The process of determining an educational research in the technological field understood as a complex and adaptive system: D-BOX as a case study

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Abstract

This work describes an educational activity that was carried out by the research group that designed D-BOX for the students of the course of Educational Technologies for Inclusion, at the University of Sannio at Benevento in the Academic Year 2020- 21. This teaching activity is aimed at stimulating students' interest in research activities conducted in the academic field. This experience was a first attempt to quickly and intuitively introduce two elements necessary to carry out scientific research: the awareness and intentionality of the researcher during all the phases that make up the process of formulating and verifying the hypotheses that are taken into account.

Keywords

Didactic technologies, university teaching, experimentation, learning by doing, OECD-PISA data, INVALSI tests.

1. Introduction

A fundamental encounter between pragmatism and didactics became concrete at the beginning of the twentieth century, when John Dewey revolutionized the educational approach at US schools, placing the learner's experience at the center of the didactic action. Franco Cambi (2016) argues that the American philosopher and politician was moved by an "instrumentalism" that deeply associated two elements: reason and practice, which together led to the formulation of a new didactic activity to be carried out in the classroom of an operational nature, which was at the same time scientific, educational, political, as well as strongly related to the work and social reality that surrounded teachers and students. Starting from this assumption that takes into account the Deweynian perspective of education, the process of determination, of a good educational practice, could be understood as a complex and adaptive system [1][2][3][4] which, in a continuous cycle of action (theoretical choice of practice) and retraction (verification of results), determines whether it can be validated or refuted. This determination process is reminiscent of a bottom-up research model, in fact the theoretical choice expressed in the system, in the reflection / selection block (see figure 1), starting from its first cycle, evaluates a practice and not

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an abstract model of education. Conversely, in the top-down research model, abstract constructs are declined in daily teaching practice. The risk factor of adopting a top-down research model is the introduction of bias resulting from abstract, idealized or simply unfeasible educational approaches.

The feedback block has the purpose of guaranteeing to the system a mechanism suitable for correcting and regulating the practice in question, so that it is possible to determine whether it is convenient or not, to proceed with new experiments that would require more time and possible financial financing. This systemic feedback must therefore be based on the scientific method. The final purpose is to make the results obtained (after an appropriate number of feedback cycles) known to the academic and school community, which will make the results stable and generalizable. However, there are numerous cases of pilot studies, which, although not satisfying the generalization criterion, may have a certain degree of interest in the academic community to activate further investigations in a specific area of research that is still little studied.

As is known, the scientific method (especially in hard sciences) promotes the collection of quantitative data of an empirical nature that allow us to evaluate the phenomena under consideration. Today, it is increasingly "supported" by data retrieval and data mining computer systems and can make use of numerous technological tools to ensure both information storage and statistical analysis. Returning now the focus to the specific case of didactic research and the retroactive system presented in this paragraph, how is it possible to define whether the practice in question has achieved a certain degree of success? Surely, this fundamental question can be addressed by relating the practice in question with a predefined threshold (threshold value), based on the convergence of the data collected with respect to official data (ISTAT, INVALSI, OCSE-PISA, UN, UNESCO, WHO, etc.) that evaluate situations comparable with those relating to the case in question. If this convergence does not take place, elements of contradiction will emerge and in the next phase of reflection / selection the practice will be rejected.

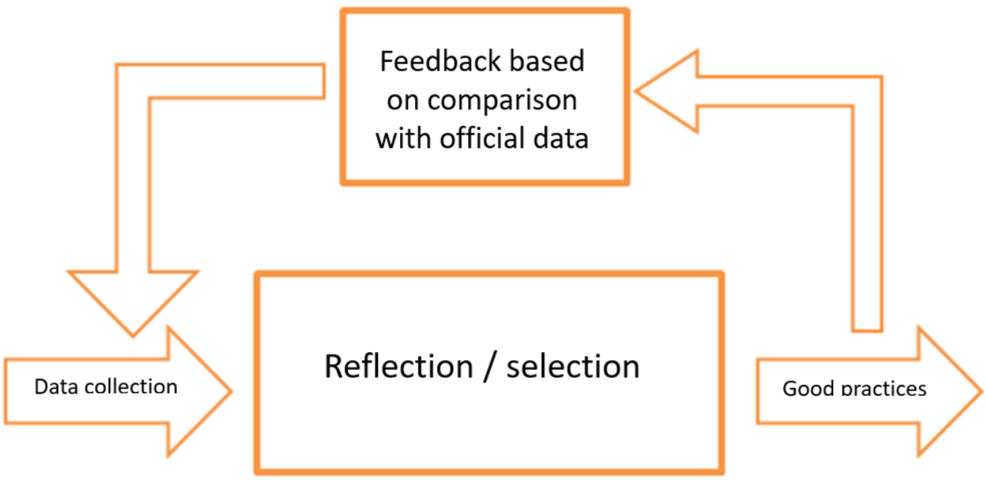

Figure 1: Process of determining a practice based on a two-block system with closed-loop feedback.

In the scientific investigation, conducted according to the terms indicated above, even discarding a practice has a highly symbolic value and involves the aptitude to put aside those personal factors that had selected it from among the many that can be investigated. In a certain sense, this design vision allows us to process the error to direct subsequent choices without the failure emotionally charging the researcher with a sense of frustration or inadequacy. The error must be elaborated to direct future actions, vary the research hypotheses, take a healthy detachment from a propensity for scientific positivism and avoid unnecessarily consuming the resources at one's disposal in economic and temporal terms. If up to now, the process of determining a good educational practice has been described, in terms of a complex and adaptive system, in a generic way, now it will be declined, by way of example, on D-

BOX [5][6]a case study. Specifically, an activity will be presented that was proposed by one of the researchers who designed D-BOX to the students of the course of Educational Technologies for Inclusion, at the University of Sannio di Benevento in the Academic Year 2020- 21, aimed at stimulating their interest in research activities conducted in the academic field and taking into consideration this possible adaptive systemic model.

The case studied and shared with the students concerns D-BOX, a project developed by Laboratory H of the Department of Human, Philosophical and Educational Sciences (DISUFF) of the University of Salerno, aimed at promoting the teaching-learning process of powers of number 2 and binary code, the reference system used as threshold included the INVALSI and OECD-PISA tests (which will be detailed below). University students were personally involved in actively participating by reproducing: 1) the study of the functioning mechanism of the artifact; 2) the use of this artifact among relatives and acquaintances to understand the problems that the researchers had also encountered; 3) the verification and comparison of their results with those proposed by the researchers in order to analyze together any differences. In this way, this exercise presented during a lesson in the course of Educational Technologies for Inclusion has contributed, albeit to a small extent, to the much desired research training reserved for university students through their direct involvement in an experiment that actually took place. Thirty-two university students were involved, a certainly small number because the course did not have compulsory attendance and was held online due to the prolonged health emergency due to COVID-19. Of the thirty-two students, five carefully reproduced the experimentation both in the family and with subjects who had the same age range as the students examined in the experimentation carried out by the researchers at the "G. Rodari ”of Perugia.

2. Going beyond habits: using numbers in binary representation to promote digital skills

The aim of the following paragraph is to analyze the context within which the initial experimentation, proposed to a group of university students, took place; recalling that it falls within the sphere of educational research relating to educational technologies.

According to the Ministry of Education, the school must promote "education to act consciously, this strategy allows you to learn how to deal with situations in an analytical way, breaking them down into the various aspects that characterize them and planning the most suitable solutions for each" [7] indeed, the various strategies implemented, to find solutions, must be shared as much as possible to ensure that a common path is traced to overcome the crisis and promote full inclusion. To define itself as inclusive, a school must have the following characteristics: 1) consider the availability of teachers towards all pupils [8]; 2) promote "a constructive climate for learning and the well-being of all students" [9]; 3) recognize and enhance individual skills and devise "training courses capable of responding to the needs of individual subjects" [10]; 4) propose a positive vision of the future of pupils as in the case of the lucky metaphor of education as "cultivation", in which young people are like plants that will become trees and bear fruit [11]; 5) pursue the goal of supporting a "school of differences" [12], which does not want to standardize but to enhance each student and each teacher in their uniqueness.

This inclusive school must be able to ensure quality and accessibility to each learner "along the entire educational path and at the same time protecting all diversity [...], in essence, the existence of particular needs is not denied, which for some students are really very special " [7]. School inclusion, therefore, represents a process that welcomes each student to "address the differences in school, classroom and programming" [13] and therefore aims at the formation of an adequate and age-calibrated curriculum of the learners. This process must go hand in hand with the training of teachers [13] capable of using technologies as innovative and inclusive teaching tools [14]. The importance of focusing on school inclusion is very relevant after the year that has just ended, in fact, in the new era of "health" globalization, digital is a "common language" that becomes a form of "thinking" "Capable of aggregating individuals from different socio-economic and cultural realities and, at the same time, capable of uniting heterogeneous groups of students as required by the European Agency for Development in Special Needs Education (2012, p.16). Consequently, it is possible to proceed, on the path already carved by the hypertext programming language and the World Wide Web, in the last two decades and in the previous centuries by the mathematical language developed in the Middle East. Specifically, from the first conception of mathematical algorithms proposed by Al-Khwarizmi (http://www.ms.uky.edu/~carl/ma330/project2/al-khwa21.html), which developed his work in the eighth century A.D. and contributed to creating an important trait d'union between European, Arab and Indian thought. As highlighted by Tahar Ben Jelloun (2001), in the short essay he dedicated to the younger generations, mathematics also served to create fruitful relationships between different cultures.

Computational thinking, therefore, turns out to be fundamental both for students who would like to pursue a career as computer scientists and for all of us, as argued by Jeannette M. Wing (2006) Avanessians Director of the Data Science Institute at Columbia University, in fact, it should be placed on the same level as reading, writing and arithmetic. Incidentally, the Ministry of Education also clearly states that the mother tongue and mathematics are united by logical and computational thinking [7] which, in the context of Italian, appears to materialize, among other things , in the "valential grammar" and, as far as mathematics is concerned, it can be traced back to the capacity for abstraction [16][17] and to go beyond our habits, such as "to use the numbers in the decimal representation, because our fingers, which constitute the most immediate counting tool, are precisely ten " [18]. Indeed, the term "computational thinking" [19] aims to affirm the following thesis: the logic underlying the programming of electronic devices is able to favor the development of procedural thinking and allows children to use an additional tool for the construction of knowledge already from primary school [20]. More in detail, as Wing (2006) points out, computational "methods and models" give us the "courage" to solve problems with another approach and from another perspective [20].

3. Some relevant results for the experimentation of the traits of national and international surveys concerning mathematics

As stated, in this experimentation we will deal with a particular aspect of computational thinking, understood as "a mental process that allows you to solve problems of various kinds following specific methods and tools, planning a strategy" [7]; a skill that has never before become fundamental for future citizens, as emerged from a crisis (the COVID-19 pandemic spread globally) that requires sophisticated computer tools and numerical processing [21] for the treatment of medical, economic, financial data but also related to the field of educational research. Indeed, the main characteristics of computational thinking, namely the resolution of problems, the design of systems and the understanding of human behavior, previously listed by Wing (2006), are fundamental for the challenges that the current crisis forces us to bear; therefore, only a conscious use of the machines and the algorithms underlying them can increase the chances of overcoming the succession of financial crises (the bubble of the new economy and the great recession of 2009) and health crises (SARS, COVID -19), which have attacked practically the whole world. It is desirable that computational thinking will favor the rational use of our planet's resources and will favor the implementation of the 2030 Agenda [22] action program for sustainable development. Below, to monitor the performance of Italian students, with regard to the subject in question, it is possible to investigate the results of national and international surveys concerning mathematics and the sciences that are the most similar to computational thinking.

4. The results of the OECD-PISA survey in mathematics and science tests

Analyzing the trend of the last two decades, it cannot be denied that the preparation in mathematics and science is having a negative trend, as stated by the 2018 data of the OECD-PISA tests, relating to 11,785 Italian 15-year-old students who are partly the result of what was done in primary school by the same students in the previous decade. In detail, in Italy "about 24% of our 15-year-old students have not reached Level 2, the basic level of competence in mathematics (OECD average 22%), while about 10% are in levels of excellence 5 and 6 (average OECD 11%) [e] 3 out of 4 students demonstrate at least the basic level of scientific competence (level 2) and 2.7% of the students are top performers (Levels 5 and 6) " [23].

Table 1
Trends in mathematics and science. Source: adapted from INVALSI elaboration on OECD-PISA 2018 database (INVALSI, 2019, p.11).

Year	2003	2006	2009	2012	2015	2018
Mathematics (average score)	466 ↓	462 ↑	483 ↑	485 ↑	490 ↓	487
Science (average score)	-	475 ↑	489 ↑	494 ↓	481 ↓	468

Table 1 shows the trends in the scores obtained by students and the up and down arrows indicate an improvement or a worsening of the average score obtained. Unfortunately, from 2015 to date there has been a negative decline in both mathematics and science. In the next sub-paragraph the situation in primary school will be analyzed, remembering that D-BOX is mainly designed for this school order in which the conditions for each discipline are created.

5. The results of the INVALSI tests for the fifth grade of primary school regarding mathematical powers

In the INVALSI tests in mathematics for the second grade of primary school, the questions are classified into three areas: 1) Numbers; 2) Space and figures; 3) Data and forecasts. In the list proposed by INVALSI (2014) the conceptual nodes around which the tests are built are clearly explained and among them the concept of the mathematical power of the number 10 (ibidem) clearly appears. Furthermore, in the Guide to reading the INVALSI Mathematics Test (2019) for the fifth grade of primary school, in the "table of the subdivision of items in relation to areas and goals" the concept of powers, no longer referring only to those of 10, falls under the heading: "recognizes and uses different representations of mathematical objects (decimal numbers, fractions, percentages, reduction scales)" [23]. In particular, in the two figures of this sub-paragraph there are some questions that deal, the first indirectly and the second directly, the concept of powers of the number 2 (Fig. 2; Fig. 3). Note that in the INVALSI tests, for primary school, there are no questions directly attributable to binary numbers.

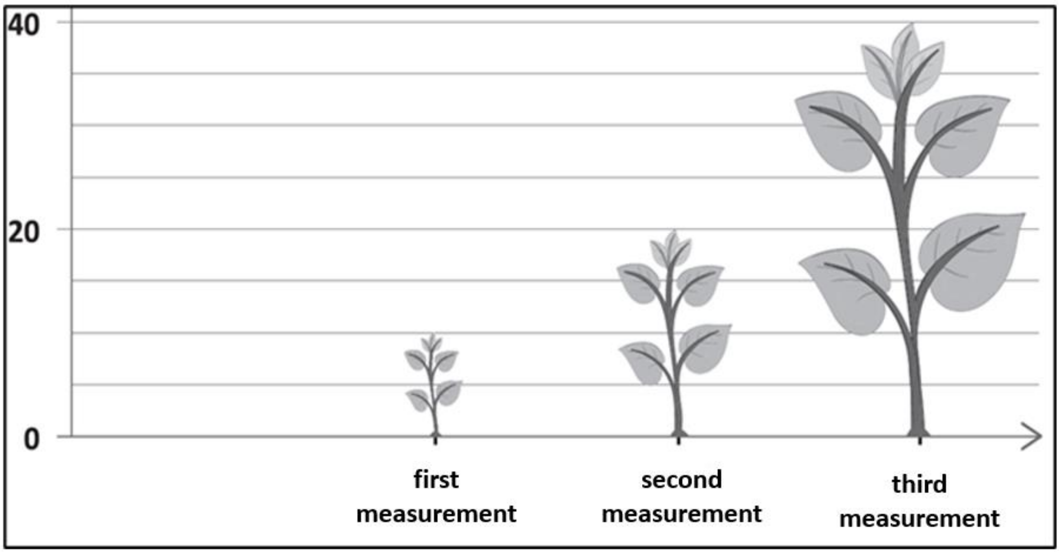

Figure 2: INVALSI test in mathematics for the fifth grade of 2018-19, question D.23, page 16. The test shows the growth of a seedling as a power in the number 2 and the candidate is asked to calculate the numerical value related to the growth between the first and the second measurement.

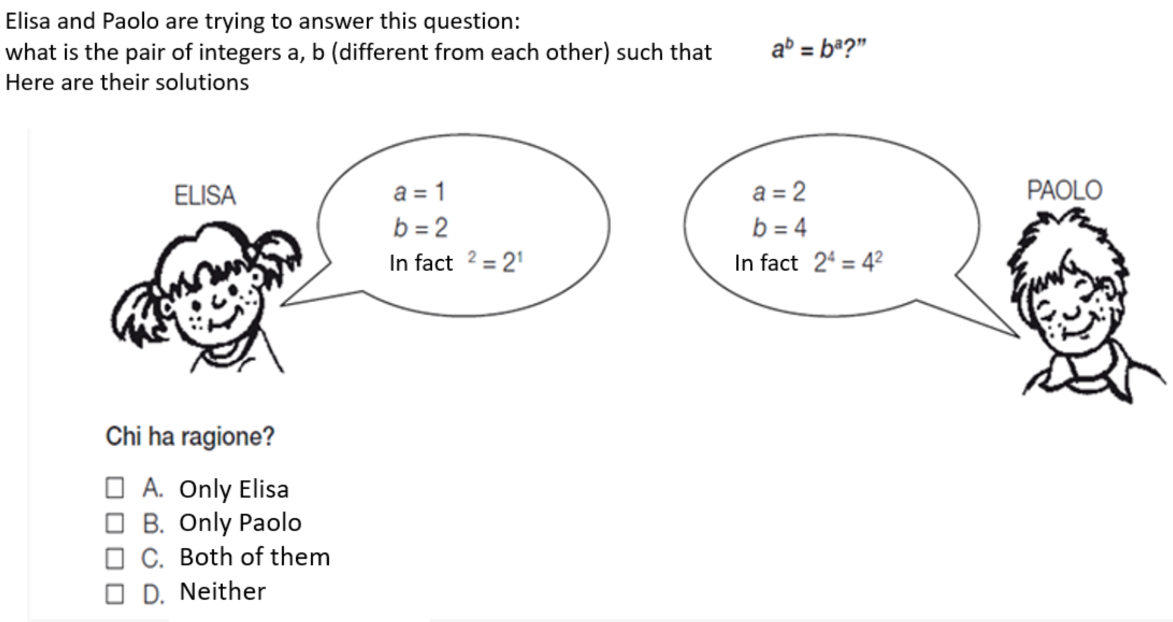

Figure 3: Question of the national INVALSI 2011 test, D18, correct answer B, percentage correct answers 63.9%, wrong answers 35.4%, m.r. 0.7%.
Readapt: The five hardest math questions + 19 to ask in class. By Stefania Pozio, first INVALSI researcher (INVALSI, 2017, p.95)

6. The experimentation of D-Box conducted in the primary school of Perugia

In this work we intend to describe the experimentation of the D-Box project, an educational game aimed at favoring the teaching-learning process of the binary code and the powers of 2, which took place in November 2020 at the "G. Rodari "of Perugia. The class in which the experimentation was carried out adopted the text by D'Amore and Pinilla (2019), in which exercises on mathematical powers were proposed. In the international scientific literature [24][25][26] the need has emerged to implement the concept of mathematical powers in the school program of the fifth grade of primary school and for this reason the game of D has been proposed. -Box to encourage learning of the powers of 2. The idea of designing the European D-Box game arises from the need to strengthen citizens' digital and mathematical skills through a playful approach.

7. D-Box design and operation

The European Recommendations make it clear that the basis of learning digital skills is the knowledge of the binary code, also highlighting the importance of learning by doing [27]. The didactic game D-Box, in fact, adopts a constructionist approach [28] placing the student at the center of their learning process and promoting the knowledge of the binary code in primary school. Specifically, the D-BOX structure is made up of eight pallets, fifteen marbles and four platforms. The four platforms are joined together to form a single structure with a staircase and slides to slide the marbles. Each platform represents a power of the number 2, in which there are recesses that house the marbles to create a decimal number to be converted into a binary number. At the base of the D-Box structure there are bases and paddles that allow the player to indicate the binary number calculated based on the arrangement of the marbles on the individual platforms [5].

The D-Box educational game was designed using the Rhinoceros CAD software (Fig. 3) and physically created with the Prusa MK3S 3D printer using PLA (polylactic acid) as a material. The 3D printer is a technology that has been shown to be beneficial in education, as it can foster cooperation between students who are committed to achieving a common goal. The D-Box game becomes "an object to think with" [29] and stimulate pupils to study scientific subjects.

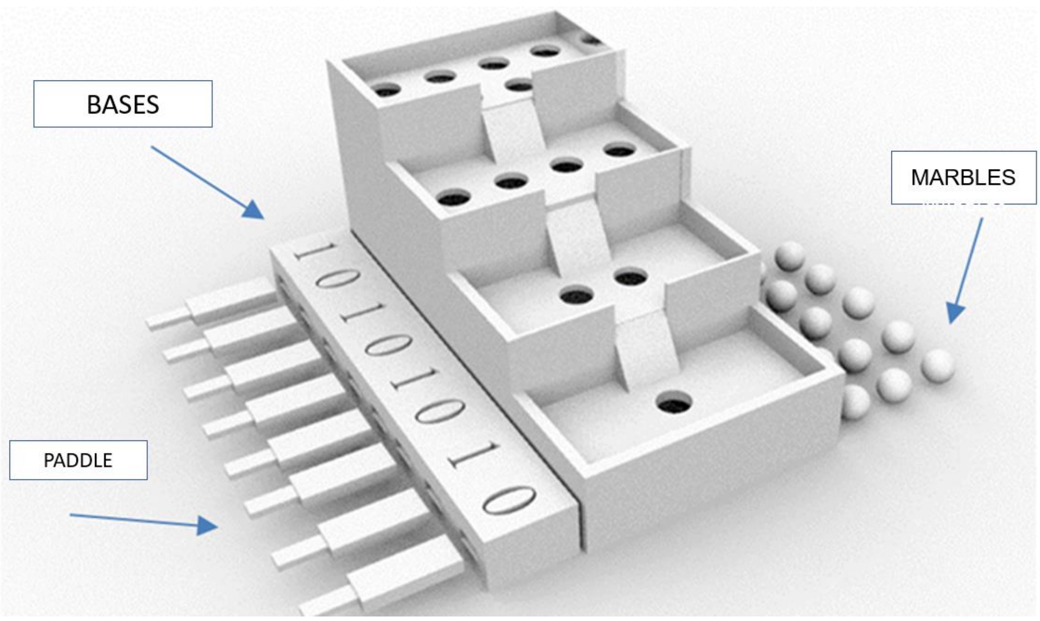

Figure 4: 3D model of the D-BOX game

8. Preliminary data from the experimentation of D-Box in primary school

In November, of the 2020-2021 school year, a first experimentation was carried out in a fifth class of the "G. Rodari ”of Perugia. The research was carried out in several phases and the data were collected through the administration of two final questionnaires: the first was addressed to the teacher of the class where the experimentation took place and the second to her pupils, the latter necessary to understand whether the pupils enjoyed the activity and to evaluate their actual acquisition of the ability to convert binary numbers [6].The analysis of the questionnaire addressed to the teacher produced a series of positive reflections, as the teacher highlighted how the playful element of D-Box allows greater involvement than normal logical-mathematical activities. Furthermore, it was highlighted that all the students, thanks to the materialization of the numerical quantity, understood the concept of the power of a number. Finally, in the questionnaire there was a SWOT analysis to estimate the strengths and Weaknesses, the opportunities (Opportunities) and the risks (Threats) of the didactic game. As regards the verification carried out by the fifteen students, in which the level of satisfaction and the perception of difficulties in applying the rules were also considered, it emerged that most of the students learned the decimal-binary conversion through the use by D-Box [6]. Therefore, the D-Box game seems to favor inclusive teaching and, in this specific case, the knowledge of binary code.

9. Conclusions

The following work proposed a reflection on the importance of designing university teaching activities aimed at promoting the teaching-learning process of scientific research methodology through the use of examples and case studies. The basic idea is to use a learning by doing approach that takes into account the stimulus offered by a teacher to act through meaningful experiences, typical of the pedagogical activism proposed by Dewey. In this specific case, the experience proposed in class is a first attempt to introduce, in a quick and intuitive way, two essential elements for carrying out a research: the awareness and intentionality of the researcher (in this case the role played by the students students present in class), during all the phases that make up the process of formulating and verifying the hypotheses taken into consideration. In this context, only one research model has been applied and some scholars may not appreciate this way of conducting an investigation. However, the effort to safeguard the multiplicity of models to be adopted in humanistic scientific research is a problem carefully discussed by Rogers and Hanna [30]. Therefore, a brief explanation of what has just been stated is proposed below. This effort, mentioned above, "is of fundamental importance for man because it saves his specificity of being [precisely] conscious and intentional [...] by reducing science to human reach (one cannot go beyond the experience), man is given the dignity of being the builder of science and not a pin in the hands of it. Man takes back his dignity" [30]. The choice of the model proposed here, compared to the other possible ones, is motivated in pedagogical terms by the fact that the scheme described in figure 1 can be explained very quickly, furthermore this way of proceeding, based on a retroactive cycle, links together some key factors that favor the teaching-learning process of this model: 1) the activity has a technical-practical character; 2) the student is encouraged to "move" in a conscious and intentional way; 3) the lesson is conducted in a laboratory way; 4) experience is placed at the center of the process and therefore the student "learns by doing". Returning to the practical and procedural aspects of the activity carried out with university students, among the various topics covered during the lesson, it is good to reiterate that they: have had the opportunity to consult the official data of INVALSI and OECD-PISA; they downloaded and consulted the scientific literature indicated by the researchers to better frame the academic context of the case in question; they produced their own SWOT analysis and identified with the teacher who had experimented in a fifth class of D-BOX primary school, reproducing the activity in their own family circle. However, at the end of the comparison with the researchers, no significant differences emerged between the data collected by the students and those that emerged at the "G.Rodari" IC in Perugia. It is good to remember that anyone can carry out their own experimentation by downloading the 3D model of D-BOX available for free on the website of the H Laboratory (http://www.labh.it/dbox/).

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