Friday 10th March - Materials Decathlon - Challenge n°3 - 40'

UNUSUAL CONDUCTIVE MATERIALS

*Technology and its applications require lighter, cheaper, more versatile new **conductive materials**. Thanks to Materials Science, nowadays conductive plastic, ceramic and even glass can be manufactured.*

1. **New conductive materials** - On the desk you have a few mixed samples: which of them in your opinion are conductive?
2. Now check your answers testing the samples with the multimeter in ohmmeter modality: if you can measure any electrical resistance then current is going through and the material is an electrical conductor. [*Suggestion: test on both sides (top and bottom) and also along the vertical axis (putting one jack on each of the two sides).*]
   Q1. Would you like to change some of the answers given in step1? Fill in **Table 1** on the answer sheet.
3. **Isotropic and anisotropic conductors**- Consider samples A (plastic), B (glass) and C (textile). Put one of the ohmmeter jacks in one spot and move the other one around in a circle of the same radius. Is the resistance the same along each direction? If the answer is yes then it means the conductor is isotropic that is to say conduction is the same in all directions.
4. In the market you can now find the so called "***Z-axis conductive tape***" used as an alternative to soldering in microelectronics and prototyping. Test the sample sticked on the plexiglass rectangular sheet.
   Q2. Is there any resistance across the surface (X-Y plane)?
5. Now consider the apparatus in the picture where in the junction between the copper strips there are different kinds of materials, conducting or not. Link one of the ohmmeter crocodile jumpers to copper junction **X** (this will be fixed) and the second one in sequence to junction:
   - **A** (common ***sellotape***),
   - **B** (***Z-axis conductive tape***)
   - **B'** (**Z-axis conductive tape** with misaligned copper strips)
   - **C** (aligned ***copper strips***)
   - **C'** (misaligned ***copper strips***).

   

   Q3. Which ones of the above junctions are letting current through?
   Q4. What can you deduce about the ***Z-axis conductive tape?*** *Is it* isotropic or anisotropic?
6. Now consider the two strips of conductive textiles: light grey (A) and dark (B). Split the team in two groups-one for each strip -and work separately though the following points
   - Take note of the initial length L_0 and resistance **R** when the strip is at rest.
   - Fix one of the extremities on the zero of a ruler and stretch the strip in 0,5 cm steps till you reach the maximum length while reading R. Fill in **Table 2A** and **2B** with the data collected.
   - Repeat two more times to check whether there's correspondence in the values: calculate the mean value and evaluate the strip sensibility (error in measured resistance for a fixed elongation)
   - Plot a graph of resistance versus elongation

   Q5. Does resistance increase/decrease with increasing elongation?
   Q6. To explain why the two kinds of textile act differently you may observe the knitting with the microscope. What can you see??

☞**OUTPUT WANTED: answers to Q1-Q7 + Tables + Plots of Resistance versus Elongation for both strips**

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Answer sheet **GROUP N°_____**

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Q1 – Table 1:

Conductive	Not conductive

Q2

Q3

Q4

Table 2A: light grey textiles						Table 2A: light grey textiles				
Elongation	**R**	**R**	**R**	**R**		**Elongation**	**R**	**R**	**R**	**R**
= L – L_0	1st m.	2nd m.	3rd ms.	mean		= L – L_0	1st m.	2nd m.	3rd ms.	mean
cm	Ohm	Ohm	Ohm	Ohm		cm	Ohm	Ohm	Ohm	Ohm

Q5

Q6

Plot the two graphs either on paper or save them in a file if you used Excel – *See general instruction to save files*.

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Teacher's Notes

Technical notes:

- Preferably work with crocodile morsets rather than spiky ones. Go "gentle" as you test resistance!

Organizational notes:

- Each student will keep a copy of the students' sheet but the group will collectively fill in the answer sheet and give it over to the teacher in charge at the end of the lab.

Correction grid

Question or Request	Note	Max. score
Q1 – Table 1	See key to answer	2
Q2	See key to answer	1
Q3	See key to answer	2
Q4	See key to answer	2
Table 2A – 2B	Mark 1,5 point each if they are partially filled; 2,5 point if full filled	2,5*2=5
Plot 2A – 2B	Evaluate if it's clear and readable	2*2=4
Q5	See key to answer; answer should be motivated on data collected (see plots)	2
Q6	See key to answer	2

Key to Answer

Q1To have the correct answer, test the samples given to students at the end of the experiment; remember to test both faces.

Q2 NO

Q3. Only B, C, C'

Q4 It is anisotropic: it lets current flow only in z-direction (note the difference with copper strip in C' junction and B' Junction with z-tape)

Q5 It depends on the textiles: see below for more details

Q6 It is different: see below for more details

Materials and equipment

- Multimeter with both crocodile jacks and pointers
- Samples of conductive and not conductive materials (conductive: Faraday film plastic, ITO glass, electro conductive textiles, Z-axis conductive tape 3M^{TM})
- Device for the study of the Z-axis conductive tape
- Ruler
- Pc + excel
- microscope

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More Technical Specification

Q2, Q3, Q4 Z-axis Conductive tape

3M Z-axisConducting Tape

Notes to the use of the plexiglass sheet with connections

Junctions:

1 in the junction between copper strips there's a layer of **traditional sellotape**: it's NOT conductive [*if you have it, preferably work with double face adhesive sellotape (comparison with junction 2 will be more consistant)*

2 in the junction between copper strips there's a layer of **Z-axisCondutcting Tape**: IT IS CONDUCTIVE but only in the transversal direction [*see below the difference in the connection between B and B'*]

3 the copper strips **are directly connected** with no other material in between.

External Connexions of the Plexiglass Sheet

X used in all tests

A connexion to junction 1: **common sellotape** (NO current detected)

B connexion to junction **2**: (**Z-azisConducting Tape**) with overlapping copper strips: (CURRENT detected) [*trasversal (Z-axis) to the Tape*]

B' connexion to junction 2 (**Z-azisConducting Tape**) BUT the copper strips are not overlapping they are **misaligned** : (NO current detected) [*this proves that in the Z-azis Conducting Tape current goes through only along the (Z-axis) of the tape*]

C **direct connexion** between the copper strips (conductive): (CURRENT detected)

C' **direct** connexion between the copper strips, however thes are misaligned [*more precisely: input X and output C'are not aligned and in between there's a conductive copper strip: see B'*]: (CURRENT detected) [*this proves that with copper current flows in all directions not just along the Z-axis*]

Possible Experiments qualitative and quantitative

- Qualitative observation Conductive/Non Conductive through the different connexions (*use the ohmmeter in the "buzzer", or build a test circuit with a small bulb*)
- Direct and quantitative measurement of resistance through the different junctions
- Direct measurement of current i through the different junctions when it's powered with 1 V or even *lower (this brings to Ampere magnitude in the flowing current.*) – and indirect measurement of Resistance (Ohm's law)
- Test the dependence with pressure applied normally to the junctions.
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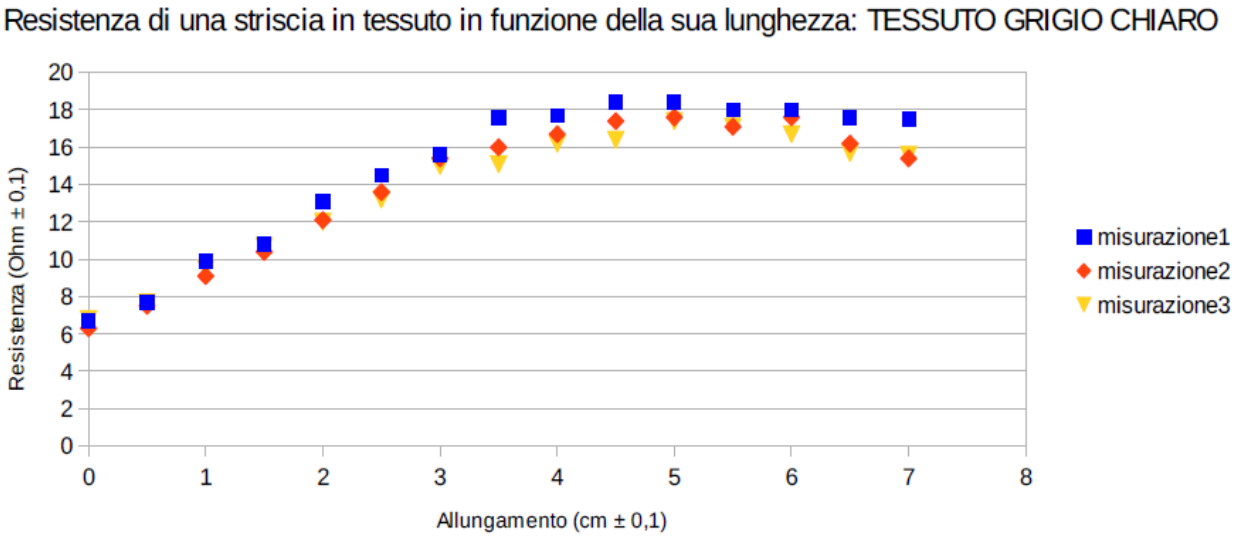
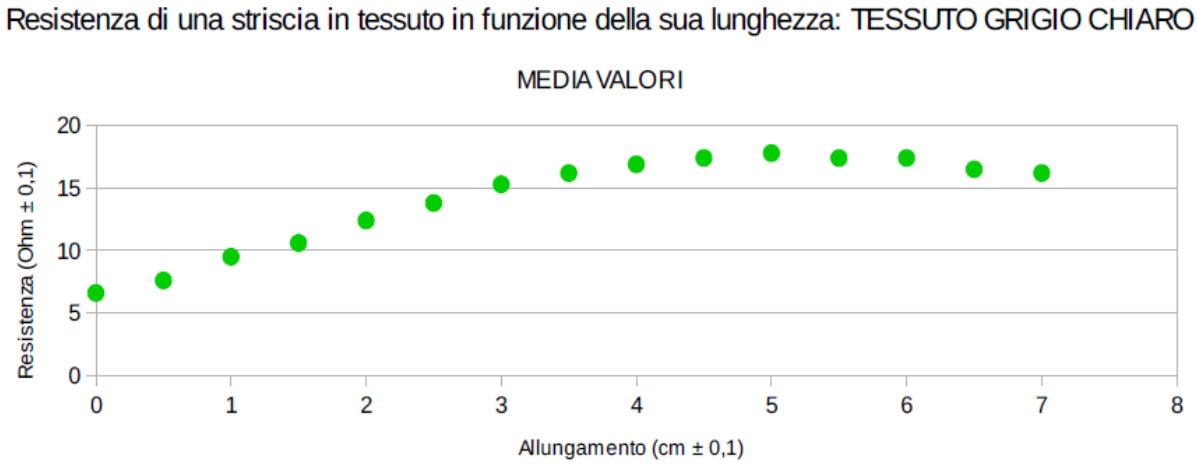
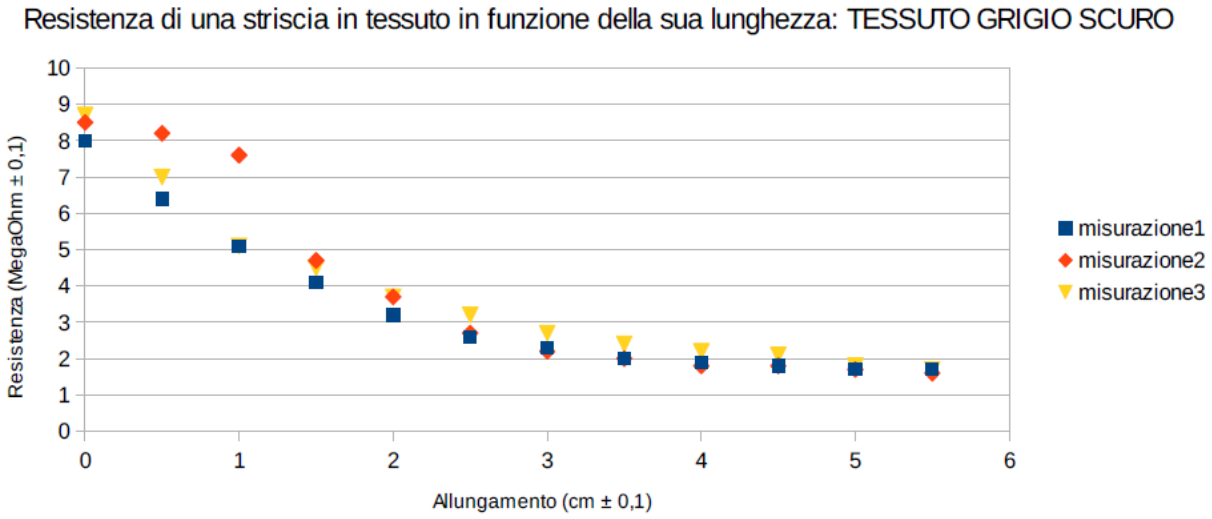
Q5 Textile conductive strips: resistance VS stretching

Below some data from students' tests first the light grey textile strip (three tests and averaged) and then the dark grey sample







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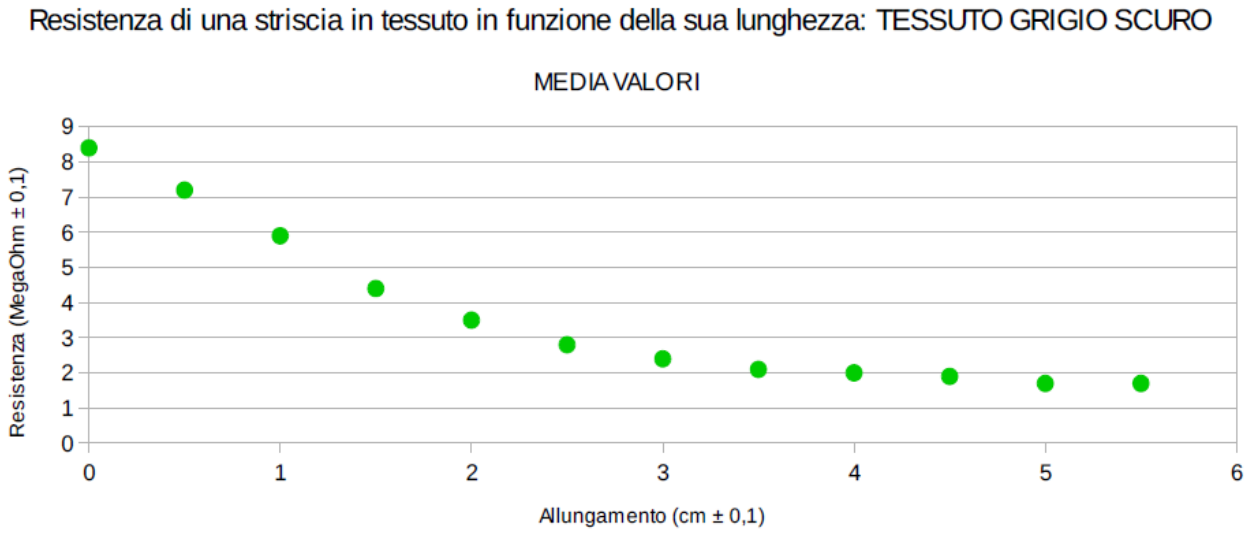
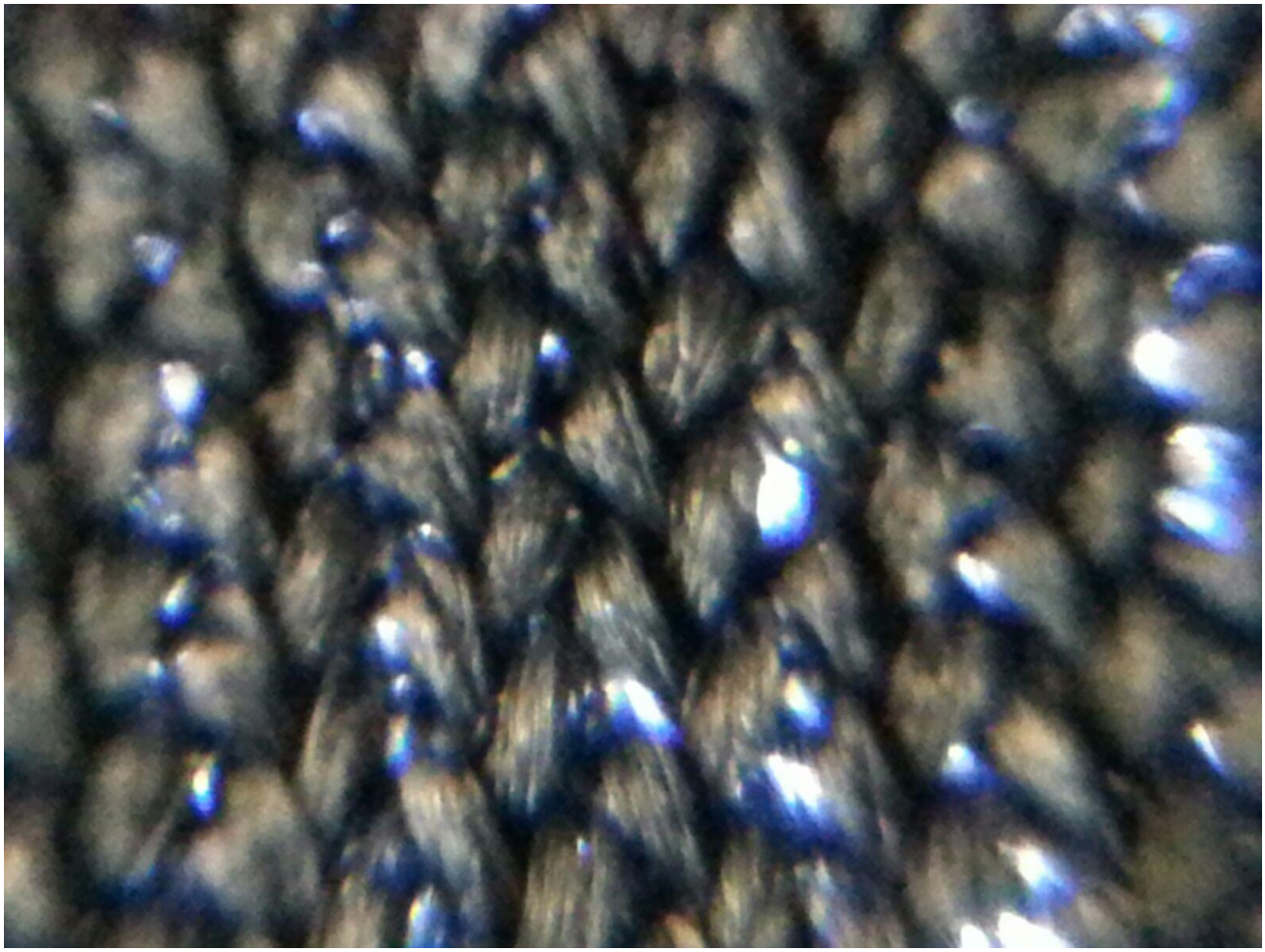


Q6.Under the microscope:

Picture 1: dark textile. Starts with a very high resistance (MegaOhms) and upon stretching R decreases



It would be great to make a video while stretching

Picture 2: light gray textile. Starts with a resistance of a few Ohms and upon stretching R increases reaching a maximum, then it decreases again.

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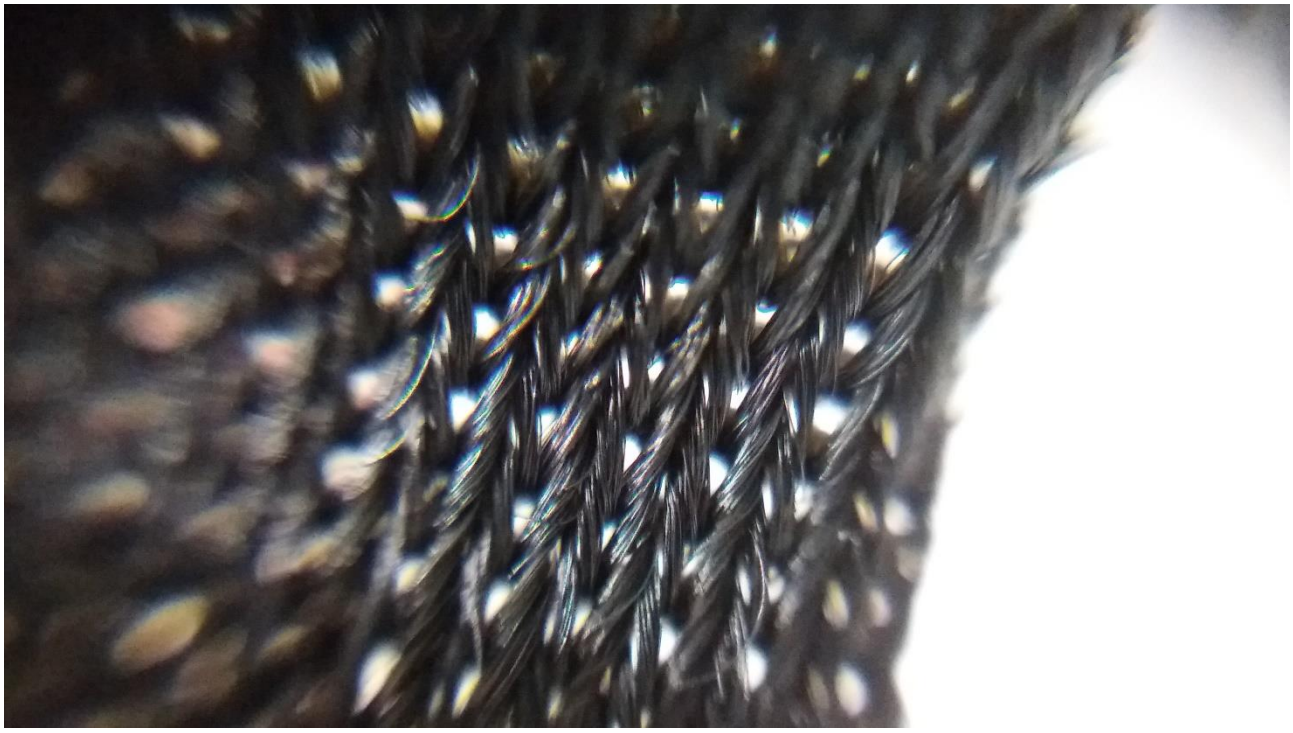

If you have more time to dedicate to the topic, possible further investigations are

- Testing parallel and in series resistances with the textile strips
- Testing and plotting the hysteresis cycle of the textile conductive strips
- Soft potentiometers: the tubular stretching resistance, the soft sliding potentiometer (plotting resistance versus length you have a liner relation), a metal zipper whose metal teeth have been connected with conductive wire [see references]
- Implementing the strips with Arduino (both the textile strips and the soft potentiometers) as sensors connected with actuators (buzzer, LED, motor….)

MoM resources

References

1. http://www.instructables.com/id/Simple-Zipper-Potentiometer/
2. https://create.arduino.cc/projecthub/Arduino_Scuola/soft-potentiometer-tutorial-8a7b02

Acknowledgments

- **Plug and wear** for donating a few kits of sensors http://www.plugandwear.com/

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Photogallery

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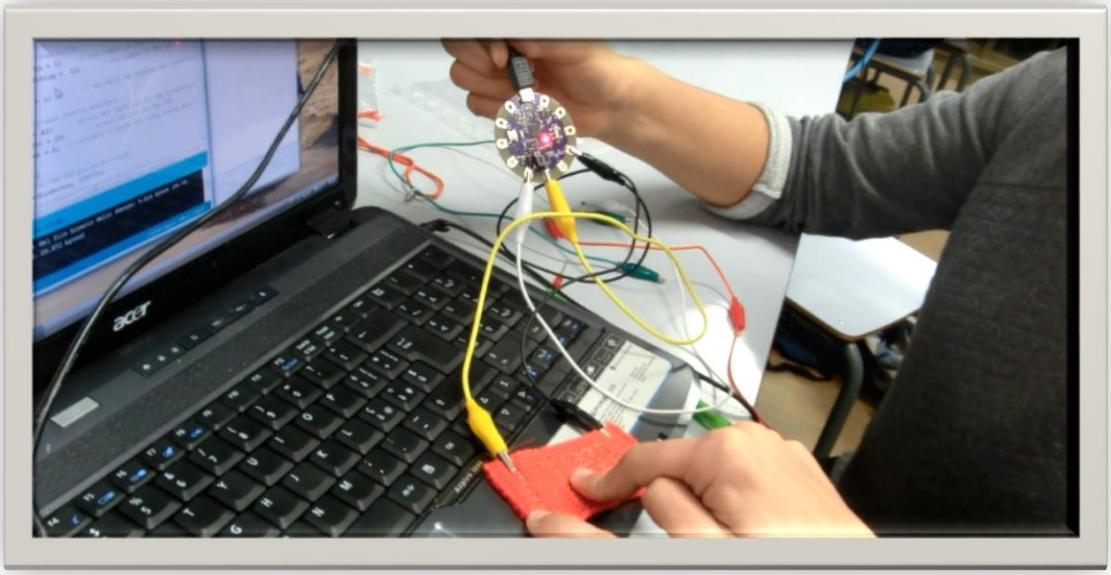

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