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| 1. **WAKE UP** | |
| WHAT WILL YOU DO | WHAT WILL YOU SAY |
| You clearly say that you are interested to find out what pupils think ‘energy’ means. You clearly say that their answers can’t be wrong, as you are looking for their opinion.  You write down all the ideas the class comes up with on the blackboard.  You express that you are excited about the input they give.  You give instructions.  You note extra ideas on the blackboard.  You express that you are excited about the input they have given. | *What is your idea about ‘energy’? What do you think others think about ‘energy’? Can you name things that have energy? Does everybody have the same idea? Why do you have that idea? Do we all agree upon that interpretation? Are there different ideas? Is this what you mean? Yes, I understand what you are saying. I see your point. Are you sure or are you guessing? Can I write it down this way? No, I don’t understand what you mean. Can you clarify? Can you explain what you mean? Can you give an example?*  *Now I am going to give you all a piece of paper and I want you all to take something to write. I want you all to write down the first thing you think about when I say the word ‘energy’. Now pass the paper to the neighbor on your left side. Read what is written on the paper and add what comes up in your mind. We are going to repeat until you all run out of inspiration.*  *Now what ideas should I add on the blackboard? What new ideas about ‘energy’ popped up?*  *I am impressed with the knowledge the class has!*  *Now look at all these ideas. Is everybody thinking the same? I seem to see different kinds of ideas. Not all ideas are the same.* |
| WHAT TO EXPECT  At first few pupils answer. It takes some time for them to come up with ideas. It looks as if they have to dig up the ideas, retrieve them from memory. It also takes some time before they believe that you are only interested to find out about their ideas and not looking for the scientific answer.  As pupils hear and read new ideas, they start to associate. The retrieving of ideas from memory is facilitated this way.  The extra information on the blackboard starts to show the different ideas, preconcepts, that pupils hold.  Ideas that came up within the trials and data collection of the research:   * Only things that are alive, only things that move have energy * Energy is a kind of substance * Energy gets lost * Energy can be created | |
| PAY ATTENTION!  Don’t judge the ideas pupils present. Be careful not to become enthusiastic when they present the scientific approach. Pupils read these kinds of signals and will stop their own way of thinking. Instead they will try to catch up with your way of reasoning.  Don’t add information, or structure their ideas. Treat their ideas with respect. Show you are genuinely interested in their ideas and their way of thinking. | |

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| 1. **IDENTIFY** | |
| WHAT WILL YOU DO | WHAT WILL YOU SAY |
| You use different colours to group ideas.  You listen carefully and try to reformulate, report the ideas and reasoning that pupils offer.  You summarize by clearly formulating the different ideas.  You project or show a picture of the following objects/ animals:  You draw 2 columns on the blackboard.  You follow the instructions pupils give. You might add new ideas.  You pick one precocent. | *Now let’s have a look at all this information you came up with about the word ‘energy’.*  *Can you group ideas?*  *Are these ideas similar? Why? Can you explain what you mean? Is this what you want to say? Do you agree with his/her idea? Why?*  *So can we summarize that the class thinks that*  *- Only things that are alive, only things that move have energy*  *- Energy is a kind of substance*  *- Energy gets lost*  *- Hot things (e.g. fire) have energy*  *- ….?*  *Now look at these objects and animals: a running leopard, a sleeping panda bear, water in a bottle, a box of tissues, a ring, fire, a toy car standing still, a magnet, a rubber band, a driving car, potassium permanganat, a bottle of glycerine , water falling from a cliff.*  *I would like you to sort the previous things in 2 groups: a group 1 ‘has energy’ and a group 2 ‘does not have energy’.*  *Which objects/ animals belong in group 1? Which belong in group 2? Are there objects/ animals that you can’t classify? Or that you are not sure of? Why is that?*  *Now I want to choose one of the ideas that you came up with and we are going to focus on that one idea now. We start with the idea that ‘only things that are alive, only things that move have energy’.* |
| WHAT TO EXPECT  During trials pupils agreed upon the fact that moving objects and living animals belong in group 1. Objects that are no longer alive/ moving belong in group 2.  One student came up with the idea that ‘everything has energy’. This idea was added on the blackboard. | |
| PAY ATTENTION !  Again!  Do not impose your own structure. Follow the class in the reasoning.  Facilitate the discussion by posing but don’t take a personal stand in the discussion. Be neutral. Only facilitate the discussion. | |

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| 1. **SHAKE** | |
| WHAT WILL YOU DO | WHAT WILL YOU SAY |
| You do small demos that combine preconceptual properties of ‘has energy’: *moving and alive* with preconceptual properties of ‘does not have energy’: *not moving and dead*.  1) Pull the rubber band through the ring. Hold the rubber band tight between both index finger and thumb. The end of the rubber band is hidden behind your hands. Pull the rubber band tight and hold it slightly tilted. Now slowly release the tension. The ring will start moving upward. (also watch video clip)  2) A small sheet of plastic, the size of the bottleneck, was put on your hand before, without showing. Putting the bottle upside down on this plastic will prevent the water from falling down. The illusion is created that the ring holds back the water. When removing the ring, a small pressure on the bottle releases the water.  3) The mixture ignites.  You pour a little bit of glycerine onto potassium permanganate. OR watch the following video clip: https://www.youtube.com/watch?v=6a-mO-MxS1A  4) You made a little hole near the bottom of the bottle. By unscrewing the bottle, the water sprays out of the hole, pushing the cardboard wall down.  5) You slowly bring the magnet close enough so that the toy car starts to move. You repeat the trick several times.  When pupils ask, you do the demos again.  You show surprise. | *1) I have a ring and a rubber band. Look what happens.*  *2) I have a bottle filled with water. I put it upside down on my hand. What will happen if I remove my hands? What happens if I put the ring on the bottle and then remove my hand? What happens if I remove the ring?*  *3) I pour a little bit of glycerine onto the potassium permanganate. OR watch the following video clip: https://www.youtube.com/watch?v=6a-mO-MxS1A*  *Look carefully what happens.*  *4) I have a bottle filled with water. Next to it I put a light cardboard wall so that the hole in the bottle faces the cardboard wall. Now I unscrew the bottle. What happens?*  *5) I bring the magnet in the vicinity of the toy car. Look what happens.*  *That’s strange. In the demos I chose objects that we classified in the group ‘doesn’t have energy’. When I combine them they start moving, become fire, push things aside.*  *This is strange. How can we explain this? Where does this energy come from?* |
| WHAT TO EXPECT  Pupils are very surprised about what happens. The demos are contra-intuitive. Pupils ask to do the demo again because they can’t believe their eyes.  They thought the water in the bottle had no energy but the water can push the card board aside. They thought the ring and the rubber band have no energy. But now the ring magically starts moving up. They thought potassium permanganate and glycerine have no energy but combined they produce fire that clearly has energy. The magnet and the car are clearly dead but only by approaching the magnet, the car starts moving.  Pupils are curious to find out how the demos work. They want you to repeat the demo over and over again.  Sometimes pupils come up with a possible explanation, but during trials the class could not reach consensus and ended up a little bit shaken.  Pupils were eager to find out how it works. | |
| PAY ATTENTION !  Don’t explain how it works straight away. Be surprised with them.  Safe the explanation for the next phase. | |

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| 1. **INTRODUCE** | |
| WHAT WILL YOU DO | WHAT WILL YOU SAY |
| You explain the scientific meaning of the concept energy. Here, you are the expert. You state very clearly how the scientist understands the concept. There is no discussion. Use multiple representations: write down the idea, project it, draw, video clip, …. .  You answer questions pupils have and clarify what you mean. | *Let us look at how a scientist thinks about the word energy.*  *The scientist says:*  *Everything has energy (also non-living, non-moving objects). Energy is a measure for possible change. It is a property. It is expressed in a number and the unit Joule.*  *When you talk about energy you use the verb ‘to have’. For instance: Thomas has energy or a chocolate bar has a lot of energy.*  *The higher the energy, the more change than can be generated.*  *Energy cannot be created, nor destroyed, but it can be converted and transformed.* |
| WHAT TO EXPECT  Pupils are open to this new idea because in the previous step their preconcept failed to explain the demos.  They ask to clarify the idea.  They have to get used to the new idea. | |
| PAY ATTENTION !  Be confident. Give a clear explanation. | |

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| 1. **SECURE** | |
| WHAT WILL YOU DO | WHAT WILL YOU SAY |
| Together with your pupils, you try to follow the scientist’s way of thinking. You apply his/ her idea on the demos.  First you give an example. You continuously link back to the scientists’ idea.  Express that it is perfectly normal that picking up a new way of thinking takes time. Show you are confident that they will pick up the idea.  You split up the class in small groups. Every group works on one problem.  You provide materials. ( see attached material list).  You walk around and facilitates the design by asking questions. You ask them how they think.  You try to keep them focused on the mindset of the scientist’ idea by reminding them of the initial question and the scientific idea.  You guard the time. During trials the design of the experiments lasted max. 15 minutes.  You comment during presentations.  You ask them to clarify.  You summarize findings. | *Now let us think back and remember the demos; How do you think that the scientist would explain. Would the scientist reclassify and why?*  *For example the rubber band. Does the rubber band have energy? Yes the rubber band has energy because it can start the ring moving up. It can generate change.*  *Now try for yourself.*  *The magnet has energy because …*  *Potassiumpermangante has energy because …*  *The leopard has energy because ..*  *The water has energy because …...*  *The panda bear has energy because ….*  *…..*  *Now I want you all to think about this question: What properties of an object can contribute to its energy?*  *I want you to think of an answer to my question and I want you to design and do a small experiment or demo that explains to me your way of thinking. Make groups of 4 students. We will hand out boxes with materials that you can use.*  *Take pictures or make a small video with your cellphone if that supports your way of thinking. Fill in the research reports that you find in the box. Hand in the report at the end.*  *You have 15’ to come up with as many experiments as possible.*  *Can each group briefly present its findings to the class?*  *Can I summarize that :*  *The energy = the measure of possible change depends on :*  *→ mass, speed, position (height), kind of substance, temperature,*  *These are all properties you could measure.*  *For instance how will you measure temperature, mass, …..?*  *All these properties contribute to the energy.*  *To start energy transfer an outside input is often required. I have to open the bottle, I push the car, …. .* |
| WHAT TO EXPECT  At first pupils hesitate to apply the idea. Articulate the reasoning yourself.  As pupils hear more examples, they get used to the idea and to the way it is articulated. They pick up the way of thinking. By hearing you and by hearing each other they learn how to use the scientific idea and they gain confidence.  They discover that the scientific idea is easy to use. Making the exercise becomes very easy. Pupils come up with great ideas. They are inventive in designing small demos. Often these demos are unexpected for the teacher.  The material they ask for is very simple or easily replaced by an alternative you have in the lab or at home.  They might provide the material themselves.  Pupils discover that the scientific idea works. They get used to using the idea, talking about it. | |
| PAY ATTENTION !  Be patient. It is normal that pupils need a bit of time to get used to the new way of thinking. Some will pick up the idea very quickly, others will need more time. That is normal.  Critical pupils are a gift in the lesson. They push the class in thinking and dialoguing more deeply.  Don’t intervene too quickly. Give them time to come up with ideas in the group. Only when you notice that inspiration drops, you join in the creative process.  Don’t propose your design. | |

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| 1. **USE** | |
| WHAT WILL YOU DO | WHAT WILL YOU SAY |
| Give pupils a number of small assignments. They work in groups, using the scientific ideas in different contexts. Here lay opportunities for integration.  Observe them and give a new assignment when they finish.  Help to keep discussions going.  You show the pupils a glass filled with warm water and you let them feel the temperature of the water..  You show the pupils a glass filled with cold water and you let them feel the temperature of the water..  Use the particle model to visualize water.  You summarize findings for the class.  Draw the situation. Add the surroundings of the object. Use the particle model.  Join in the discussion. | *I am given you small assignments. You work in groups of 4/5. Discuss the answer. Report on paper.*  *WHAT IF?*  *Think of effects:*  *1. What if the sun would stop shining?*  *+ Black smokers including in answer*  [*https://www.youtube.com/watch?v=6ByT4ponpUQ*](https://www.youtube.com/watch?v=6ByT4ponpUQ)  *2. What if people could not store energy? + video* [*https://www.varta-storage.com/fileadmin/templates/video/120612-Varta-Final-1080\_english\_V4.mp4*](https://www.varta-storage.com/fileadmin/templates/video/120612-Varta-Final-1080_english_V4.mp4)  *3. What if electrons could not move?*  *4. What if dead things would not have energy?*  *5. What if people could make chlorophyll?*  *6. What if you really would not have energy when you are really tired and say ‘I don’t have energy anymore’.*  *FIND ARGUMENTS CONTRA*  *1. Energy is a substance.*  *2. Energy gets lost*  *3. The table has no energy because it doesn’t’ live.*  *4. When a torch was used for a long time, the battery is empty.*  *EXPLAIN*  *Magic tricks 1 and 2*  *What happened to the energy of KMnO4 and glycerol?*  *Demonstration: The weird coin*  *Demonstrate the ‘water-in-glass- trick’*  *I have a glass filled with warm water. Feel the temperature of the water. What will happen with the temperature of the water as time goes by? What will happen with the energy of the water? Where did the energy of the water go?*  *Now I am going to place a glass filled with warm water in a bowl filled with cold water. Feel the temperature of the cold water.*  *Now I asking you the same questions: What will happen with the energy of the warm water as time goes by? Where did the energy of the warm water go? What will happen with the energy of the cold water? Where did the energy of the cold water go?*  *So now you discovered that in this situation energy does not get lost.*  *Is there a difference with the first situation? Feel the air nearby the glass filled with warm water. What is air? How can you picture it?*  *So am I correct that we discovered that in these experiments energy didn’t get lost? It didn’t disappear. Energy was transferred to the surroundings.*  *Often this means that energy gets spread over many particles.*  *Watch the video … and explain what you see.*  *SITUATIONS*  *I give you situations. Tell me what happens with the energy of the underlined object? Where does its energy go to?*  *A pendulum is swinging*  *I push a car*  *I start the engine of the car*  *I switch on a torch*  *I run the marathon* |
| WHAT TO EXPECT  They are motivated. Discussion is intense. It goes quickly .  Pupils will say that the temperature of the water will drop and that consequently the energy of the water will go down. They will say that the energy has gone, disappeared.  They will say that the temperature of the cold water and its energy will go up, disappear.  Pupils now will take the surrounding water into account.  Pupils smoothly follow your line of thoughts.  At first pupils will hesitate to answer. Then add the answer yourself. As more examples appear on the blackboard, pupils will pick up the way of thinking and start answering themselves. They can hear yours en other pupils’ answers. This will strengthen them in their thinking and makes them more confident .  The scientific way of thinking seems easy, it works well. | |
| PAY ATTENTION !  Do not meddle too soon. Give them time to think. Only intervene when you feel that a group loses motivation or discussion cant’ get started.  Give pupils time to think. Be patient. Use small straight forward questions to keep them thinking. Gently push their thoughts. | |