Relationship between organization and properties of matter: hands-on activities at elementary school using carbonaceous materials

Lydie Valade, Jean-Louis Pellegatta, Myriam Dubreuil, Laurence Toral

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RELATIONSHIP BETWEEN ORGANIZATION AND PROPERTIES OF MATTER: HANDS-ON ACTIVITIES AT ELEMENTARY SCHOOL USING CARBONACEOUS MATERIALS

RELAÇÃO ENTRE ORGANIZAÇÃO E PROPRIEDADES DA MATÉRIA: ATIVIDADES DE TRABALHO NA ESCOLA PRIMÁRIA USANDO MATERIAIS CARBONÁCEOS

RELACIÓN ENTRE ORGANIZACIÓN Y PROPIEDADES DE LA MATERIA: ACTIVIDADES PRÁCTICAS EN LA ESCUELA PRIMARIA UTILIZANDO MATERIALES CARBONÁCEOS

Lydie Valade[1,2], Jean-Louis Pellegatta[3], Myriam Dubreuil[4] & Laurence Toral[5]

[1]LCC-CNRS, Université de Toulouse, CNRS, Toulouse, France
[2]Chimie et Société, Fondation de la maison de la chimie, Paris, France
[3]Chimie et Société Occitanie, Toulouse, France
[4]Lycée Déodat de Séverac, Toulouse, France
[5]Ecole Elémentaire, Tarabel, France
chimieetsociete@maisondelachimie.com

ABSTRACT | A hands-on activity is presented for elementary school students to discover the composition of matter and its consequences on chemical and physical properties. Natural forms of carbon (coal, graphite and diamond), synthesized forms (charcoal and activated carbon), and the differences in their physical properties are listed and discussed. Students build a flat hexagonal portion of the graphene sheets of graphite and a tetrahedral portion of the 3D structure of diamond. They experiment with conductivity of a graphite pencil and compare it with that of a wood stick and a copper wire. They also explore adsorption properties of activated carbon by decolorizing a grenadine solution. This activity develops manual skills and collaborative work. Students learn how to select appropriate observations for producing an experiment report both orally and by writing.
KEYWORDS: Elementary school education, Hands-on science, Chemistry education, Physics education.

RESUMO | É apresentada uma atividade prática para alunos do ensino fundamental que lhes permite descobrir a composição da matéria e assim sendo as suas consequências sobre as propriedades químicas e físicas. Formas naturais do carbono (carvão, grafite e diamante), formas sintéticas (carvão vegetal e carvão ativado) e as diferenças de suas propriedades físicas são listadas e discutidas. Os alunos constroem o motivo hexagonal plano presente nas folhas de grafeno da grafite e um motivo tetraédrico correspondendo a estrutura 3D do diamante. Eles fazem uma experiência sobre a condutividade de um lápis de grafite e a comparam com aquela de um pedaço de madeira e de um fio de cobre. Eles também exploram as propriedades de adsorção do carvão ativado ao descolorir uma solução de granadina. Esta atividade desenvolve habilidades manuais e o trabalho em grupo. Os alunos aprendem a selecionar observações apropriadas para elaborar um relatório sobre o experimento, tanto oralmente quanto por escrito.
PALAVRAS-CHAVE: Ensino fundamental, Ciência prática, Ensino de química, Ensino de física.

RESUMEN | Se presenta una actividad práctica para que los alumnos de la escuela primaria descubran la composición de la materia y sus consecuencias en las propiedades químicas y físicas. Se enumeran y discuten las formas naturales de carbono (carbón, grafito y diamante), las formas sintetizadas (carbón vegetal y carbón activado) y las diferencias en sus propiedades físicas. Los estudiantes construyen una porción hexagonal plana de las láminas de grafito y una porción tetraédrica de la estructura tridimensional del diamante. Experimentan con la conductividad de un lápiz de grafito y la comparan con la de una varilla de madera y un alambre de cobre. También exploran las propiedades de adsorción del carbón activado decolorando una solución de granadina. Esta actividad desarrolla las habilidades manuales y el trabajo en colaboración. Los estudiantes aprenden a seleccionar las observaciones apropiadas para producir un informe de experimento tanto oralmente como por escrito.

PALABRAS CLAVE: Educación en la escuela primaria, Ciencia práctica, Educación en química, Educación en física.

1. INTRODUCTION

In most countries of the world, effort has increased to enhance scientific education, in order for future citizens to better understand their surrounding world and be able to analyze political decisions *e.g.* in terms of health or environment. Efforts are often conducted jointly between educators and scientists (Crosby, 1997; Szteinberg et al., 2014), various teaching methods are compared (Gregorius et al., 2010; Paik, 2015) and many outstanding approaches (Araujo et al., 2015; Morais, 2012, 2015, 2020; Wally et al., 2005) have been employed to fight against "chemophobia" (Laszlo, 2006) and transfer chemistry knowledge in informal settings (Mikou & Bensalah, 2012; Ouali, 2015). The hands-on activity on carbonaceous materials presented in this article was initially set up for "Chimie & Terroir" (C&T), an out-of-class annual scientific outreach event, organized by "Chimie et Société"(CetS), a division of the Fondation de la Maison de la Chimie . It was conducted three times with 300 students each time over three days and took place in twelve elementary schools along the journey of the "Caravane de la chimie" (Valade et al., 2018).

Following a demand from teachers, the activity was adapted and conducted in class, in line with the program of Cycle 3 (age 9-11) of French elementary schools which recommends the following acquisition of skills in science and technology: "*Acquire the scientific language necessary to analyze and describe the observations and experiments allowing understanding the world around us, using texts and diagrams; conduct experiments to acquire spatial and temporal benchmarks and notions of scale; describe the state and constitution of matter on a macroscopic scale; identify the main families of materials and their classification according to their physical and chemical properties*" (MEN, 2015) p.12-13, 15, (MEN, 2016) p.61-63.

According to this program, the hands-on activity on carbonaceous materials is based on experiments using known materials and simple equipment for discovering the relationship between the composition and the properties of matter. The hands-on activity is accompanied with a reporting activity in the form of a worksheet and oral and written personal reports to evaluate the acquisition of scientific language. We report on how the activity was transferred to a class so as to provide teachers with materials and instructions for reproducing it.

2. RATIONAL AND CONTEXT

At elementary school age, it is of course not intended, neither intendable, to formally teach chemistry. The objective should be to arouse curiosity for science in general, to show how chemistry allows us to understand the composition and behavior of the world around us, and to overcome the first idea, still unfortunately dominant in the population, that chemistry is a source of risk rather than of well-being (Steiner, 1989). Within the Chemistry and Society community (CetS), all researchers and teachers agree that children should discover chemistry through experimentation and observation. Discover through fun activities using a limited number of new words and concepts is the aim to be followed.

Therefore, a joint preparation of the activity must be carried out by both researchers and teachers in order to meet the teachers' demand that (i) the activity be part of the acquisitions imposed by the program, and (ii) its content be adapted to the expected school level. On the basis of the hands-on activity on carbonaceous materials set by Chemistry and Society (Valade et al., 2018), and of activities such as that reported for visualizing the atomic structure (Cipolla & Ferrari, 2016), the authors jointly built the sequences and content of the in-class activity described in this article. A worksheet was edited where the student could report their observations (Supporting Information 1 "student worksheet", p. 5-8).

Another advantage of such a collaborative action also lies in the possibility of using equipment from research laboratories that schools cannot afford buying.

3. DESCRIPTION OF THE EDUCATIONAL PRACTICE AND ITS IMPLEMENTATION

The activity was conducted in three sessions by two researchers, a high school teacher and the elementary school teacher of a class of fifteen children, aged 10. The teacher continued the activity during further science class on the basis of one hour weekly for four weeks. During this additional time, students wrote a personal report and presented their work to their schoolmates using poster presentation. Note that this activity was carried out after introducing atom composition through the activity reported in (Cipolla & Ferrari, 2016). The organization and main content of the activity are summarized in Table 1.

Table 1- *Summary of the chronological organization and content of the activity*

Session	Session 1	Session 2	Session 3
Duration	30 min	30 min	1 h
Content	• list carbonaceous materials • identify natural and synthesized forms • list applications and properties • locate coal and diamond on earth • explain and date the formation of coal and diamond	• build the hexagonal arrangement of carbon in graphite • observe the planar organization • build the arrangement of carbon in diamond • associate the tetrahedrons in three-dimension	• compare the electrical conductivity of wood, graphite and copper • relate structure and properties of graphite and diamond • experiment adsorption properties of activated carbon
Student involvement	Discussion and worksheet	Experiment and worksheet	Experiment and worksheet

Session 1 took the form of a discussion for introducing the difference between natural and synthesized carbonaceous materials and identifying the origin and period of formation of natural forms of carbon. Session 2 concerned the construction of the graphite and diamond structural organization. Finally, session 3 focused on a property of a natural and a synthesized form of carbon, respectively. The students filled the worksheet to note their observations (Supporting Information 1 "student worksheet", p. 5-8). In a final discussion, students were asked to formulate the knowledge they have acquired from the experiments.

The following sections detail the different stages of the activity and provide additional information and resources as support for teachers.

3.1 Carbonaceous materials: natural and synthesized

When asking the students what kind of carbonaceous materials, they knew and for what use, they cited charcoal and coal. As the same word "*charbon"* is used in French for both charcoal and coal, students were surprised that we duplicated the word on Table 2 filled on the whiteboard. This was an opportunity to introduce the difference between natural and synthesized materials, explain the two different categories and add new entries. We showed samples of lignite, anthracite (Figure 1), charcoal, activated carbon and woven carbon fibers used in composite materials.

Table 2- *Classification of current natural and synthetic carbonaceous materials and their applications. The words with * correspond to most frequent answers by students. The table is not exhaustive of all applications of carbonaceous materials but limited to few known uses in everyday life.*

Natural forms of carbon	Applications	Synthesized forms of carbon	Applications
Coal*	Heating*	Charcoal*	Barbecue*
Lignite	Heating	Coke	Heating, metal extraction
Anthracite	Heating	Activated carbon	Aquarium*, water and air purification, medicine
Graphite	Pencil		
Diamond	Jewelry*, abrasives	Carbon fibres	Composites (sport equipment, airplane and boat structures, …)
		Synthetic diamond	Abrasives

Charcoal is actually made of 70-90% of carbon, but is man-made by the pyrolysis of wood, called carbonization. However, the carbonization process is a rapid process (2-4 days) compared to the natural formation of coal, a fossil fuel resulting from the decomposition of plants (Schobert, 1989a, 1989b; Tarbuck et al., 2015). Diamond is another natural form of carbon but can also be synthesized *e.g.* by chemical vapor deposition from methane (Werner & Locher, 1998), or at high pressure and temperature from graphite (Meihua et al., 2015). Coke may also occur naturally (Kwiecinska & Petersen, 2004) but the material needed for metal extraction from ores is produced by heating coal in the absence of air to eliminate impurities. Activated carbon and carbon fibers are other examples of synthesized forms of carbon. Activated carbon is produced in two stages: (i) the carbonization of various starting materials (wood, peat, lignite, bones, coconut shell, bio wastes, etc) and (ii) a treatment that removes the 10-30% remaining organic residues from charcoal and generates porosity (Hernández-Montoya & Bonilla-Petriciolet, 2012; Kibami, 2017). Activated carbon offers a large adsorbent surface area that can be used *e.g.* for drinking water filtration, air purification, supported catalysis. Carbon fibers are used in composite materials and are prepared from synthetic polymers following three stages: (i) oxidative stabilization of the polymers, (ii) carbonization and (iii) graphitization (Park & Heo, 2015).

3.2 The natural forms of carbon: formation of coal and diamond

A short video, *e.g*. (Edutree, 2014), explaining the formation of coal was used to focus attention (Blonder et al., 2013), and help to understand the transformation of vegetation into coal. Nowadays extracted coal results from vegetation that started to transform about 360 million years ago (Orem & Finkelman, 2003) (Table 3).

Table 3- *Geological periods and percentage of nowadays coal originating from them.*

Geological period	Length in million years ago (MYA)	Percentage of coal formed (%)
Devonian	420 to 360	Apparition of plants
Carboniferous	360 to 300	25
Permian	300 to 250	30
Jurassic	200 to 145	15
Cretaceous	145-100	12
Paleocene	66 to 23	12 (mainly Lignite)

Favorable environmental conditions (climate, oxygen and carbon dioxide levels, nature of trees) explain the highest production during the Carboniferous and Permian periods. The Paleocene period mainly resulted in lignite. Sedimentation and movements of the earth crust buried the altered vegetation that was exposed to high temperatures and pressures and progressively transformed it into peat, lignite, coal, anthracite and graphite. This transformation is called coalification and the degree of coalification is measured by the carbon content: from 50 % in wood, 50-55 % in peat to more than 90% in anthracite and 100% in graphite (Figure 1).

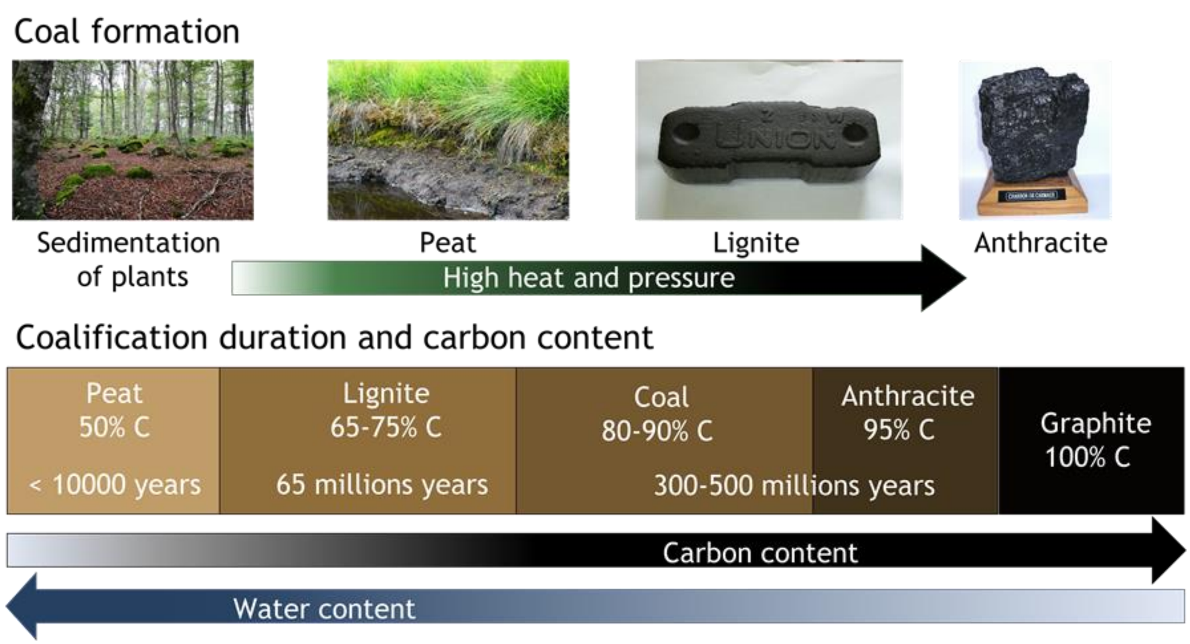


Figure 1 The steps and duration of the coalification process: from plants to graphite.

Diamond is another natural form of carbon containing 100% of carbon, however, the formation of diamond requires more extreme conditions of temperature and pressure compared to coal. Moreover, diamond is formed at deeper conditions than coal, at a minimum of 150 km from the earth's surface *versus* a maximum of 3 km for coal, corresponding to the portion of the earth crust dating back more than 1.5 billion years (Carlson, 2005). Consequently, diamond formation occurred far before plants occupied earth.

These long periods of time were not easy for students to grasp at their age. A geological time scale starting at the earth's formation was used to illustrate the timing of diamond formation, the presence of the first plants, the Carboniferous period, the period of dinosaurs, and the first humans in comparison to the duration of human being lifetimes (Figure 2).

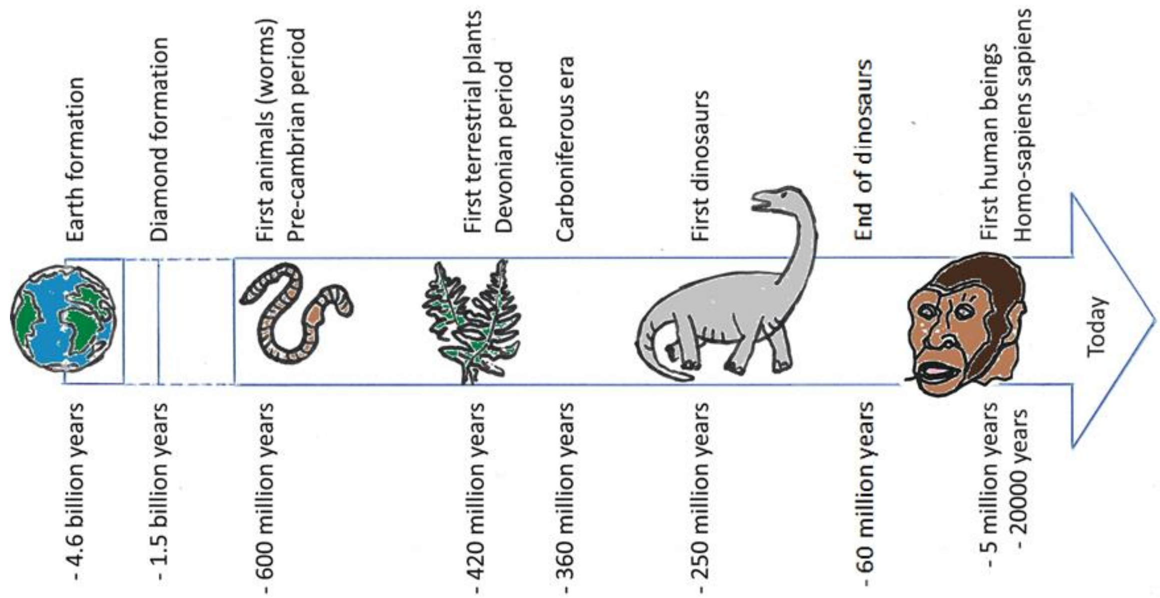


Figure 2 This geological time scale can be set up on a 5m ribbon to figure out duration by transposing time to distances. Men appear at 5 mm, dinosaurs at 25 cm, coal formation at 36 cm, first plants at 42 cm, first animals as worms at 60 cm, diamond at 1.5m, and earth at 4.6 m. Each millimeter represents 1 million years.

3.3 Graphite and diamond are both made of carbon

Children have all used graphite pencils and seen diamonds on rings. They were asked to list the differences between graphite and diamond in terms of color and hardness: graphite is black and soft, while diamond is transparent and hard. We explained that, although they look very different, both graphite and diamond are made of 100% carbon. If we used a microscope that magnifies 10 billion times, we could observe the organization of carbon atoms in graphite and diamond which explain their properties. Note that the activity on atom composition (Cipolla & Ferrari, 2016) had been conducted prior to that on carbonaceous materials, including the association of atoms into molecules with the example of water and methane molecules. We could therefore explain that each carbon atom has four electrons to share with neighbors. When two atoms engage one electron each, a bond is formed.

In diamond, carbon atoms engage all their four electrons to bond to four other carbon atoms arranged at the apex of triangular shaped pyramids named tetrahedrons. In graphite, carbon atoms bond to three other carbon atoms and form flat hexagons (Tee & Tonge, 1963). As previously reported, three-dimensional visualization of the organization of atoms in matter is useful for understanding their properties (Kao et al., 2015; Siodłak, 2017). The students built hexagons using toothpicks and 3cm polystyrene balls (see templates in Supporting Information 2, p. 2). Bottle caps can also be used (Siodłak, 2017). They were able to figure out that the hexagons are planar. They connected their own hexagon to others to form the hexagonal pavement emulating the structure of one layer in graphite, named graphene. They then built the tetrahedral arrangement of carbon in diamond (see template in Supporting Information 2, p. 3) and connected them together. They could pile layers of planar sheets of graphene to figure out the organization in graphite and compare it with the direct three-dimensional arrangement in diamond (Figure 3).

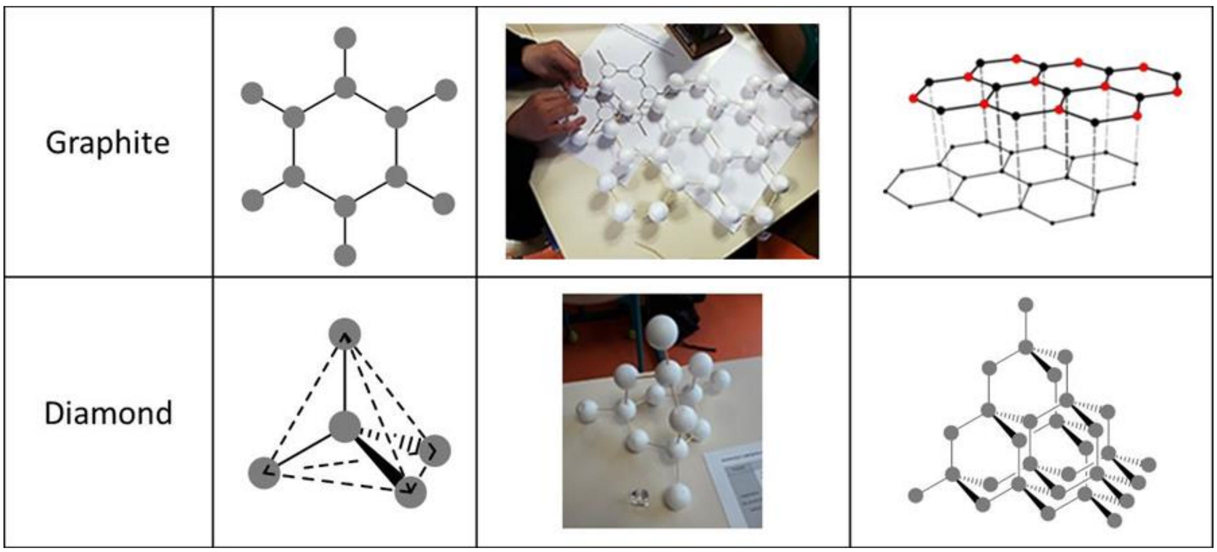


Figure 3 The organization of carbon atoms in graphite and diamond; students' construction of the hexagonal and tetrahedral units and assemblies of the units to visualize graphite and diamond structures.

3.4 Properties of graphite and diamond: hardness, color and conductivity

In graphite, the carbon richer form of coal, the hexagonal sheets are stacked, and gas is present between layers (Lavrakas, 1957). This organization makes the layers able to slip over each other, which explains that graphite is a soft material. Graphite is used in pencils and layers of graphene are deposited on paper during writing. In diamond, carbon atoms are strongly bonded in all directions thereby forming a structure which cannot be easily deformed: diamond is a hard material.

In graphite, each carbon atom has one delocalized electron (contributing to delocalized π-bonds). These delocalized electrons form a cloud over and below each layer. This electronic cloud absorbs light and can support electrical transport. In diamond, carbon atoms use all their four electrons (in σ bonds) to bond to four other carbon atoms. There are no delocalized electrons to block light transmission or support electrical transport. Therefore, graphite is black and conductive while diamond is transparent and insulating.

For reasons of availability, experiments focused on graphite-containing materials: the graphite stick of a pencil was used for the conductivity experiment and the adsorption properties were explored using activated carbon for aquarium use.

3.5 Conductivity of graphite: light a bulb

A flash light equipped with clips (Figure 4), was given to the students. They successively connected the clips to a wood chopstick, a graphite pencil (carpenter pencil) and a copper wire and observed the brightness of the bulb; they concluded that wood does not conduct electricity, and the graphite pencil conducts less than the copper wire. We explained that:

- Wood, which transforms into graphite after coalification, is made of cellulose and lignin, *i.e.* organic matter containing carbon, hydrogen and oxygen atoms organized in such a way that no electrons are available to transport electricity. Wood is insulating;
- The graphite pencil contains a mixture of conducting graphite, in which delocalized electrons support the transport of electricity, and clay which is insulating. The mixture conducts electricity;
- Copper is a metal which conducts electricity as graphite but better than the mixture of graphite and clay, explaining that the bulb is brighter.

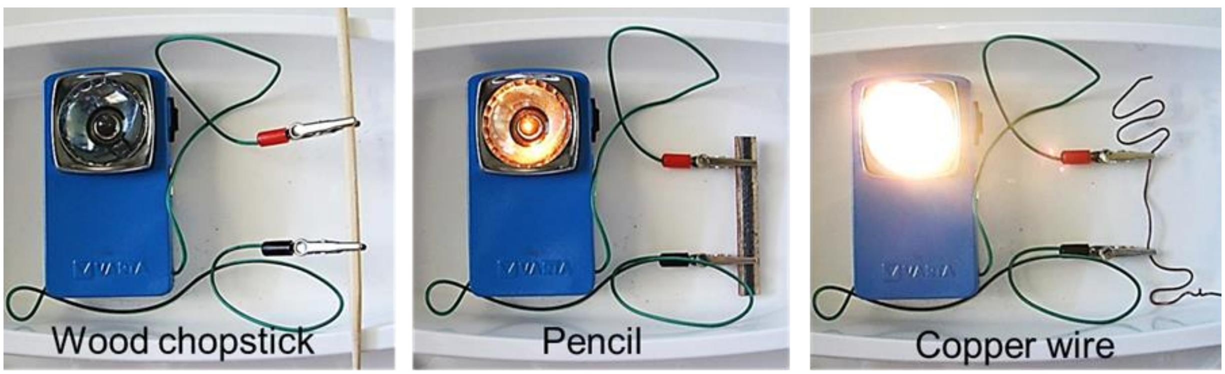


Figure 4 A flash light with switch externalized: the switch is replaced by clips. The students connect the clips to a chopstick, a graphite pencil and a copper wire and observe the brightness of the bulb.

3.6 Adsorption properties of activated carbon, a synthesized form of carbon: decolorizing grenadine

The students received a column and filled it with activated carbon and water (Figure 5). An alternative equipment can be used (see Supporting Information 2, p.7). Help was given by the animators to avoid air entrapment while packing the column. Students added 200mL of a solution of grenadine (or food coloring) to the column and collected the filtrate at 1 drop per second. They observed that the liquid filtered is colorless. We explained that the color is due to a dye contained in the grenadine syrup. When water and grenadine are passed through activated carbon, the dye is trapped in the pores at the surface of activated carbon: we used an egg box and ping-pong balls to illustrate the adsorption process (See Supporting Information 2, p. 7). The dye is separated from water and grenadine, it accumulates on the surface of the activated carbon and can be removed from it. Additional information on the adsorption of a dye on activated carbon is available in (Martins & Nunes, 2015).

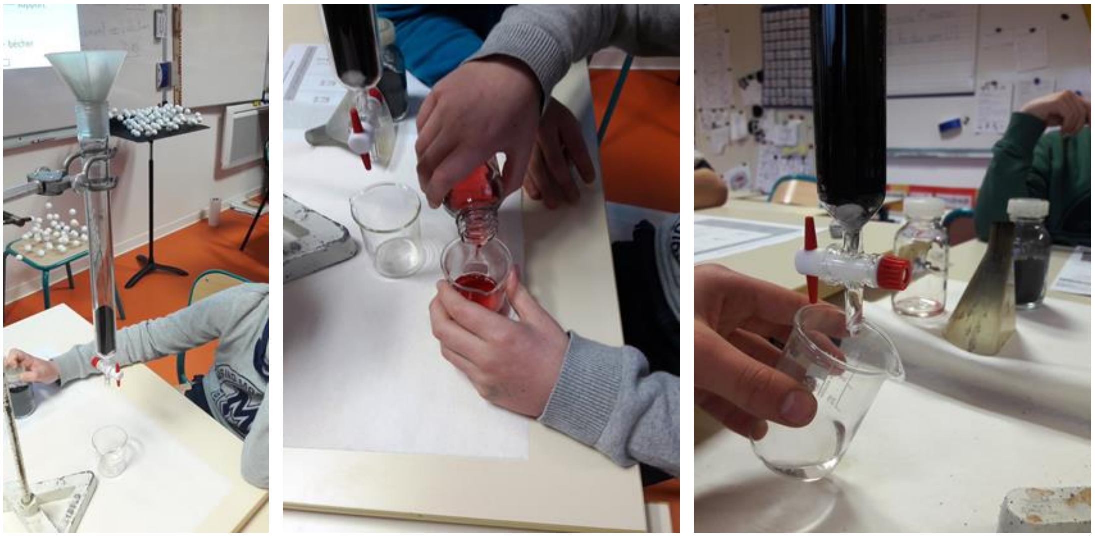


Figure 5 From left to right, steps of the experiment protocol: set up of the equipment, preparation of the column and grenadine solution, colorless filtrate.

Note on materials and hazards: Grain-like "JBL Carbomec-activ" activated carbon was purchased from an aquarium store. The amount of activated carbon necessary for each chromatography column was previously washed with water to eliminate dust and stored in vials to minimize manipulation by the students. Grenadine syrup (containing Carminic acid-E120) or liquid food coloring (red-Azorubine-E122, yellow-Tartrazine-E102 or blue-Brilliant Blue FCF-E133) available in food stores can be used as coloring agent. Either a solution of grenadine syrup in tap water (1/1 in volume), or 2 drops of food coloring added to 200mL of tap water, was prepared.

4. EVALUATION OF THE IMPLEMENTATION OF THE PRACTICE AND MAIN RESULTS

The activity allowed to work on the following skills of the program of the cycle 3 in science and technology detailed in (MEN, 2016), p. 61-62. Examples of students' productions are given to illustrate the adequation between requirements of the program and acquired skills.

a) *Practice scientific and technological procedures*
   - *Interpret a result, draw a conclusion:* as shown in Figure 6, the students wrote their observations on worksheets (Supporting Information 1).

b) *Appropriate tools and methods*
   - *Use the appropriate equipment to conduct an experiment:* the students received the equipment and the diagram and protocol of the experiment was projected (Figure 7).
   - *Organize an experimental production space on your own:* the students organized the experiment on their table (Figure 5).

c) *Practice languages*
   - *Report observations, experiences, conclusions using precise vocabulary:* this was done by using the worksheets (Figure 6).
   - *Explain a phenomenon in writing:* students wrote a personal report (Figure 8) and prepared a poster exhibition in their school.

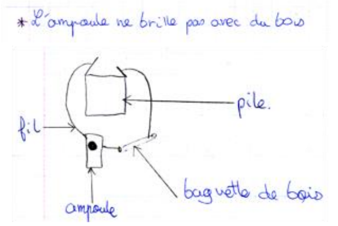
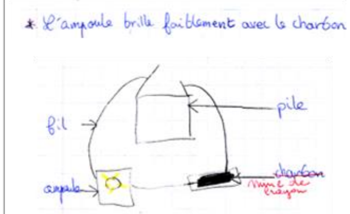
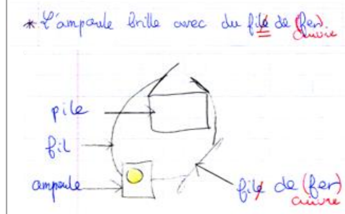
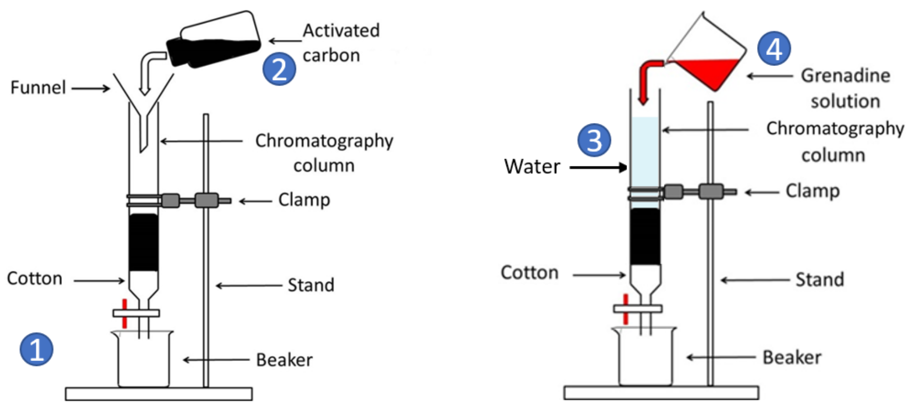
Experiment	Wood chopstick	Pencil lead	Copper wire
Connect clips to each material **Observe light bulb** **Draw the circuit**	Light is *~~ON~~ / OFF 	Light is *ON / ~~OFF~~ 	Light is *ON / ~~OFF~~ 
Electrical property	The wood chopstick *~~conducts~~ / does not conduct electricity. It is *~~conductive~~ / insulating	The pencil lead *conducts / ~~does not conduct~~ electricity. It is *conductive / ~~insulating~~	The copper wire *conducts / ~~does not conduct~~ electricity. It is *conductive / ~~insulating~~ The bulb shines *more / ~~less~~ than with the pencil lead.
Explanation	Wood is made of organic matter that does not conduct electricity.	The pencil lead is made of a mixture of conductive graphite powder and clay which is insulating.	Copper is a metal and conducts electricity better than the mixture of graphite and clay.

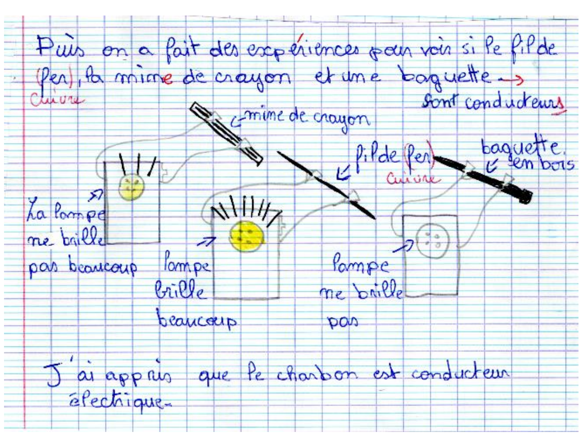
Figure 6 Conductivity worksheet (Supporting Information 1, p.7) with student's drawings and comments copied from the French version.



1. Equipment set up.
2. Activated carbon addition.

3. Water addition.
4. Grenadine solution addition.

Figure 7 Adsorption properties of activated carbon: projected diagrams and protocol steps.



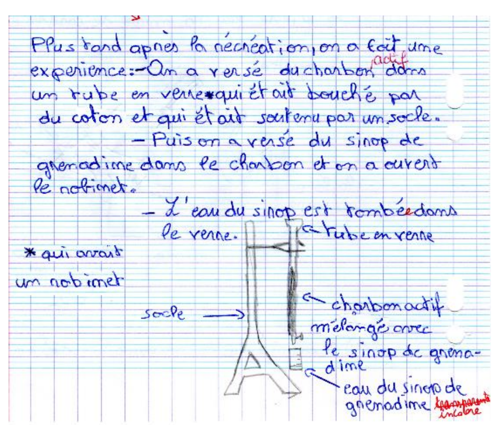


Figure 8 Extract of a student's report describing the protocol and the observations. Examples with conductive properties and adsorption properties. Classification of materials: conductors, insulators, adsorbent materials.

Through simple experiments on the macroscopic properties of matter, the activity fits into the THEME: Matter, movement, energy, information, Subtheme: *Describe the states and constitution of matter at the macroscopic scale* appearing in (MEN, 2016) p. 63.

As mentioned in (MEN, 2015) p. 9, the observation stage is essential in all scientific fields. By observing reality, science and technology provoke students' questions and the search for answers. The proposed experimental activities allowed students:

a) *To set up an experiment by following a protocol* (Figures 5, 7): experiments based on known materials and the use of simple equipment were adapted to the students' age.
b) *To observe and describe phenomena* (Figure 6): students reported their observations on worksheets.
c) *To report the experimental results in writing* (Figure 8): through writing a personal report, the students used texts and drawings of the experiments to describe their observations.

At the end of the activity, the students were asked to tell what they have learned from the experiments. Through this first oral evaluation, we noticed that they understood well that two materials made of the same element can have different properties at macroscopic scale due to their solid-state arrangement at microscopic scale. Figure 9 shows how they translated this knowledge into their personal report. While the geological timescale (Figure 2) allows acquiring temporal benchmarks, the construction of the hexagonal sheets of graphite and tetrahedral structures of diamond (Figure 3) and their association in three directions to figure out the atomic organization within a material, is useful for the acquisition of spatial benchmarks and notions of scale.

<table>
<tr><th>Instructions</th><th>Student's production</th></tr>
<tr><td>Draw diamond and coal (macroscopic scale)

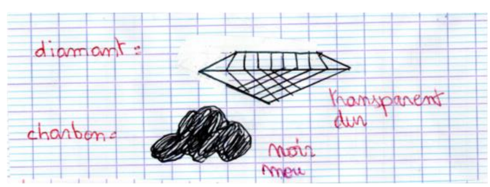
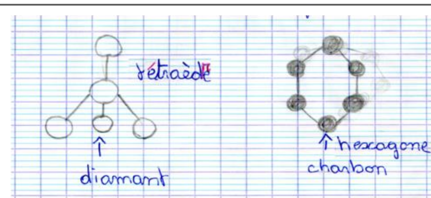
Write observable properties</td><td>
</td></tr>
<tr><td>Draw the organisation of carbon in diamond and coal (microscopic scale)</td><td>
</td></tr>
</table>

Figure 9 Comparison of macroscopic and microscopic scale. Properties at macroscopic state. Spatial organization at microscopic state.

The activity developed manual skills and collaboration during the experiments. As mentioned in the description of the activity, the teacher continued the activity during other science courses. In addition to the documents filled during the activity, each student wrote a personal report. The teacher helped the students understand how to choose among their observations in order to draw conclusions using appropriate vocabulary. They also presented their work orally to their schoolmates in the form of a poster exhibition.

5. CONCLUSIONS AND IMPLICATIONS

The adequacy between the activity and skills can be summarized as follows:

a) Experiments based on known materials and the use of simple equipment are adapted for *"understanding the world around us". Students "acquire the scientific languages necessary to analyze the observations and experiments*" by filling a worksheet (Figure 6, Supporting Information 1). They write personal reports and draw schemes of the experiments "to *describe their observations using texts and diagrams*";
b) The geological timescale (Figure 2) allows "*acquiring temporal benchmarks*". The construction of the hexagonal sheets of graphite and tetrahedral structures (Figure 3) of diamond and their association in three directions to figure out the material, agree with "*conduct experimental approach to acquire spatial benchmarks and notions of scale*";
c) The macroscopic properties of graphite and diamond (color, hardness) are easy to list by the students to "*describe the state and constitution of matter on a macroscopic scale*" (Figure 9);
d) The experiments with conductivity and adsorption help the students to identify electrical conductors, insulators and adsorbent materials among "*main families of materials*" and to classify them "*according to their physical and chemical properties*" (Figure 8).

The reported hands-on activity on carbonaceous materials provides ideas that teachers from any country can adapt to their class. The activity can be upgraded to be conducted with students aged 12 to 15. It includes multidisciplinary knowledge and practice. The combined implication of researchers and teachers allows to

- offer good equipment conditions for the experimentation
- build an activity at the appropriate education level.

As the activity should be conducted according to class schedules, it requires the participation of one educator for 4 students. The time devoted to each session is too short to ensure that each student has understood all observed phenomena. The activity is a first approach based on observation: it must be completed by the teacher by going back over each acquisition in several sessions. After this essential step, all students are able to build an autonomous presentation of their observations.

Meeting researchers and using professional laboratory equipment increases the students' interest in the activity. This was not surprising because, during our various outreach activities, we have noticed that the equipment is always what attracts at first: it encourages students and adults to ask questions and interact with the researcher.

Let's finally tell an anecdote showing that the activity increased students' curiosity. The class that carried out the activity reported in this article was selected to talk to astronaut Thomas Pesquet when he was on board the ISS. One student greatly surprised him when he asked if graphite was a conductor in space.

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