The dust catcher: transforming dusty collections of scientific instruments into tools of education

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Abstract. This work is aimed at presenting an ongoing physics education project based at the Museum of Physics of the University of Turin. The goal of this project is studying the educational significance of the history of physics by leveraging on the collections of scientific instruments preserved by the Museum of Physics and by the former Physics Cabinets of a selected sample of old secondary schools in northwestern Italy.

Background

The historical collections preserved by University-based physics museums are usually made of instruments originally acquired for teaching *and* research. Yet, the sad state of affairs of most of these collections is that these instruments are by and large unused *neither* in research (a wholly understandable thing) *nor* in teaching (and this is far less understandable). This state of affairs is made even more sad by the growing awareness in the science education community of the science education functions of science museums (Falomo Bernarduzzi et al. 2014, Filippoupoliti et al. 2014, Heering 2017) as well as of the advantages of introducing history of science topics into the teaching of science (Leone 2014, Matthews 2015).

In 2017, to partially reverse this state of affairs, the Museum of Physics of the University of Turin, Italy, launched a collaborative effort with a significant sample of secondary schools in Turin and Cuneo provinces, in northwestern Italy. It is our hope that this ongoing effort will serve as a catalyst to the rescue, preservation and diffusion of the scientific heritage and can play a seminal role in transforming dusty and directionless sets of display cabinets into tools of education.

The Museum of Physics of the University of Turin, Italy

The Museum of Physics of the University of Turin was established in 2009 to preserve the collection of scientific instruments of the former Physics Cabinet of the University. Since 2017 the museum belongs to the University of Turin Museum System (SMA) and recently participated to a microclimatic study aimed at assessing the microclimatic quality of its main exhibition hall (Ferrarese et al 2018).

As in most historical collections preserved by University-based physics museums, part of its instruments was originally acquired for teaching purposes while part of them were actual research devices (Galante et al 2008, Rinaudo et al 2018). The origin of the Cabinet

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collection of the University of Turin dates back to the early 1700s, under the professorships of the Cartesian Fathers J. Rome (1720-1732) and F. Garro (1732-1748). A significant contribution to the collection occurred in 1739 when the noted French physicist Abbé Nollet donated a large collection of physics instruments to Charles Emmanuel III, King of Sardinia who, in turn, gave them to the University. In the second half of the eighteenth century a major renovation in the physics research at the University of Turin, most notably in the field of electricity studies, occurred when Father G.B. Beccaria took over the chair of physics (1748-1781). The largest part of collection, however, dates back to the nineteenth century, especially under the professorships of G.D. Botto (1826-1855), G. Govi (1861-1878) and A. Naccari (1878-1916). Although part of the instruments was acquired from well-known foreign instruments makers, like Ruhmkorff or Duboscq, a significant number of them were built by Italian instrument makers and most notably by E.F. Jest and C. Jest who, besides having a reputation of skilled craftsmen, were the official instrument makers of the University of Turin. The instruments now preserved by the Museum are over 1000 and are mainly devoted to the subjects of electricity and magnetism as a result of the special attention paid by the eighteenth and nineteenth century physicists in Turin toward those emerging fields. About 45% of the collection is exhibited in 23 showcases along the corridors of the ground and 1st floor and in 23 showcases in the Wataghin Hall.

Census of the school collections

The collaborative effort between Museum of Physics and schools started with a census of the collections of physics instrument of historical-scientific interest preserved by the most ancient public and private secondary schools in the selected provinces (Rinaudo et al 2017). Out of this sample we have so far identified 17 nineteenth century classical lyceums and gymnasiums preserving significant collections of scientific instruments that were formerly part of the old Cabinets of Physics (Figure 1-2).

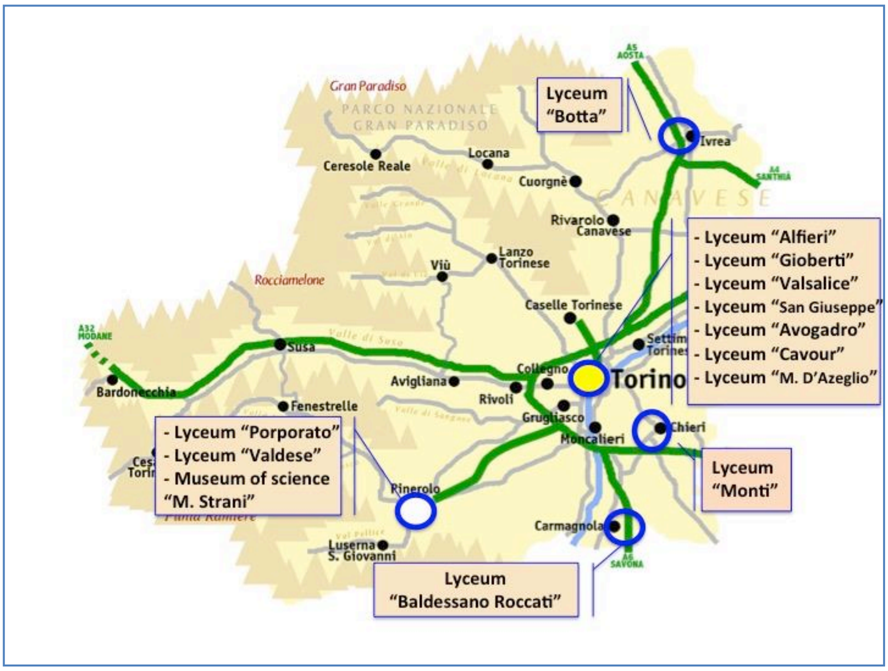

Figure 1. Classical lyceums surveyed in the Turin province

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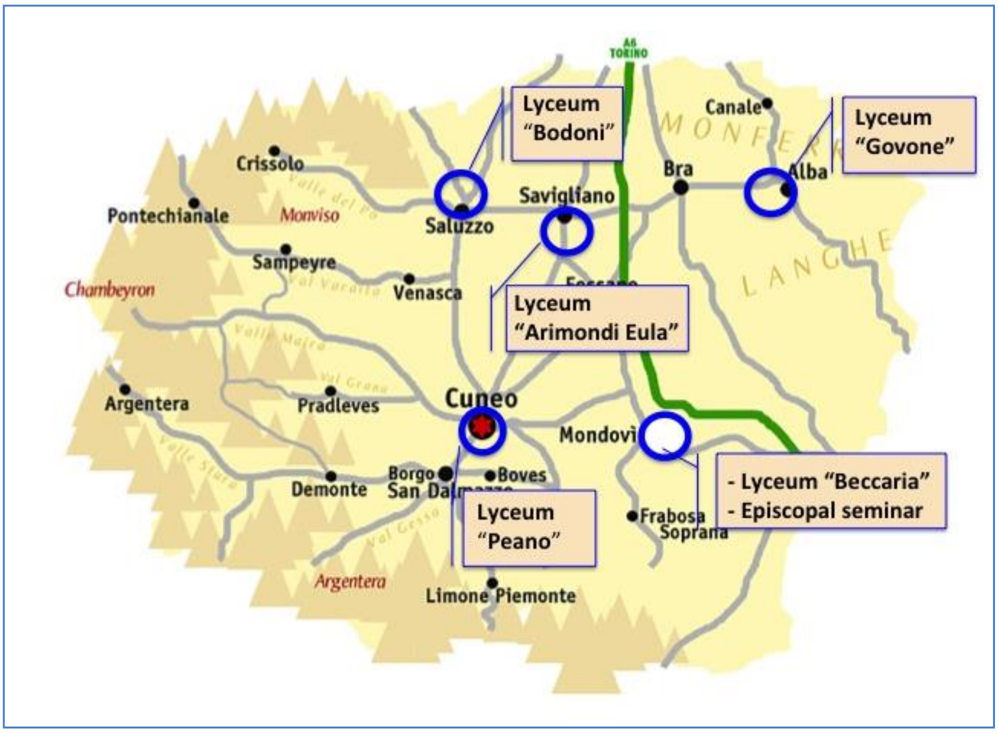

Figure 2. Classical lyceums surveyed in the Cuneo province

These collections are very diversified in terms of size, state of conservation and degree of cataloguing and actual use for educational purposes. We have found indeed that the school collections can be classed into four classes according to their degree of organization and maintenance:

1. instruments stored in boxes in school closets and no longer used (e.g. Lyceum Baldessano Roccati, Carmagnola and Lyceum Sociale, Turin)
2. instruments stacked in furniture or shelves in the laboratory (e.g. Lyceum Alfieri, Turin)
3. instruments in part exposed in showcases and sometimes shown during lessons (e.g. the very rich collection of Lyceum Govone in Alba, whose instruments are in part displayed in showcases along the corridors of the school and in part are shown to the students during the physics labs)
4. real school museum, open to visitors, at fixed times (notable examples of this class are the MuBec, the Beccaria Museum within the Lyceum Vasco-Beccaria-Govone in Mondovì (Fig. 3), and the Museum of Natural History "Don Bosco" in the Lyceum Valsalice, Turin)

As regards the degree of cataloguing of the surveyed collections, a varied landscape emerges, ranging from poor or non-existent records about the instruments (e.g. Lyceum Valsalice) to full cataloguing of the holdings (e.g. MuBec, Mondovì).

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Figure 3. Beccaria's frictional electrical machine
preserved by the Beccaria Museum in Mondovì

Though the quantitative analysis of the collections surveyed is still ongoing, this census has highlighted a number of very interesting issues, not least of which are the relationships between these collections and the collection held by the Museum of Physics, University of Turin. A case in point is the spread throughout the surveyed schools of instruments made by E.F. Jest and C. Jest who, besides having a reputation of skilled craftsmen, were the official instrument makers of the University of Turin. Another case in point is the identification of instruments formerly owned by one of the "fathers" of experimental physics in Turin, G.B. Beccaria, who, in the second half of the eighteenth century, was responsible of a major renovation in the physics research at the University of Turin through significant contributions to the study of the properties of electricity. Interestingly, though Beccaria held the chair of physics and though the old inventory of the former Cabinet of Physics of the University lists a number of 1700s frictional electrical machines, the Museum of Physics of the University is conspicuous by its lack of any of these instruments. However, it was encouraging to find out that a fine example of Beccaria's frictional electrical machine is preserved by the one of school collections surveyed by us.

Changing dusty collections into tools of education: analysis of a case-study

Once the main school collections of historical-scientific interest have been identified, we have been focusing on some of these collections with the goal of studying their specific educational significance. An interesting case-study is represented by the Gioberti Lyceum in Turin, since this school meets three essential conditions: (1) it hosts a large collection of physics instruments of historical-scientific interest, (2) it houses a large historical archive still preserving the inventories of the old Physics Cabinet and the mandates of payment for the purchased instruments, and (3) it is peopled by many teachers actively engaged in training seminars in physics education organized by the University of Turin (Henke at al. 2015, Höttecke et al. 2011).

The main targets of the project pursued at Gioberti Lyceum are: compiling a census of the collections of the instruments of historical-scientific interest preserved by the school and selecting the most significant instruments in the fields of fluids and electricity, chosen according to their historical, educational and aesthetic significance; studying students' prior knowledge through the administration of questionnaires designed according to the historical development of physics; designing experimental activities rooted in the history of physics and in the historical development of the selected instruments preserved by the school, and, finally, testing the efficacy of these activities. The project carried out at the Gioberti Lyceum, and in part at the Museum of Physics of the University, involved a sample of 188 grade-12 and grade-13 students. A subset of 45 grade-13 Gioberti students participated to the whole set of activities below discussed.

1.Blowing the dust away from the collection

The origin of Gioberti Lyceum dates back to 1822 when it was called "Collegio San Francesco da Paola". The scientific collection of the physics laboratory includes more than 1200 instruments mainly of electromagnetism, mechanics and optics. A significant portion of this collection was part of the former Physics Cabinet of the Lyceum. From the analysis of the oldest inventories we managed to exactly date about 400 instruments (169 instruments prior to 1870, 45 purchased between 1870 and 1900 and 134 dating back to the first half of the 20th century).

Most of the instruments are of French construction (e.g. manufactured by the builder A. Loiseau, Paris) and one single, but significant, item (a battery of Leiden jars) was manufactured by Jest (see section 3 above). The oldest part of the scientific collection is made of instruments of thermology, fluids and electrostatics (Figure 4).

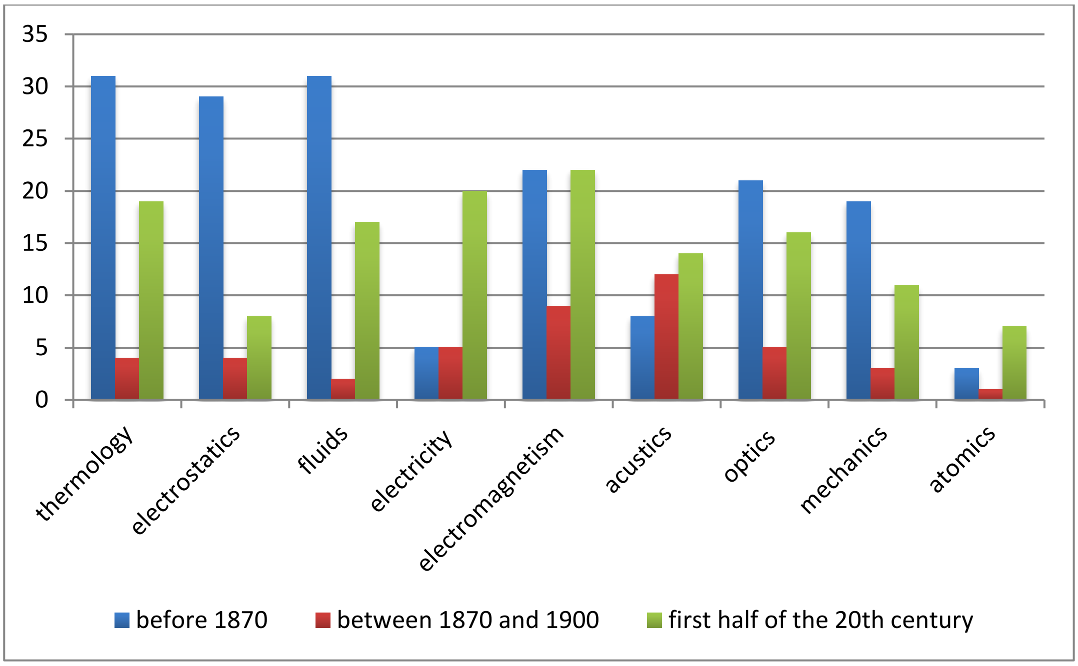

Figure 4. Classification of instruments identified in the oldest inventories

2.Discovering students' prior knowledge with an eye on the history of physics

As discussed above, the activities at the Gioberti Lyceum concerned topics and scientific instruments in the fields of fluids and electricity. In the following, we focus our attention on the activities in the domain of electrostatics, usually addressed in grade-13 of the Italian Classical Lyceum curriculum (Miur 2010).

In order to explore the educational power of the history of physics as a tool to anticipate students' prior knowledge we administered a specially designed questionnaire. Most items of the questionnaire were designed on the basis of the historical evolution of electricity studies with the goal of understanding if the possible difficulties experienced by students are historically rooted. In the questionnaire are indeed explored student's prior knowledge about subjects like:

- the universal validity of the third Newton's law, i.e. also to the case of rubbing plastic rods (e.g. early fathers of electrostatics like G. Cardano and W. Gilbert, XVI century, believed that "amber is not attracted in turn by a straw") (Cardano 1550/2013);

- rubbing vs. heating as the actual cause of the attraction in rubbing experiments (for Gilbert "amber does not attract by heat", however he did not discard the idea that the heat produced by friction is a relevant factor to obtain attraction) (Gilbert 1600/1893);

- the air as the agent responsible for the attraction/repulsion electrostatic effects (as it was argued by the Jesuit natural philosopher N. Cabeo) (Cabeo 1629);

- the electrification as a phenomenon involving the space surrounding the rubbed object (e.g. Nollet 1749);

- the principle of charge conservation (Roller et al.1954).

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The above subjects were addressed by proposing to students two experimental situations. By way of example, in one of these situations, a plastic rod is repeatedly rubbed with a wool cloth; after approaching the rod to some paper bits we notice that the bits stick to the rod (Figure 5). This problematic situation is followed by a number of statements about whom the student has to express his agreement or disagreement (true/false) and explain the reasons for his answer. Interestingly, 69% of the sample of Gioberti students who participated to all the activities (size 45 students) answered that, as it was believed by Gilbert, *the attraction of the paper is caused by the heat produced by friction*. Most of the students who expressed and agreement with this view motivated their answer with various reasons (e.g. according to these students the heat produced by friction "increases/causes attraction", "produces energy", "creates/produces electric charge", "alters the electronic configuration").

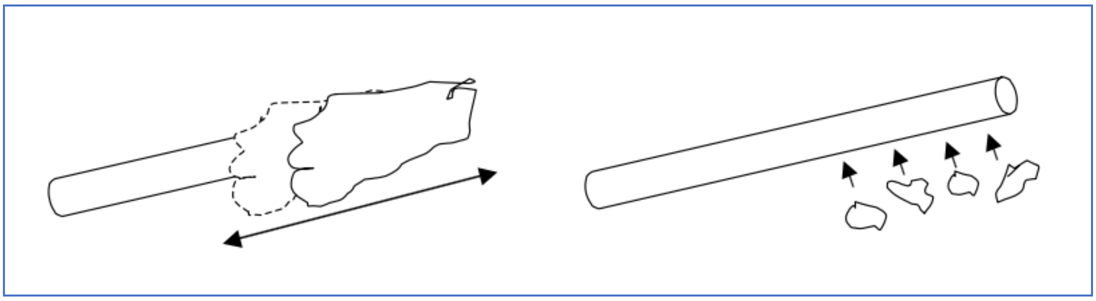

Figure 5. First item of the questionnaire on the electrification by rubbing

3.Promoting the learning of subject contents

After administering the pre-test, an historical introduction followed. During this phase, the students explored the old collection of scientific instruments preserved by the school, with a particular attention for the electrostatics devices. Then, the students experienced the evidence gathered in the early years of electrostatics, when by sensitive instruments like Gilbert's *versorium* (a sort of ante-litteram electroscope consisting of a metallic needle allowed to pivot freely on a pedestal, like a compass needle) the scientists started to systematically study which materials are "electrics", i.e. are electrified by rubbing and which are "non-electrics". Gioberti's students built their own versoriums with cheap and common-use materials (cork stopper, paper clip and sample holder) and used them to make their own first qualitative observations of electrification by rubbing.

The activities continued with the construction of other instruments inspired by the local collection: an electroscope (during this phase the students explored the different behavior of conducting and non-conduction materials) and a Leiden jar (by means of plastic cups and aluminum foils). In subsequent lessons, the teachers addressed again the topics and methods touched in the previous phase.

At the end of these activities, a post-test identical to the pre-test was administered to the students. Interestingly, while 69% of the students agreed in the pre-test with the statement "*the attraction of the paper is caused by the heating produced by rubbing*", only 16% of them still agreed with this view after the experimental activity and after having dealt with the teaching unit on electrification.

Another experimental situation posed to the students evidenced a significant progress between pre-test and post-test. In this situation, a rubbed plastic rod is put close to a small ball of elderwood hanging on a cotton thread (i.e. a device like the many XVIII century electrostatics pendulums displayed in the Museum of Physics). As a consequence of this, the ball approaches the rod, touching it and then moving away. The administered pre-test proposed, among others, the hypothesis that "the ball is approaching because it is pushed by the air that tends to move towards the bar due to the effect that rubbing has produced around the bar" (see Cabeo's hypothesis in section 4.2): as much as 29% of the students answered "true" to this hypothesis in the pre-test while almost no students answered in this way in the post-test.

However, this approach has not always proved effective. An emblematic example of this is provided by the results concerning the statement "*the pieces of paper exert an attraction towards the bar*": about 87% of the sample answered negatively to this item both in the pre-test and in the post-test, thus emphasizing the well-known difficulties posed by Newton's 3rd law.

Conclusions

Based on the findings of this case-study several conclusions can be drawn. First, as regards history in the narrow sense, by the analysis of the inventories it was possible to obtain previously unavailable information on the dating of part of the instruments of one of the most significant collections of scientific instruments preserved by schools in northwestern Italy. Of particular interest is the fact that a large number of Gioberti Lyceum instruments dates back to 150 years (or more) ago. Besides this, previously unknown additional information (e.g. on manufacturers and on the cost of the instruments).

A second set of conclusions concerns the educational significance of the history of physics. In this regard, the analysis of the administered questionnaires emphasizes that a number of misconceptions of the students concerning electrification by rubbing (e.g. the roles of *heat* and *air*) can be anticipated by drawing on the early history of the researches on electricity. Furthermore, a significant learning on several subject contents was evidenced by the post-test questionnaires.

The seven Gioberti Lyceum teachers that participated to this project expressed a positive opinion on the historical approach adopted here, both as regards the understanding of the topics and as regards the students' interest. In particular, the average level of agreement on the statement that the historical approach is useful to motivate students turned out to be 4.7 on a 1 to 5 Likert scale (where 1 is complete disagreement and 5 is perfect agreement). This positive outcome was shared by the 188 students participating to the project and to whom it was administered a final satisfaction questionnaire. On the whole, the students concluded indeed that the activities were interesting (3.9 on a 1 to 5 Likert scale) and that the adopted historical methodology was effective (3.7).

In short, we are of the opinion that this case-study shows that it is possible to successfully transform a dusty collection of scientific instruments into a tool of education.

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References

Cabeo, N. (1629). *Philosophia Magnetica*. Ferrara: Franciscus Succhi.

Cardano, G. (1550/2013). *De Subtilitate*. Nuremberg: Petreius. English translation: *The De Subtilitate of Girolamo Cardano* (ed. J.M. Forrester). Tempe: ACMRS.

Falomo Bernarduzzi, L., Albanesi, G., Bevilacqua, F. (2014). Museum Heroes All: The Pavia Approach to School-Science Museum Interaction. *Science & Education*, *23,* 762-780.

Ferrarese, S., Bertoni, D., Dentis, V., Gena, L., Leone, M., Rinaudo, M. (2018). Microclimatic analysis in the Museum of Physics, University of Turin, Italy: a case study. *European Physical Journal Plus*, 133, 538.

Filippoupoliti, A., Koliopoulos, D. (2014). Informal and Non-formal Education: An Outline of History of Science in Museums. *Science & Education*, 23, 781-791.

Gilbert, W. (1600/1893). *De Magnete*. London: Peter Short. English translation: *On the loadstone and magnetic bodies*. New York: Wiley & Sons.

Heering, P. (2017). Science Museums and Science Education. *Isis,* 108(2), 399-406.

Henke, A., Höttecke, D. (2015). Physics Teachers' Challenges in Using History and Philosophy of Science in Teaching, *Science & Education, 24,* 349-385.

Höttecke, D., Silva, C. (2011). Why Implementing History and Philosophy in School Science Education is a Challenge: An Analysis of Obstacles. *Science & Education*, 20, 293-316.

Leone, M. (2014). History of Physics as a Tool to Detect the Conceptual Difficulties Experienced by Students: The Case of Simple Electric Circuits in Primary Education. *Science & Education*, *23,* 923-953.

Matthews, M. (2015). Science Teaching: The Contribution of History and Philosophy of Science (20th Anniversary Revised and Expanded Edition). New York: Routledge.

Nollet, J.A. (1749). *Recherches sur les causes particulières des phénomènes électriques*. Paris: Guérin.

Rinaudo, M., Leone, M., Marocchi, D., Amoroso, A. (2017). The dust catcher: discovering the educational value of the historical scientific heritage. In: GIREP-ICPE-EPEC 2017. *Book of Abstract.* Dublin.

Rinaudo, M., Leone, M., Marocchi,D., Amoroso, A.(2018). Il Museo: strumento di didattica della fisica?. In R. Bonino et al (eds.), *Matematica e fisica nelle istituzioni* (DIFIMA 2017).

Roller, D. and Roller, D.H.D. (1954). *The Development of the Concept of Electric Charge*. Cambridge: Harvard University Press.

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