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Discussions

Making rainfall (fractal!) features fun: scientific activities for teaching young children

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Abstract

Research projects now rely on an array of different channels to increase impact, including high-level scientific output, tools and equipment, but also communication, outreach and educational activities. This paper focuses on education for young children and presents activities that aim to help them (and their teachers) grasp some of the complex underlying scientific issues in environmental fields. More generally, it helps children to become familiarized with science and scientists, with the aim to enhance scientific culture and promote careers in this field. The activities developed are focused on rainfall: design of a disdrometer to observe the variety of drop sizes, careful recording of successive dry and rainy days and reproducing patterns using a simple model based on fractal random multiplicative cascades, and the production of a scientific book with, and for, children. These activities are discussed in the context of current state of art pedagogical practices and goals set by project funders, especially in a European Union framework.

1 Introduction

Research projects now rely on an array of different channels to increase impact. This includes obviously high level scientific output, tools and instrumentation, but also communication, outreach and educational activities. This paper focuses on education for young children (5–12 years old) and presents a number of activities and a science book with the aim of assisting them (and their teachers and parents) to grasp some of the complex underlying scientific issues in the field of environmental science, with a focus on rainfall. More generally it helps children to become familiarized with science and the role of scientists, with the aim of enhancing scientific culture and promoting careers in this field. The classroom activities presented form part of the dissemination effort of the NEW Interreg IV RainGain project (www.raingain.eu) and the Ecole des Ponts ParisTech Chair “Hydrology for resilient cities” endowed by Véolia. They are specifically dedicated to transmitting knowledge on rainfall features: design and implementation of a drop measurement device, recording and modelling of the succession of dry and rainy days, and writing of scientific book with and for children. The activities will be discussed in the context of current pedagogical practice and goals set by project funders, especially in a European Union framework.

A pedagogic perspective

Good science education is essential in early childhood, not only for social and cognitive development, but also for engaging young learners with science (Sackes et al., 2009). However, science is often perceived as unappealing to young learners (Koren and Bar, 2009; Sjøberg and Schreiner, 2005; Stefansson, 2006; Muller et al., 2013). Many studies have highlighted the need to engage and enthuse learners at a young age: Tai et al. (2006) found that American students reporting an interest in science careers at the age of 13/14 were more likely to obtain a university degree in a science field than those with no interest; the Royal Society (2004) found that 63 % of their UK study participants had first considered a career in a science and engineering field by the age of 14; Maltese and Tai (2010) found 30 % of participants having an interest in middle school or high school.

A positive attitude towards science in school will often to lead to a positive commitment and lifelong interest in the subject (Simpson et al., 1994). Bennett and Hogarth (2009) showed that positive attitudes to school science declined significantly between the ages of 11 and 14, whilst Lyons (2006) found that students are often not engaged by the "autocratic" way science is represented in their classes, finding that it is often disconnected from the natural world they experience on a day-to-day basis. Maltese and Tai (2010) found that early interest in science was provoked by specific memorable activities (specifically school-based experiences related to demonstrations) or an exceptional teacher.

Previous work has also found that the key to students' understanding of science is activities which actively involve the student. This is summarized by the famous Chinese proverb – “Tell me and I’ll forget; show me and I may remember; involve me and I’ll understand”. As such, numerous studies (e.g. Muller et al., 2013; Alrutz, 2004; Buncick et al., 2001; Cleaves, 2005; Dorion. 2009, 2007; Ellington et al., 1981; Harvard-Project-Zero, 2001; Lyons, 2006; Maltese and Tai, 2010; Odegaard, 2003; Royal Society, 2004; Osborne et al., 2003; SATIS, 1986; Sloman and Thompson, 2010; Tai et al., 2006; Tobias and Hake, 1988; Wagner, 1998) have found that including a variety of activities and methods to engage students with different interests and learning styles, providing an engaging classroom environment and allowing students to feel comfortable asking questions are important factors that can invoke interest in science.

Using hands-on activities is clearly a popular and successful method to engage students. However, many teachers find science challeging to teach and as such turn to picture books and children’s science literature for assistance. Sackes et al. (2009) explored the benefits and limitations of using children’s literature to introduce science concepts. The Authors found that although some books are poorly written and can spread misconception, those written under the guidance of science consultants were great learning tools, offering unique opportunity for introducing science concepts in the early years, fostering interest, curiosity and positive attitudes, as well as integrating literacy and science (Broemmel and Resarden, 2006; Castle and Needham, 2007; Coskie, 2006; Monhardt and Monhardt, 2006). Pringle and Lamme (2005) found that picture books in particular were a very useful for communicating concepts in a welcome and familiar format, and demonstrating logical connections that exist between classroom learning and the natural worlds outside the classroom. Thus children’s books – when produced *and* used accurately and effectively (Ford, 2006) – are a key part of supporting children’s development of scientific concepts (Zeece, 1999).

The following chapters outline a number of hands-on activities and a scientific book that have been developed to support the teaching and learning of complex topics at a young age.

2 Drops are not all the same: the flour or oil disdrometer experiment

This activity consists in designing and testing disdrometers made of a plate with few mm of flour or oil to observe of rain drops individually.

The aim of the activity is two-fold:

1. learning how to design and test two instruments as well as compare their pros and cons in “laboratory” and “actual” conditions;
2. unveiling the unknown diversity of rain drop sizes and providing some basic explanations.

The activity was implemented in October 2013 in a classroom with children aged 5–6.

2.1 Historical and scientific background

The idea of this activity is to reproduce a famous experiment by Marshall and Palmer (1948) who used dyed filter paper to get an estimate of the Drop Size Distribution (DSD) in a more “artisanal” way. They used these observations to calibrate the famous relation $Z = aR^b$ (with $a = 200$ and $b = 1.6$) between the reflectivity Z measured by weather radar (basically the power of the wave backscattered by drops in the atmosphere) and the rain rate R,the variable hydro-meteorologists are interested in. This relationship is still commonly used, and its establishment was a milestone in weather radar applications. A similar experiment was carried out by Lovejoy and Schertzer (1990) who used 128 cm × 128 cm chemically blotted paper. They showed that drop centres are not homogeneously distributed but rather exhibit some clustering with an underlying scale invariant fractal distribution. It was later confirmed by Gabella et al. (1999) who reproduced the same experiment on more numerous events. A similar low-cost experiment using flour was also recently carried out to study DSD in high school (Mazon and Viñas, 2013). Interestingly, rain drop fossils have also recently been used to characterize ancient DSD and thus provide information about air density 2.7 billions years ago, when the imprints were formed (Som et al., 2012).

2.2 Presentation of the experiment and discussion

2.2.1 Design and lab test of the devices

The disdrometer is made of few mm of flour or oil in a plate (or any similar sort of medium). To understand the functioning of the oil disdrometer, children first need to notice that oil and water are not miscible. This is done using a glass containing either milk or oil, to which a drop of water is added using a pipette (Fig. 1a). The water within the pipette is coloured to increase the visibility of the output. The behaviour within the two glasses is very different (Fig. 1b): in the milk, everything gets mixed, whereas in the oil, the drops remain independent from and sink. In order to help children interpret and analyse the experiment, they are asked to illustrate their observations (Fig. 1c). This use of personal drawings is one of the basic ideas of underlying the pedagogy promoted by “La main à la Patte” foundation (http://www.fondation-lamap.org/en/international).

The disdrometers are constructed by placing a few mm of flour or oil onto a plate. Artificial drops of coloured water are dropped onto the distrometer using a pipette. Half the children test the flour device, while the other half test the oil distrometer (Fig. 2). The basic premise of the session is for it to be interactive, allowing the children and the teacher to discuss, understand and compare the functionality of the devices.

The main learning concepts are:

- Once a droplet falls onto the flour disdrometer, it creates a small wet crater that remains visible.
- Once a droplet falls on the oil disdrometer, it does not mix with oil and remains visible where it landed.
- The flour device can be easily transported while the oil one cannot. Indeed, as soon as the device is not completely horizontal, droplets begin to move and merge

when they reach the lowest part of the plate/recipient. This does not occur with the flour device which tolerates being slightly tilted.

- The oil disdrometer retains a better imprint of drop size. Indeed with the flour device, the water slightly spreads around the small crater, meaning the actual size is lost, and only relative sizes are accurate. With the oil device, the shape of droplets are lost as they become spherical, however the volume remains accurate since the water and oil do not mix.

2.2.2 Outer implementation and drop analysis

The second part of the activity consists of testing the disdrometers under actual rainfall. For this a volunteer needs to go outside with the disdrometer uncover it for a few seconds and return it for analysis (Fig. 3a). Typical results are displayed on Fig. 3b.

At this stage it should be noted that the oil disdrometer is unsatisfactory under real conditions because when a droplet impacts, or more precisely "crashes", into the oil surface, it brakes up in several droplets, thus biasing the results. However, the fact that a device which seemed effective during inside lab testing, failed under "real" conditions is an interesting lesson for children. In order to help children take note of the various sizes of drops and their inhomogeneous distribution, they are also asked to illustrate their observation (Fig. 3c).

Once they have observed the variety of drop sizes, they are given some insights into the formation and development of rainfall. The main elements for such a young audience are:

i. Water vapour evaporates from the Earth's surface and moves up through the atmosphere until it reaches a colder height, where it starts to condense around a small particle (known as a "condensation nuclei" e.g. dust, soot, pollutants).

ii. Droplets grow by further condensation or merging with other droplets after a random collision. Numerous droplets merge together to form clouds.

iii. Once a droplet becomes too heavy to be held in the atmosphere, it begins to fall.

iv. As the droplets fall, there are further collisions and break-ups leading to a range of droplet sizes (equivolumic diameter) typically between 0.2 and 5–6 mm at ground level, the more numerous ones being of size 1–2 mm.

2.3 Going further

Similar images can be obtained with the help of a 2-D Video-Disdrometers which estimates the features (size, fall velocity, and position) of the drops falling within a sampling area of approximately 11 cm × 11 cm (see Kruger et al. (2006) for a detailed description of the device). This device enables observations - such as those obtained with the flour disdrometer – to be recorded automatically. Figure 4 displays the droplets recorded over 1s (for each plot) during an event that occurred on 24 September 2012 in Ardèche (France). The corresponding time of each plot is indicated above it. Such figures can be used to further illustrate the diversity of drop sizes and the variability observed over time, and compared to the children's drawings. An example of use of such data can be found in Gires et al. (2015) who computed the time needed for a given number of drops to fall through the sampling area, and showed that the distribution exhibited a power-law fall-off confirming the inhomogeneous nature of drop distribution.

3 Rain or no rain: a fractal perspective

This activity consists of recording a daily time series of rainfall occurrences over 2 months, in order for children to understand the complexity of successive dry and wet days, and to implementing a stochastic cascade model to reproduce patterns similar to the observed ones. The activity was tested in a classroom with children aged 5–6 years in January 2014.

The aim of the activity is two-fold:

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1. Assisting children to understand the difficulty of carefully recording data over a long period of time.

2. Introducing the notion of “model”; as well as “randomness”, with which they are not familiar. The idea is for the learners to become involved in the concept rather than to formalize the complexities of it, which would be difficult for them to grasp.

3.1 Historical and scientific background

Rainfall occurrence patterns are tricky to characterize, model and simulate at all scales and it still remains an open issue. See, for example, Gires et al. (2013) or Schleiss et al. (2014) for recent papers on cascade-based or a geostatistic-based approaches. However, it is an important concept, given the importance of the rain/no rain intermittence. An illustration of this is the number of zeros recorded in rainfall time series. For instance Hoang et al. (2012) typically reported roughly 96–98 % zeros for a long (many years), high resolution (5 min) rain gauge time series over France. For practical reasons due the necessary implementation of the experiment in classrooms, the activity was conducted at a daily resolution, similar to Hubert and Carbonnel (1989) who analysed a 45 year daily rainfall time series of Dédougou (Burkina Faso).

A possible solution to model observed rainfall occurrences patterns is to rely on a scale invariant multiplicative cascade framework (Lovejoy and Mandelbrot, 1895; Lovejoy and Schertzer, 1985; Hubert, 1988). Cascade models were initially developed to tackle atmospheric wind turbulence and explain how energy is transferred scale to scale down to the dissipation scale. It was later used for rainfall, assuming that the unknown equations governing rainfall inherit the scale invariant properties of the Navier–Stokes equations (Hubert, 2001). They remain the same after scale contraction; suggesting that similar structure will be visible at all scales. The cascade concept, formalized by Kolomogorov in 1941 and refined in 1962 (Kolomogorov, 1962) was first hinted at by the so-called father of weather prediction Lewis Richardson (1922) in a foot note:

> Big whorls have little whorls that feed on their velocity, and little whorls have smaller whorls and so on to viscosity – in the molecular sense.

To illustrate these cascade models, let us introduce the pedagogical discrete case, where scales are discretized (Fig. 5a). At the beginning the activity ($\varepsilon_0 = 1$) it is uniform over a structure (a d-dimensional cube, $d = 1$ for the time series studied here) of characteristic length L ($\lambda = 1$). One step of the cascade process consists in breaking each structure into smaller ones with a scale ratio λ_1 (larger than one and usually equal to 2 although it is not mandatory). As a consequence after n steps, there are λ_1^{dn} sub-structures of characteristic length $l_n = \frac{L}{\lambda_1^n}$. The resolution of the process, which is the ratio between the outer scale (L) and the observation scale (l_n), is then equal to $\lambda = \frac{L}{l_n} = \lambda_1^n$. The activity ε_n (i.e. $\varepsilon_{n,i}$, with $i = 1, \ldots, \lambda^d$) affected to a daughter structure is equal to its parent's one multiplied by a random variable ($\mu\varepsilon$): $\varepsilon_n = \mu\varepsilon\,\varepsilon_{n-1}$. Building a cascade process basically requires determining: (i) how to divide each structure into sub-structures, (ii) the probability distribution of the random multiplicative increment. The key assumption is that these two properties are the same at all scales. The probability distribution of the random increments should be chosen so that $\langle \mu\varepsilon \rangle = 1$ to ensure ensemble conservation through scales.

Numerous models have been suggested in the literature and only the simplest one will be discussed here since it will be implemented within a classroom environment. It is often called β-model (Frisch et al., 1978; Mandelbrot, 1974; Novikov and Stewart, 1964) and assumes that structures are either dead (inactive) or alive (active). In this model, the multiplicative random increments $\mu\varepsilon$ only have two possible states, whose probabilities of occurrence are defined by:

$$Pr\left(\mu\varepsilon = \lambda_1^c\right) = \lambda_1^{-c} \text{ (alive)} \tag{1a}$$

$$Pr(\mu\varepsilon = 0) = 1 - \lambda_1^{-c} \text{ (dead)} \tag{1b}$$

where, c is a parameter of the model. The value affected to the boost $\mu\varepsilon = \lambda_1^c$ ensures conservation of the average activity ε (i.e. $< \mu\varepsilon > = 1 \Leftrightarrow < \varepsilon_n > = < \varepsilon_0 >$ where $< >$ denotes ensemble average). At each step of the process the fraction of alive structures decreases by a factor $\beta = \lambda_1^{-c}$, and their activity is increased by the factor $1/\beta$ to ensure (average) conservation. After n steps of the process i.e. at a resolution $\lambda_n = \lambda_1^n$, the sub-structure activity (equal to the product of the successive random increments)

$$\varepsilon_n = \varepsilon_0 \prod_{i=1}^{n} (\mu\varepsilon)_i \tag{2}$$

exhibits two possible states, dead or alive, with the probability of occurrence:

$$Pr\left(\varepsilon_n = \lambda_n^c\right) = \lambda_n^{-c} \text{ (alive)} \tag{3a}$$

$$Pr\left(\varepsilon_n = 0\right) = 1 - \lambda_n^{-c} \text{ (dead).} \tag{3b}$$

Such model was for instance employed by Over and Gupta (1996) or Schmitt et al. (1998) in a continuous version to represent rainfall occurrence pattern.

3.2 Description of the experiment and discussion

3.2.1 Careful recording of rainy and dry days over a period of 2 months

The first step consists of recording rainy days over a long period of time and plotting the data. Over a two month period the recording of rainy and dry days was undertaken at the start of the day, during the teacher's introduction to the day's schedule. If rainfall was noticed between 09:00 LT (local time) on the previous day and 09:00 LT that morning, then it is considered as a rainy day. To determine whether it had rained during the night children checked whether ground was wet while coming at school. At the time of the experiment, children did not attend school on Wednesday, Saturday and Sunday, thus they alternatively volunteered to be responsible for recording this information on each of these days. If the teacher resides near to the school, they can also record the observations during holyday period, otherwise it is simply considered as "missing data". A bar time series was used to graphically represent the data, with each bar representing a day. The time series obtained that year is displayed Fig. 6. Black bars correspond to rainy days and white ones to dry days.

It is important to use this time to raise the children's awareness of the time and effort needed to collect and properly record data over a long period. This is often difficult and not really gratifying (or at least recognized) work, yet it is essential to scientific research and the quality and robustness of the obtained results relies on its proper realization. This is a practical way for learners' to understand and comprehend what "scientific research" consists of, and the role of the research scientist – they are essentially acting as researchers for the duration of this activity.

3.2.2 Modelling the succession of dry and rainy days

The second stage of this activity consists of implementing the cascade model that will enable the children to reproduce patterns similar to those they observed for their own recorded time series. It is way to smoothly introduce the notion of a model. The word "model" itself is actually not mentioned in the class since it is too abstract for them to understand. The idea is simply to have them notice that while implementing a "recipe", they are able to generate time series that look like their observations. It also enables to introduce the notion of randomness.

Designing an activity imitating a β-model that can be implemented by 5–6 years old children is problematic, but a suggestion is displayed Fig. 5b. Each child is given the scheme with empty boxes (all white) and asked to follow these steps:

i. Filling the boxes: each child is given a dice with either 4 or 5 black sides, the remaining sides are white. For each box, the child throws the dice; if a black side is obtained, he colours the box black, otherwise it remains white (see Fig. 7). This mimics the generation of the random multiplicative increments $\mu\varepsilon$ discussed in Sect. 3.1. Black corresponding to "alive" and white to "dead".

ii. Generation of the time series: for each box of the time series (bottom part of Fig. 5b) which correspond to a day, the child follows the line up the upper box at the top of the scheme. If they encounter a white box, then they leave it white as a dry day. If all the boxes are black, then the day is denoted rainy and it is coloured black. This process actually mimics Eq. (2) taking advantage of the fact that a multiplication by zero yields a zero as an output anyway. It means that a β-model is actually implemented to generate a 16 day time series. Once completed, the children cut out the time series and line them up to obtain a longer one.

Figure 8 displays examples of time series generated by children with either 4 or 5 black sides on their dice. Once completed, a discussion about whether the simulated time series exhibited patterns similar or not the observed series took place (Fig. 6). It is important for them to understand that although the series they obtained are not the same – since the outcome of throwing a dice and hence their boxes colour is random – the patterns are similar because the same underlying process was used. They also noted that time series produced with a 4 black sided dice were much drier that for the other dice. It was concluded that simulations looked like observations for dice with 5 black sides and much less 4 black side dice. This is in agreement with expectations. Indeed, for the Paris area, we typically have $c \approx 0.3$ on scales ranging from 1 to 16 days, which yields to a probability of an "alive" random increment equal to $\lambda_1^{-c} \approx 0.81$. This value is actually very similar to $5/6 \approx 0.83$ found with the 5 black side dice.

The activity went well overall. The main difficulty for children of this age was understanding how the time series should be filled from the black and white boxes. The group explanation was not always sufficient and a one-to-one explanation would have been preferable, along with using supporting examples. It might also be a good idea to use a 3 level model rather a 4 level model so that the activity is bit shorter given the limited concentration capacity they have at this age.

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3.3 Going further

Only rainfall occurrence was addressed in this activity, meaning the complex rainfall process was reduced to the oversimplifying binary question of rain or no rain, which it not the case in reality, since the intensities observed during rainy period are extremely variable over wide range of scales.

The c parameter of the β-model can be interpreted as the fractal co-dimension of the geometrical set made of the portion of time where some rain was recorded. It characterizes in a scale invariant way the space occupied by the geometrical set. It appears that this fractal co-dimension depends on the threshold used for defining the occurrence or not of rainfall. Indeed when increasing the threshold, the support get smaller and the fractal co-dimension increases (Lovejoy et al., 1987; Hubert et al., 1995). It means that in order to characterize and model an actual rainfall time series an infinity (one per threshold) of fractal co-dimension is needed. This is an intuitive (not mathematically rigorous) way of understanding multifractal fields, which is a framework enabling to analyse, model and simulate fields extremely variable over wide range of scales such as rainfall.

4 Writing a scientific book on rainfall with and for children aged 8–12 years

This activity involved writing a scientific book for children aged 8–12 years, based on questions they raised themselves. It was tested in a class with children aged 8–9 years in Sceaux in the October and November 2014. The book was published in February 2015 (Gires, 2015).

The process leading to this book was designed by the editor of the “Minipomme” (Ed. Le Pommier) collection in which it was published. It is split into three main successive steps:

i. A 1.5 h interactive session with the scientist and a class of 8–9 years old children: they were given the general topic (in this case, rainfall) of the book a few hours prior to the session and asked for questions they had about the topic. It was designed as an interactive session, meaning that it was more than a simple questions and answers session; the scientist did not directly give the answers, but tried to encourage the children to think about the process and suggest some answers themselves before providing a more precise explanation. Naturally some of the questions raised were surprising and unexpected, in which case the scientist went on to research the question in more detail before providing an answer during the second session. The two most striking examples in this specific case were “What is the taste of rain?” and “Should I walk or run under the rain to get less wet?”. The latter was especially fun, and after a little research it turns out that almost ten papers based on numerical or actual experiments can be found on this topic in the scientific literature (see Bocci (2012) for a recent study with many references within). It appears that in general one should run as fast as possible when it is raining, but in some windy conditions or for certain body shapes, there exists an optimal velocity.

ii. The scientist writes the book: the goal was to have all the questions raised by children answered (at least partially) within the book. It is made of two parts:

    - First a lively story involving discussions between a few characters which contains the most of the scientific elements. The story would be more than a simple dialogue; a genuine fiction would take place so that children do not even notice they are learning and grasping new concepts. The story developed was based on the random and fortunate meeting of two young children with a “rain explorer” who takes them onboard her “drop’s vessel” for a journey into the clouds. The story is structured around four main questions: “How do ou measure rainfall? Does it rain the same everywhere and all the time? How droplets are formed? What happens when droplets fall?” In addition there are few sidebars for additional details on difficult topics or definition of complex words.

  - Second, a section that includes some complements for children as well as their parents (here three topics are addressed: rainfall radar measurement, lighting and thunderstorms, three states for water), and some suggestions of experiments so that children can put in practice the newly acquired knowledge either at home or in class rooms. The experiments consist of the design and testing of a flour disdrometer (see Sect. 2), and the building of a simple rain gauge out of a plastic bottle.

iii. A 1.5 h interactive feedback session: the draft of the book was given to children for reading over a few days before a feedback session with the scientist was held. The idea was to check whether everything was understandable, and whether they had some suggestions regarding to the characters. Following this session, the scientist made some minor adjustments to improve the book.

iv. Illustration: finally the book was illustrated by a professional designer, with a scientist providing precise schemes for drawings involving scientific content.

5 Conclusions

In this paper we presented various hands-on activities for young children designed to help them get familiarized with some complex notions associated with rainfall in a playful way. They designed a device whose main purpose is to record drop size; implemented it and observed the variety of drop sizes. They also carefully recorded the succession of dry and rainy days over a period of two month before reproducing observed patterns with the help of a random fractal cascade model. Finally they helped shaping the content of a scientific book on rainfall. The goal of these activities was not only for them to acquire knowledge on the specific topic of rainfall but also to get familiarized with science and scientific approach; to become curious about their surrounding, to develop a willingness to observe more precisely their environment, to notice details and ultimately to begin asking questions.

The development of these activities highlighted the importance of a genuine collaboration between scientists and school teachers, which turns out to be necessary for a successful implementation. The scientist brings the initial ideas, the expert knowledge for accurate science and makes sure that simple explanations are not simplistic and biased ones. The school teacher helps in adapting the language to young children, and also to shaping the activity so that it fits into the classroom habits and let children comfortable with it.

Future work will involve the development of more activities on rainfall to ultimately obtain a whole activity kit on this topic. It will also be necessary to actually set up an appropriate protocol that enables a quantitative evaluation of the activities both in terms of knowledge on the specific topic of rainfall and children's engagement with science. This will require collaboration with pedagogical experts as well.

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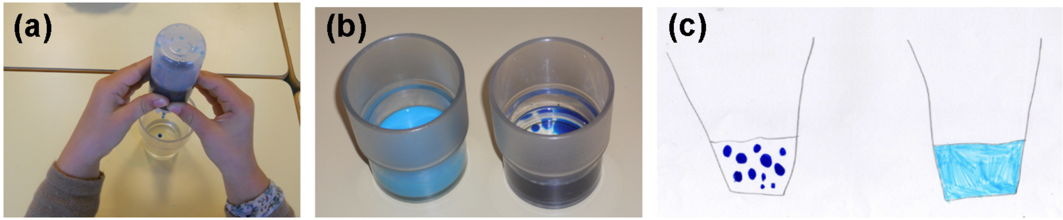

Figure 1. Illustration of the fact that water and oil are not miscible. **(a)** Adding coloured water drops with a pipette in a glass of oil. **(b)** Outcome of the experiment with milk (left) or oil (right). (c) Drawing of a child to represent the two configurations.

Figure 2. Design and test with artificial drops of tinted water of the flour or oil disdrometers in a classroom.

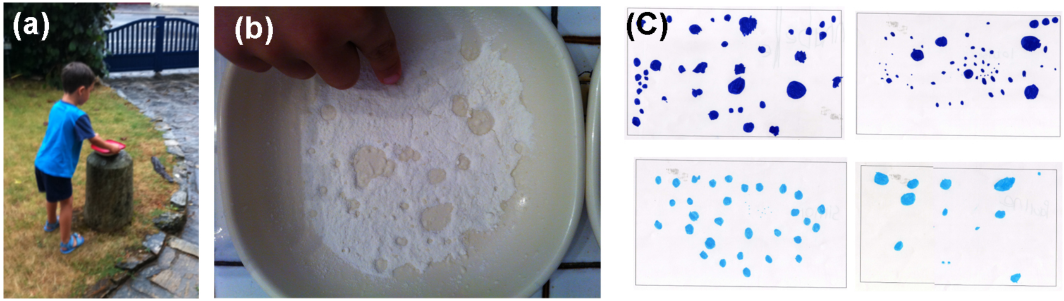

Figure 3. Use of the flour disdrometer in rainy condition. **(a)** Experimenter bringing the device under rain and uncovering it few second. **(b)** Example of outcome where the various sizes of drops are visible. **(c)** Drawing by children of their observations.

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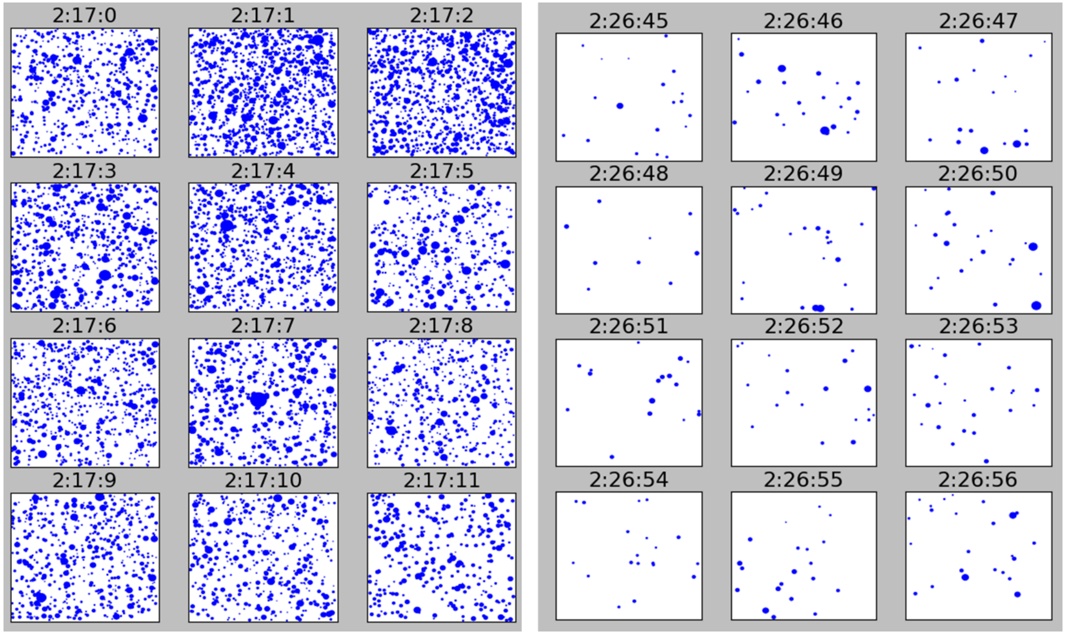


Figure 4. Representation of drop by drop data collected by a 2-D Video-Disdrometer during an event that occurred on 24 September 2012 in Ardèche (France). Each plot corresponds to 1 s and the timing is indicated above it. The size of the sampling area which is represented is 11 cm × 11 cm. Raw data provided by Laboratoire de Télédétection en Environnement of Ecole Polytechnique Fédérale de Lausanne.

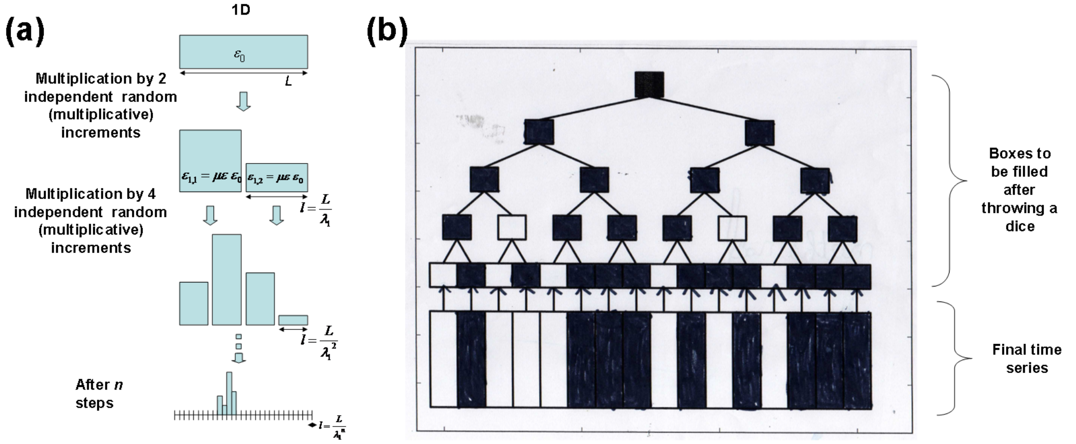


Figure 5. (a) Illustration of the pedagogical case of discrete multiplicative cascades. **(b)** Illustration of activity designed to model the specific case of the β-model cascade.

Figure 6. Daily time series of rainfall occurrence recorded by a class of 5–6 years old children in Sceaux (France) in October–November 2013.

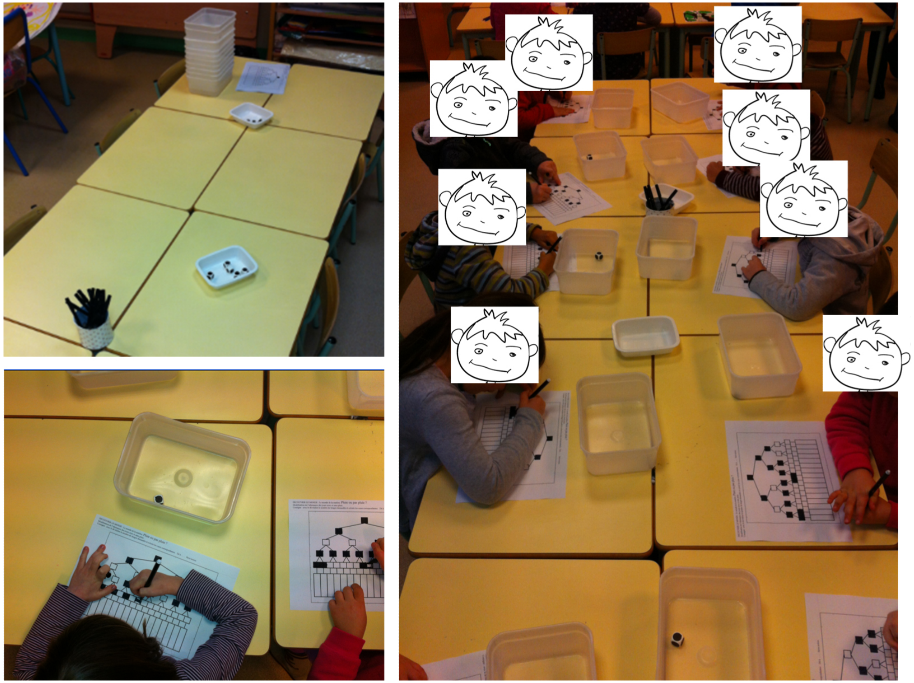
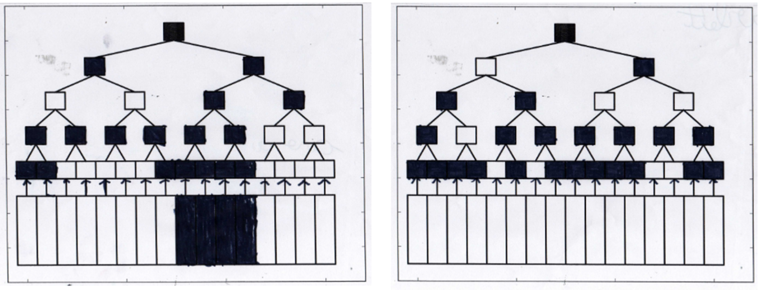


Figure 7. Implementation of the activity mimicking the β-model in a class of 5–6 years old children in Sceaux (January 2014).

Obtained with a dice with 4 black sides



Obtained with a dice with 5 black sides

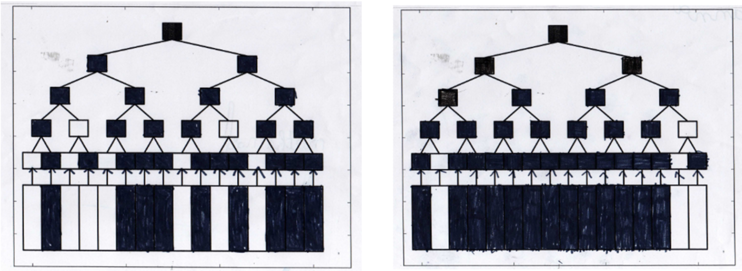


Figure 8. Examples of daily time series generated by the children with the β-model scheme.