatching explained those differences in terms of the different generations within a collection of tadpoles. ‘Some might be daddies and some might be babies.’ ‘Some might be mummies’. Others explained, ‘Some grow faster and some grow slow’. While their teacher appreciated the difficulties inherent in counting tadpoles, she wanted to explore in what manner some form of quantification might introduce children to the idea that all the tadpoles would not hatch or metamorphose at the same time. The teacher drew a matrix of six large squares on white paper and placed it under the transparent container holding the frogspawn. This matrix highlighted the tadpoles against the white background. The children were asked to choose a square and to count the tadpoles that had hatched and the number that had not hatched. Choosing one square introduced children implicitly to a simple sampling strategy. It also encouraged children to count for themselves to produce their own drawn record. Despite the challenges of counting moving targets, the children carefully counted and recorded in drawings the number of tadpoles ‘hatched’ and ‘not hatched’ within their chosen square.



Figure 1. Counting the number of hatched tadpoles (4-6 year olds)

number of not yet hatched as ‘dead’. Movement is strongly linked to children’s conception of objects as living things so the moving tadpoles being described as ‘alive’ might not be unexpected. Their reasoning that ‘not yet hatched’ frogspawn were dead revealed that some of the children’s essentialist reasoning that all tadpoles hatch at the same time was still intact. These children seem to have inferred that all the viable tadpoles had indeed hatched at exactly the same time.

The enquiries of this class suggest viable ways in which children might be introduced to variation in hatching of tadpoles. A number of possibilities for the investigations of collections of small animals was discussed with the project group, such as counting the number of tadpoles or butterfly caterpillar eggs hatched day by day. This was expected to reveal a pattern such as a smaller number hatching initially followed by a larger number and then a gradual fall in the numbers on later days (that is, a normal distribution). The possibility of counting the number of tadpoles having emergent front or back legs on particular days in

Their drawings confirmed that all children had observed that all tadpoles had not yet hatched. In Figure 1, the child is shown to have counted eleven ‘hatched tadpoles’ and eleven that had ‘not hatched’. In this instance, the written record matches the drawn record. (Several green plants are also depicted.) The teacher noted that in their discussions, some of the children described the number of hatched tadpoles as ‘alive’ and the

the observation period was also discussed. These proposals tended not to be realised as school holidays and fatalities to the collection of frogspawn intervened. For future reference, this prototype activity led to the appreciation that the size of the tank and the number of eggs was an important consideration in children's recording of the distribution of numbers hatching over time. A similar realization emerged in the context of attempts to record moulting episodes of Indian stick insects *Carausius morosus*. The data collection must be manageable for young children.

While planting seeds and growing plants is a ubiquitous and frequent experience in early years settings, children revealed an unequivocal essentialist expectation that seeds that looked the same and would grow and develop in the same way. A number of interventions associated with growing seeds emerged as the result of discussions between the project teachers and researchers.

Children who thought the seeds they were handling were all the same drew all the seeds in a manner consistent with this belief. Being encouraged to look at the seeds under a digital microscope helped reveal to children some of the differences between the seeds which they were subsequently able to show in their drawings.

Some children planting seeds outdoors explained their view that, if the seeds they were to plant received the same amount of water and sunlight and were planted at the same time, they would all grow to the same height and produce the same number of leaves, flowers, roots etc..

One of the children in a class of 4-6 year olds found a seed from a sycamore tree in the school field. The child brought the seed to the attention of her teacher who in turn showed the children the sycamore tree. Standing under the branches of the tree, they discussed and modelled playfully how the seeds (referred to colloquially as 'helicopters') might spiral down from the tree. The children asserted that the seeds would all fall to the ground immediately below the tree. To help them appreciate that the seeds could fall at different distances from the tree, the children were encouraged to work in pairs and to count their steps until they found a seed from the tree, at which point the children placed a marker flag at the seed's location as in Figure 2.

The number of steps taken to the seed was recorded on each flag to show the distance of the seed from the tree. Adults were on hand to support counting as the number of steps to each seed represented a challenge for many of the younger children, especially as the numbers



Figure 2. Marking the position of the seed (4-6 year olds)

went beyond twenty. Children willingly engaged in the counting as far as they were able and eagerly recorded numbers on flags with an adult's help. The flags provided a simple visual record of the different distances the seeds fell from the tree that children could see at a glance and discuss. The quantitative data of distances in the form of number of steps helped to provide children with information that could be pooled together later and discussed and potentially be aggregated into a chart or graph (Russell and McGuigan, 2016b). The investigation provided children with evidence that seeds are subject to variation

in form and behaviour as well as circumstances, providing a low-key introduction to competition and survival - key ideas in evolutionary thinking.

Several teachers engaged children with a non-fiction story, 'The Tiny Seed' by Eric Carle. The narrative explores how the germination and subsequent growth of seeds is affected by environmental factors - another implicit introduction to survival and competition. Children responded with interest to the demise of the majority of the story's seeds and described some of their own experiences of pets and birds eating seeds in their own outdoor areas.

From the starting point of the fictional story, children were encouraged to observe and compare the growth of their own seeds. Across the 4-7 years age range, children grew a variety of plants including carrots, peas, cress, beans, tomatoes and sunflowers. Their teachers shaped activities so that children were encouraged to look closely to observe not just similarities but also differences between collections of germinated plants of the same kind.

In one class (children age 4-6 years), children grew peas in a wormery so that they might observe and compare the differences not only in the shoots and leaves of the peas but also to compare root growth through the transparent sides of the container. This apparatus thus provided novel opportunities for children to observe and compare differences in the individual plants' root systems. Sticky labels and marker pens were used to record length on different days, while also taking standard measures of length in cm. Once a measurement strategy had been invented and agreed for one of the plant's roots it could easily be used by children to compare root growth between other plants.

Differences between sunflower seedlings were observed as children (age 4-5 years) made drawings of the changes in their seedlings. They were helped to observe closely, to check their observations and draw accurately the shape and colour of some of the attributes such as the leaves. Drawing focused children's attention on the plants' developing features. While each child had their own potted sunflower seedling, they were asked from time to time to bring all the pots together to compare their plant's growth with that of others in the collection. Teachers' management of these careful observations and recordings helped children to identify and describe qualitative differences across the collection. Children commented that some stems varied in height while some seeds had not germinated at all. They used their maths vocabulary to describe the heights of sunflower plants and used ordinal relations to line up seedlings from shortest to tallest. With adult help, they were able to transform this row of plants ordered by height into something resembling a pictogram, putting live plants of similar height together into columns. Each child added their plantlet to what was referred to as a 'living chart' of seedlings, observing carefully and judging where they thought each seedling should be located in the array. Typically, a child might put her plant in one column and then, following observation and discussion of the plant's height, move it to a different column that she thought more accurately reflected the height of her seedling.

One child had a seed that was just showing signs of growth. He demonstrated what was happening to the seedling by curling up his body as if to show the seedling coiled up inside the seed. This whole body action expressed multimodally his idea that the shoot was only just emerging from the seed and appearing above the soil. He put his seed pot at the very far left of the group, indicating that his plant was the smallest. Children were able to identify the tallest and shortest plants and referred to all those in the middle as 'middle-sized'. They traced around the shape of the chart with their fingers to describe the curve, also attempting to make the outline shape of the chart with a finger in the air when invited to do so.

These interactions involving partial and whole body gesturing and qualitative comparisons helped children appreciate the different heights of the seedlings and may be the first form of recognition of the curved shape of the normal distribution or 'bell-shaped' curve. It is from such early experiences that we might expect children to develop an awareness of the value of more systematic measures that will enable comparisons and support judgements about variations in height.

The activities associated with growing sunflower seeds reveal children using a variety of representational formats e.g. drawings, paintings, speech, actions, miming, lists, number and charts to show their understandings. Different formats offer different affordances for revealing and communicating understandings. Each of the representations highlights different aspects of children's observations of variation in the sunflower seedlings. The drawings enable children to reveal ideas about differences in the colour, shape and number of leaves. Relative height can be shown in drawings while measured height can be added in written mathematical notations. Shape and movement might be shown in actions. Moving between (or 're-describing') representations in different ways is a metacognitive strategy that helps children to construct new understandings (Karmiloff-Smith, 1995; Russell and McGuigan, 2003). The 3-D 'living chart' could not show the detail that is possible to add through the use of additional notations in children's drawings and measurements, but it did succeed in showing the overall pattern of differences in height of the seedlings and differences in the number of seedlings at different heights. In constructing the 3-D arrangement, children were introduced to the overall shape of the distribution of height of all the plants being grown by the class.

Slightly older children (6 and 7 year olds) making observations and recordings of bean seeds growing in separate pots were invited by their teacher to decide for themselves the observations to be made and how any measurements might be taken. The teacher wanted children to discuss and justify different measurement strategies and also to learn about plants in general and the changes in the different attributes of the bean seedlings that were being measured. They were encouraged to share their data with one another and to make comparisons across the collection of data associated with the growing bean seeds. Some children focused on the number of leaves, others on the height of plants or the length of roots. Their drawings and writings included qualitative, semi-quantitative and quantitative observations. In their interactions, children were encouraged to move between these different representations. For example, the height of plants was compared directly, side-by-side, using non-standard (finger widths) as well as by using standard measures. Children were eager to discuss and compare their own with other children's seedlings and used the accumulating data to highlight differences between the plants. Using measurement in this way helped children to recognise, describe and compare differences within the collection of bean seedlings.

They were then asked to pool the data collected in relation to the number of leaves on each plant. One of the practitioners drew chalk lines as the axes of a large chart in the playground. Each child was invited to place their bean seedling on X-axis of the chart according to its



Figure 3. Drawing around the assembled plants helps make the shape of the distribution more visible.

number of leaves. Their teacher spotted some 'exaggerated' counting due to an initial desire of some children to have grown the plant with the most leaves. She reminded them to count accurately so they could trust the results! The numbers of leaves were re-counted and plants were placed in columns according to the number of leaves. Children appreciated that there were fewer plants at either end and a lot more in the middle. Drawing around the assemblage of plants as shown in Figure 3. helped to make the shape of

the distribution of number of leaves more visible and evident to children.

Recording measurements in 3-D charts using real plants and drawing around the shape of the collection of plants led children to describe the shape of the distribution as, 'like a volcano' and 'like a hill'. The term 'hill shape' emerged as useful in helping children to recognise similar patterns in their charts of measurements of their hands and feet. This provided the research group with a useful vocabulary to use in place of the more formal and obscure (to young children) 'normal distribution' – the correct term to which children might be expected to be introduced in later years in their learning. This shape cannot be seen by looking at individual drawings or by comparing one plant with another. It emerged only when children aggregated the data for one attribute across the collection of plants. The early years teachers seemed to have found an innovative, accessible and low-key way to introduce children to a recurring pattern in the distribution of continuous variation across a population.

Children observed and measured variability in a number of contexts, enabling them to appreciate the recurring 'hill-shaped' pattern. While encouraging children to compare physical characteristics (especially non-continuous traits such as eye or hair colour) of people tends to be avoided, on the basis that it might highlight differences about which children are sensitive and raise anxieties. Measurements of hand and foot size tend to be acceptable and were explored in parallel with 6 and 7 year olds. Project teachers invited children to suggest measurement strategies and required them to explain to their peers why a particular approach should be used. Once agreement was reached, the preferred strategies were adopted by the class to produce a collection of data. While many creative measurement ideas were lost in the negotiations, a variety of measurement strategies were used by children across the early years sample:

- Measurements of hand span or hand length were made along with measures of the length of foot from heel to toe.
- In some classes, string and strips of paper were cut to match the size of the hand or foot and then measured in cm.
- Some classes drew around the hand or foot and then used rulers to measure the span or length represented in the drawing. In others, a ruler was used directly on the hand or foot to make the measurement.
- Children drew around their hands and feet and added standard measurements in cm.

The experience of measuring hands and feet and of pooling data revealed size differences that surprised some 6 and 7 year olds. To help them think of these differences positively, they were encouraged to consider variations as making them 'special'. Their teacher drew out the axes of a chart onto which children were invited to stick their own cut-out hand or footprint. The similarity in overall hill shape of the charts created to aggregate data for handprints, footprints and plant growth was not immediately apparent to children. They discussed the overall shape of each chart in turn without making spontaneous links between the charts. It was only with the scaffold provided when project teachers explicitly encouraged children to look for similarities in the shapes of several charts with discussion of the assembled information that some children were enabled to notice that the overall shape of the charts for hand and foot measurements was the similar.

DISCUSSION AND CONCLUSIONS

The experiences explored within the research reported here were designed to lead to the formulation of viable strategies for use in early years settings. The activities were intended to take account of young children's essentialist reasoning as a starting point and to help them to

build new understandings that might be found to be foundational in terms of later evolutionary thinking. Essentialist ideas tend to lead children to think of living things in the same species as sharing a common ‘essence’. Such ideas may serve children well as they seek to name and classify animals. However, such reasoning fails to take account of variation within species that is key to making evolution through natural selection possible. Practical observation and measurement strategies used by teachers in this study, in which children compared the differences within groups of living things both qualitatively and quantitatively, helped children to appreciate variation. Children’s awareness of the differences in attributes within groups of living things is an important foundational understanding within evolutionary theory. This research suggests that adopting a perspective based on progression within and beyond the early years has enabled the identification of key foundational experiences having the potential to support longer-term developments in understanding evolution by natural selection.

Within the research, some familiar early years approaches were shaped towards multimodal interventions to support children’s understandings. The emphasis in practice was on children representing their ideas in different modes, including speech, drawings, writings, mime, measurement, lists and charts and in translating across and between these modes to construct their understandings. In the course of the research, some insights were gained into how children might shift from mainly qualitative to semi-quantitative and increasingly quantitative observations. Insights were also gained into how mathematical tools might transform strategies such as ordering data in linear sequences into preparing outcomes as charts comprising physical objects. Shifts from ordinal lists to charts helped children to show and describe a collection of measures gathered by the class. Children’s descriptions of the (normally distributed) pattern in their data as ‘hill-shaped’ provide a useful basis for generating later understandings of the relationships between distribution of attributes in populations. This provided the research group with a useful vocabulary to use with young children. These representational practices are likely to be foundational for children’s development of ‘thinking scientifically’. Rather than abandoning speech, drawing, mime, writing, 3-D modelling etc., as they are introduced to more complex mathematical and symbolic capabilities in the course of their development, we see learners continuing to explore, use and make sense of the full range of representational possibilities as an indispensable aspect of their scientific reasoning. (Indeed, just as scientist do!).

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