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# Historical Perspectives of Science and Technology Education: A Case of Leonardo da Vinci

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## Abstract

This study highlights the importance of integrating the history of technology into science education to improve primary student teachers' (undergraduate students of the Department of Pedagogy and Primary Education of the National and Kapodistrian University of Athens) understanding of key concepts in science and technology, such as mechanical advantage, criteria for distinguishing types of levers, their applications in everyday life, and the conceptualization of force vectors. Additionally, the research aimed to enhance primary student teachers' understanding of the Nature of Science (NOS) and the Nature of Technology (NOT), emphasizing that science and technology are distinct yet interrelated and identifying what constitutes technology. To ensure credibility, peer debriefing and thoroughly documented research conditions were employed. Statistical analyses, including Chi-square and Fisher's exact test, were used to evaluate the significance of the results, addressing each research question in detail. The findings revealed a significant improvement in primary student teachers' comprehension following the intervention compared to the control group, underscoring the effectiveness of the instructional approach. The study also suggests further exploration of simple machines and the incorporation of more extensive mathematical components in future research.

## Keywords

History of Technology, Simple Machines, Nature of Science Teaching, Nature of Technology Teaching

## 1. Introduction

Science and technology play a significant role in modern societies and influence almost every aspect of contemporary life, a fact reflected in both modern curricula and educational policy texts (European Commission, 2014; NGSS Lead States, 2013). Researchers pointed out that teachers can deliver the importance of science and technology directly to their students through the instruction they provide (Hsu et al., 2011; Rohaan et al., 2008), and indirectly, through their influence on their students' social and family life (Lawson et al., 2019; Vollebergh et al., 2001). Moreover, it has been observed that forming a positive attitude towards science and technology often occurs prior to the age of fourteen, thereby underscoring the pivotal role of primary education teachers (Osborne & Dillon, 2008). In this context, the education of primary teachers is considered crucial both during their undergraduate studies and throughout their professional careers, although science and technology are not among teachers' favorite school subjects (Kazempour & Sadler, 2015). Related literature recommends the integration of core concepts of technology, explicating technology-related learning objectives, and adopting appropriate instructional approaches within university-level science courses to address the issue of overloaded curricula (Yaşar et al., 2006). The present study focuses on the scientific and technological literacy of primary education teachers during their undergraduate studies. An essential component of the aforementioned literacy is teachers' knowledge about the Nature of Science (NOS) and the Nature of Technology (NOT) (Allchin, 2014; Neumann et al., 2020). In this line, in the present study, the introduction of the history of technology is combined with the use of authentic historical material, specifically Leonardo da Vinci's manuscripts, and storytelling as a teaching tool.

### 1.1. History of Science and Technology in Science Teaching: Using Original Historical Material

Regarding the introduction of history of science in science teaching, it enhances in-context teaching (Kipnis, 1996; McComas, 2011; McComas et al., 2020) and facilitates the conceptualization of the cognitive aspects of science, as well as comprehending the epistemic and value aspects of science (Clough, 2006; McComas et al., 2020; Neumann et al., 2020). A proposed way of introducing the history of science and technology in teaching is using original historical material. This approach is suggested by many researchers (McComas et al., 2020; Stefanidou & Skordoulis, 2017); however, it is noted that suitable material is not always abundantly available, and often students need to have sufficient prior knowledge to handle the material (Kubli, 1999). In order for students to familiarize themselves more easily with the historical material, the use of storytelling as a teaching tool is suggested. Storytelling as a teaching tool enables the introduction of history of science and technology by vividly presenting the cultural and social context in which scientific knowledge develops, making it a suitable means for introducing aspects of the NOS (Hadzigeorgiou, 2018). It highlights the human face of science, making it more relatable and increasing students' engagement (Metz et al., 2007; Neumann et al., 2020; Stinner et al., 2003). Moreover, it enhances teaching within its historical and philosophical framework (Clough, 2020), connecting the social and cultural environment in which scientists have worked with the concepts, theories, and ideas that emerged through history, thereby incorporating elements of the "humanization" of science (Hadzigeorgiou, 2018; Klassen, 2006a). Additionally, storytelling enhances interest in science (Hadzigeorgiou, 2006; Kokkotas et al., 2010). It effectively illuminates the work of scientists, the questions they pose, and the processes they follow, revealing the diversity and subjectivity of science and technology (Clough, 2011; National Research Council, 1996). Finally, storytelling enables the utilization of manuscripts without modifications that could potentially lead to misunderstandings, ensuring the functional integration of historical material.

### 1.2. Technology Content Knowledge: The Lever Topic

Regarding the technology content knowledge, the lever topic was selected for introducing concepts of technology and engineering, particularly in primary education, as levers are associated with numerous everyday life applications and situations related to students' experiences (Marulcu & Barnett, 2016; Norbury, 2006). Simple machines such as levers, for the aforementioned reasons, create engaging learning environments (English et al., 2013; Taylor, 2001). People, in general, rely on simple machines like levers when they need to exert less force that results in moving objects over a greater distance (a principle of engineering) (Erdogan & Stilman, 2014). In recent decades, the field of robotics has experienced significant development and research interest, with levers specifically being perhaps the most fundamental structural element of these robotic systems (Erdogan & Stilman, 2014, 2016).

### 1.3. Using Original Historical Material in Science and Technology Teaching: A Case of Leonardo da Vinci

Using original historical material in science and technology teaching asserts a prominent role in the history of science and technology in teaching (Stefanidou & Skordoulis, 2017). Takenouchi and Makizono (2014) also emphasize that the use of manuscripts such as those of Leonardo da Vinci improves the aesthetic aspect of engineering students' designs. Furthermore, Leonardo da Vinci, who apart from engineer and scientist he was a great painter as well, went beyond mere sketches or drawings, creating fully integrated designs characterized by perspective and quality, featuring a variety of simple machines such as levers and mechanisms (Cardwell, 2001; Moon, 2007). His work attempts to portray both the external and internal characteristics of machines and mechanisms, offering opportunities for representing engineering design (Kemp, 2011; Landrus, 2010; Moon, 2007; Pacey, 2001; Taddei & Zanon, 2005; Usher, 1988) that strongly resemble contemporary architectural or engineering designs (Galluzzi, 2001; Taddei & Zanon, 2005). Moreover, Leonardo da Vinci was a conscious representative of the view regarding the formation of the cognitive field of technology and the recognition of the engineering profession (Usher, 1988). Additionally, his work highlights the temporal dimension of technology, as it emerges from the beginnings of human civilization, and contributes to understanding the relationship between science and technology, particularly that while they influence each other, they are not identical. This perspective aligns with one common aspect of NOS, emphasizing the chronological precedence of technology in this dynamic relationship (McComas, 2008). In summary, the manuscripts of Leonardo da Vinci were chosen, among other reasons, because they can support the teaching of aspects of the NOS and NOT, as previously mentioned.

### 1.4. Aspects of NOS and NOT in Science Teaching

Given the potential benefits of integrating NOS into science education, researchers advocate for teachers to develop a deep understanding of these concepts and emphasize the need for further research on integrating NOS with other curricular content. Such integration can enhance students' conceptual and procedural knowledge while also motivating teachers to incorporate it into their instruction without significantly compromising other science content (García-Carmona, 2021; Schizas et al., 2024). This is particularly crucial for science teachers who struggle to translate their understanding of NOS into effective teaching practices. Additionally, in countries such as Greece, where explicit references are limited in science curricula, such integration becomes even more important (Schizas et al., 2024).

The question of what should be taught regarding the NOS in K-12 science curricula remains a subject of ongoing debate within the international science education community (Allchin, 2011; Clough, 2018; Dagher & Erduran, 2016; Kampourakis, 2016). While there is no single definition of NOS (McComas, 2014), a consensus has emerged around a set of core NOS aspects that should be included in the science curriculum within school settings, and by extension, in teacher education programs (McComas, 2008). This consensus has evolved from science educators' reviews of literature across disciplines, including the history and philosophy of science, sociology, and research from cognitive sciences such as psychology. These fields collectively offer a rich description of what science is, how it operates, how scientists function as a social group, and how society itself directs and responds to scientific efforts (Lederman, 2007; McComas, 2008; McComas et al., 1998; Niaz, 2009; Osborne et al., 2003).

Regarding the NOT, although it is widely recognized as an essential component of education, progress has been limited, with ongoing debates about which fundamental aspects should be included in school curricula. Nonetheless, there are some general aspects on which researchers tend to agree (Clough et al., 2013; De Vries, 2016b; DiGironimo, 2011; Kruse, 2013a; Pleasants et al., 2019; Waight & Abd-El-Khalick, 2012).

These efforts are reflected in modern curricula globally. In this study, we follow the guidelines of the Next Generation Science Standards (NGSS Lead States, 2013), which highlight the connection between scientific and technological literacy, and Science for All Americans, with dedicated sections for NOS and NOT (American Association for the Advancement of Science, 1989a, 1989b).

In a study involving students and graduate primary education teachers, Constantinou et al. (2010) observed difficulties in distinguishing the purposes of science and technology, as well as their overall differences. The researchers also reported a high percentage of teachers who consider technology as an application of science. Moreover, students across all school levels share the same perspective (Constantinou et al., 2010; De Vries, 2016a; Hadjilouca et al., 2011; Ryan & Aikenhead, 1992). The researchers attribute the above findings to the fact that this perception is often directly taught in the school context or intensively promoted by the press, magazines, the internet, entrepreneurs, and technology product advertising (De Vries, 2016c; Kruse, 2013b). It is also reinforced by its frequent articulation in science manuals and textbooks (Gardner, 1993, 1999). Additionally, it is observed that students have a vague perception of the engineer's field of study, which is limited to the engineer who constructs, maintains, and deals with practical problems. Despite being surrounded by various technological products and achievements, they do not precisely know what an engineer engages in. They lack an understanding of the breadth of the engineer's field, failing to mention areas such as biotechnology, chemistry, etc. (Cunningham et al., 2005), which they typically attribute to scientists (Constantinou et al., 2010).

In terms of the common aspect of NOT, specifically what constitutes technology (Kruse, 2013a), empirical research highlights that the dimension primarily recognized is technology as an artifact, specifically as a high-tech artifact (Clough et al., 2013; Compton & Compton, 2013; De Vries, 2016a; Knight & Cunningham, 2004), with the electronic computer responses to be dominating (De Vries, 2016a). The remaining three perspectives—technology as knowledge, as a process, and as an expression of human will or intention—are minimally or not mentioned at all. According to Compton and Compton (2013) and De Vries (2016a), these findings reflect the narrow perception widely held in society, prominently projected through various media channels such as the internet, magazines, and television. Students generally consider technology to improve human life by solving problems encountered by people. This simplistic view, as noted by other researchers, develops outside the school environment and is reinforced by the daily use of various devices from a young age. It emerges as "a fact of life" even though it is not explicitly mentioned in formal education that technology helps and facilitates, always yielding positive outcomes.

Regarding NOS and NOT teaching, the literature suggests explicit approaches (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Akerson & Volrich, 2006; Lederman, 2007; Lederman & Lederman, 2014; McComas et al., 2020; Sexton, 2023; Stefanidou et al., 2020). It appears that the field of utilizing the history of technology to teach concepts of science and technology, alongside aspects of NOS and NOT, has not been sufficiently investigated. The present study aims to address this research gap.

## 2. Purpose of the Study

The purpose of the present study is to investigate how primary student teachers conceptualize basic concepts of science and technology, along with aspects of NOS and NOT, in an integrated historical approach, in the context of storytelling.

Research questions of the present study are as follows:

1) If and to what extent can history of technology contribute to students' conceptualization of the three types of levers (mechanical advantage, criteria for distinguishing the types of levers, and applications in everyday life).

2) If and to what extent can the history of technology contribute to the conceptualization of force vector.

3) If and to what extent can history of technology enhance aspects of NOS (such as the fact that although science and technology are not the same, they have an impact on one another) and NOT (such as what constitutes technology).

## 3. Research Methodology

### 3.1. Place-Time

Fieldwork was conducted during the winter semester of 2020-2021 at the Department of Pedagogy and Primary Education of the National and Kapodistrian University of Athens (NKUA).

### 3.2. Sample

The study was conducted with primary student teachers (undergraduate students of the Department of Pedagogy and Primary Education of the NKUA), and a convenience sample was used. Regarding the pilot phase, a total of 23 primary student teachers participated. In the main phase of the research, a total of 48 primary student teachers participated in the experimental group and 49 in the control group. The sample was predominantly (85.6%) comprised of females as most students of the Department of Pedagogy and Primary Education of NKUA are women.

Concerning participants' background, most of them followed the Humanities orientation during Senior High School (84.5%), indicating limited experience in science classes. Regarding their technological background, they have all attended during secondary education, a related mandatory subject. In terms of participants' academic background, they all attended an Introductory Physics Course (IPC) in the previous semester, focusing on topics such as force and Newton's Laws. Levers and simple machines were not included in the IPC.

### 3.3. Teaching-Learning Sequence and Educational Material

The directed inquiry teaching model was implemented for both the experimental and control group. Participants engaged in a laboratory activity on simple machines and levers following an inquiry-based didactic intervention consisting of three two-hour sessions. The educational material developed for this intervention was delivered via PowerPoint presentations by the first author. Specific interruptions were incorporated into the instructional intervention to facilitate group discussions, exploration, formulation of questions, and completion of tasks outlined in the provided worksheets. A second colleague played the role of an observer throughout the instructional sessions. The difference in instruction between the two groups was the inclusion of elements from the history of technology. In this study, the experimental group participated in educational activities which incorporated Leonardo da Vinci's manuscripts through storytelling. Samples of the worksheets and PowerPoint presentations supporting the historical contextualization and the storytelling process, are provided in **Appendix A**. Specifically, in the experimental group, the PowerPoint presentations followed the narrative briefly described below and were interrupted to allow comments, questions from participants, and worksheet activities. In the control group, similar PowerPoint presentations with similar images were used without reference to Leonardo da Vinci's manuscripts. This distinction is also evident in the worksheets accompanying the educational intervention. As shown in "Samples of the Worksheets" provided in **Appendix A**, while the experimental group's worksheets make clear reference to the manuscripts and broader historical aspects of technology (**Appendix A**, Section 3), the control group's worksheets include only an image—taken from Leonardo da Vinci's manuscript. However, this information is not shared with the participants, who are presented with the image merely as a depiction of a lever (**Appendix A**, Section 4).

The storytelling narration in the present study was developed based on eight points suggested by Norris et al. (2005) and are briefly summarized below:

1) Events (event-tokens): For the purposes of this research, the history of finding the Codices Madrid I and II was considered suitable to support the needs of storytelling in the teaching intervention. The core "question/mystery" that run throughout the story relied on the history of discovering these specific manuscripts. Specifically, in 1967, Dr. Jules Piccus from the University of Massachusetts, specializing in Spanish literature, visited the National Library of Madrid in search of manuscripts containing medieval ballads. By chance, he discovered two large volumes, measuring 22 × 13 centimeters, bound in red Moroccan leather on the library shelves. To his surprise, he found that these were manuscripts by Leonardo da Vinci. While some researchers were aware of the existence of these manuscripts, they considered them lost or stolen. Although these volumes were listed in the library catalogs, as is sometimes the case in large and old libraries, some volumes, over the years, could not be located (Nicholl, 2005). These manuscripts are now known as "Madrid Codices I and II". These manuscripts discuss machines, primarily focusing on mechanisms that are combinations of simple machines.

2) The Narrator: In this case, the first author served as the narrator.

3) Narrative Appetite: This element is associated with suspense and anticipation, creating interest in the main question of whether Codex Madrid I was indeed

Leonardo da Vinci's treatise on machines. It is noteworthy that, before the discovery of the Madrid Codices, scholars found several references to his then-known manuscripts, which concerned da Vinci's intention to write a treatise on machines, which he called "Elementi Macchinali" (Elements of Machines) (Cianchi, 1998; Galluzzi, 2001; Taddei & Zanon, 2005). Whether this treatise was ever written is unknown (Galluzzi, 2001). After the discovery of the Madrid Codices, some proposals were initially made to identify specifically Madrid Codex I, due to its structure and content, with the aforementioned treatise, proposals that could not be satisfactorily documented (Galluzzi, 1987).

4) Past Time: The narration unfolds in the past, with events that have already occurred. However, temporal movement back and forth is possible within the storytelling.

5) Structure: The narrative follows a typical structure, comprising an initiating event (discovery of manuscripts), complications contributing to the action (investigation to draw conclusions), and a resolution of success or failure (here, the uncertainty about whether Codex Madrid I is the treatise referred to by Leonardo da Vinci).

6) Agency of the Narrator: The narrator's choices and their consequences are evident in presenting Leonardo da Vinci's views on machines and mechanics through the presentation of his manuscripts.

7) Purpose of Storytelling: The storytelling serves a specific purpose related to conveying information about Leonardo da Vinci's treatise on machines, exploring the historical context of the discovery, and engaging students in the process.

8) Role of the Reader or Listener: The engagement of the reader or listener is encouraged through the narrative. Students are expected to interpret the content, recognize the context, generate questions, and respond to the story, fostering active participation during the interrupted storytelling, subsequent discussion, and worksheet processing.

In summary, for the teaching intervention, manuscript pages from various sources were used, including: the Code Madrid I from the Biblioteca Nacional in Madrid, the Codex Atlanticus from the Biblioteca Ambrosiana in Milan, and pages from the Royal Library of Windsor Castle. All these pages were accessible online (E-Leo, n.d.).

### 3.4. Data Collection

Identical pre and posttest questionnaires were administered to both groups. The questionnaire included fourteen closed/short-answer questions (quantitative data) and three open-ended questions (qualitative data).

The questions along with their answer codes are detailed in **Appendix B**. Specifically, the first research question was investigated using questions Q6, Q7, Q9c, Q11a, Q11b, Q12a, and Q12b. The second research question was investigated using question Q8, and the third research question was investigated using questions Q1, Q2, Q13, and Q15.10 from the questionnaire.

### 3.5. Reliability and Validity

Content validity of the questionnaire is covered by the fact that all items refer to the research questions and vice versa all three research questions were covered by the considered items (Gay et al., 2012). The content of the questionnaire was double tested by two experts in science and technology education, who both agreed on all items (Polit & Beck, 2006).

Moreover, worksheets were used supplementary as a secondary data source. Peer debriefing was also used to increase the credibility of the data analysis. The criterion of descriptive adequacy was applied, in order readers to know as much detail as possible about the research conditions. A thorough description of the content in which the research was undertaken was provided, so that readers can determine the extent to which the findings can be applicable to alternative settings.

Ethical review and approval were waived for this study since during the design and implementation procedures were followed to ensure ethical standards regarding the anonymity and consent of the participants, and password protected data storage.

### 3.6. Data Analysis

This study combines quantitative and qualitative methods. The data from the short-answered questions (e.g. Q11b Choose A, B, C or D) were examined alongside the closed-ended questions (Explain/Calculate), as the response to these questions was either correct or false.

Qualitative content analysis and descriptive statistics were used to analyze the qualitative data (Gay et al., 2012). Topics from the pilot phase were recorded, categorized, and grouped into patterns. Subsequently, after the completion of the main research, categorization was done on the existing topics of the students' responses during the pretest and posttest. Any different topics that emerged were added to the initial ones. Additional patterns were created for Q1 and Q2 (Gay et al., 2012).

Kruse's (2013b) categorization was used for Q1, Q2, and Q13, distinguishing responses as naive, partially informed, or informed. Naive answers were those that lacked knowledge or were based on misconceptions, showing little awareness of the broader implications and complexities of technology. Partially informed answers contained some more informed views but exhibited a mix of accurate and inaccurate perspectives or lacked sufficient detail and nuance to be considered fully informed. These responses may hint at a deeper understanding but fail to fully articulate or generalize the concepts. Informed answers were those that were more detailed and included examples that extended beyond what was mentioned during teaching, demonstrated a clear understanding of the nature of technology and science, understood their pros and cons, critically examined their impact on society, and considered society's influence on them. To validate the analysis, two coders assessed 15 questionnaires per group (about 30% of each group's questionnaires), resulting in an 85% agreement rate (Cohen et al., 2018).

Particularly, for the content analysis of item Q1: "What is technology? (Give examples)", responses were categorized as naive if they exclusively referred to technology as artifacts of modern and high technology, or as applied sciences, purposing only on daily life's improvement. Partially informed responses included technology as old and modern artifacts, knowledge, and as a process, along with references to its historical dimension. There were no informed responses including the perspective that people should know how to use technology, understand its pros and cons, and critically examine its impact on society.

Regarding item Q2, "In your opinion, are there any differences between Technology and Science? List them", responses were categorized as naive if students portrayed technology as the hands-on aspect of science, considering science as the necessary theoretical component for technological development. Additionally, responses simply stating that science and technology interact without elaborating on their roles were also classified as naive. Partially informed responses were considered those mentioning technology as a distinct body of knowledge, addressing design, skills, and technique as fundamental dimensions of technology, discussing at least two differences between technology and science. There were no informed responses, which means that there was not one response that included multiple examples, acknowledging both positive and negative aspects.

Regarding item Q13, naive responses were categorized as those referring to the engineer's involvement with "practical" matters, such as the construction, repair of machines, and various techniques, and the scientist's involvement with "theoretical" matters. Partially informed responses were categorized as those from students referring to the engineer's involvement with planning and design, finding solutions to various problems, engagement in research, and more theoretical matters, as well as references to the breadth of the engineer's areas of involvement. There were no informed responses that reflected a sophisticated view of scientists and engineers and their role in society.

A significance level of 5% was set for all statistical criteria (Cohen et al., 2018) and the Chi-square criterion and Fisher's exact test were used for the statistical test of significance of the results (Howitt & Cramer, 2017).

## 4. Results

Regarding the first research question, the results of items Q6, Q7, Q9c, Q11a, Q11b, Q12a and Q12b are presented; for the second research question, the results of items Q8 are presented; and finally, for the third research question, the results of items Q1, Q2, Q13 and Q15.10 are presented.

### 4.1. History of Technology Contribution to Conceptualizing the Three Types of Levers

Regarding the first research question (*If and to what extent can History of Technology contribute to the conceptualization of the three types of levers*), items Q6, Q7, Q9c, Q11a, Q11b, Q12a and Q12b were analyzed. Item Q6 consisted of sub-item Q6a (*How many types of levers do you know? Please list them by name*) and sub-item Q6b (*How can we distinguish between the types of levers?*). In the pretest, most students in both the experimental and control group did not provide correct answers or any answer at all to both sub-items. In the posttest, a significant improvement was observed. In sub-item Q6a, according to Fisher's exact test ($p$ = .436), no significant difference was found between the two groups' responses (95.8% of students in the experimental group and 89.8% in the control group answered correctly). In the posttest, in sub-item Q6b, 64.6% of the experimental group answered correctly compared to 40.8% of the control group. The difference between the two groups was statistically significant according to the Chi-squared test ($\chi^2(2)$ = 6.276, $p$ = .013) (**Table 1**). Additionally, an interesting finding in both groups was that 20.8% of the experimental group and 26.5% of the control group reported that only the fulcrum position helps distinguish between lever types, without mentioning the role of force and load's position.

**Table 1.** Table of results of the statistical criteria applied to the students' responses.

| Items | Pretest | | Posttest | |
|---|---|---|---|---|
| | $\chi^2$ | $p$ | $\chi^2$ | $p$ |
| Q1 | A | - | 7.612 | .006 |
| Q2 | A | - | 10.548 | .001 |
| Q6a | b | - | * | .436 |
| Q6b | b | - | 6.276 | .013 |
| Q7 | 3.059 | .080 | 18.901 | <.001 |
| Q8a | 3.981 | .137 | 1.293 | .255 |
| Q8b | * | .674 | 13.379 | .001 |
| Q8c1 | 0.364 | .834 | 3.945 | .139 |
| Q8c2 | 0.522 | .470 | 5.900 | .015 |
| Q9c | b | - | 4.166 | .041 |
| Q11a | b | - | 11.262 | .001 |
| Q11b | b | - | 0.471 | .493 |
| Q12a | b | - | 10.732 | .001 |
| Q12b | b | - | 1.114 | .285 |
| Q13 | a | - | * | .016 |
| Q15.10 | * | .681 | 6.949 | .034 |

a: Only naive answers were given; b: Only incorrect answers were considered; A: No responses were given; *: Two-tailed Fisher's exact test was conducted.

In question Q7 (*For each type of lever, mention at least one corresponding object we use in everyday life*), during the pretest, students in both groups were unable to answer correctly; however, some students matched the example of a lever from everyday life with the wrong-named kind of lever or provided only a single example of a lever they use. This observation led the researcher to directly ask the students in the field why they mentioned these examples of levers and recorded their responses. The responses of most students were similar (e.g. "T3: I don't know about the types of levers but these are the levers I know", "T18: It's hard to describe but I see these levers in the car", "T70: I think it's called the door handle, a lever", "T84: because these are examples of very common levers, we use them to operate machines"). Additional content analysis was performed on pretest responses that referred to examples of levers from everyday life. Examples corresponding to the first type of lever were provided by 31.3% of the experimental group and 46.9% of the control group, while examples matching the second type of lever were given by 4.2% of the experimental group and 6.1% of the control group. The remaining percentage in both the experimental and control groups provided either responses with no examples or examples that were irrelevant to the question. The difference in responses between the two groups was found to be statistically insignificant ($\chi^2(1) = 3.059$, $p = .080$). In the posttest, 60.4% of the experimental group were able to provide examples for all three types of levers, compared to 24.5% of the control group. Overall, most students in the experimental group were able to provide correct answers for all three types of levers, in contrast to most students in the control group who provided correct answers only for one type of lever. The comparison of responses between the two groups, using the Chi-square test, revealed a statistically significant difference ($\chi^2(3) = 18.901$, $p < .001$) (Table 1).

In sub-items Q9c, Q11a, and Q12a, participants were required to identify the type of lever depicted in the image. During the pretest, none of the participants in either group were able to provide a correct response. Findings of the posttest revealed statistically significant differences. Specifically, in sub-item Q9c, 89.6% of the experimental group was able to correctly identify the type of lever, which was significantly higher compared to 73.5% of the control group ($\chi^2(1) = 4.166$, $p = .041$) (Table 1). In sub-item Q11a, 62.5% of the experimental group was able to correctly identify the type of lever, while only 28.6% of the control group was able to do so ($\chi^2(1) = 11.262$, $p = .001$) (Table 1). Finally, in sub-item Q12a, 93.8% of the experimental group was able to correctly identify the type of lever, while only 67.3% of the control group was able to do so ($\chi^2(1) = 10.732$, $p = .001$) (Table 1).

In sub-item Q11b and Q12b, participants were required to choose the correct answer after calculating the mechanical advantage. During the pretest, no participants were able to provide the correct answer. In the posttest, both groups demonstrated improvement. Specifically, in sub-item Q11b, 81.3% of the experimental group and 75.5% of the control group provided correct responses. The difference between the groups was not found to be statistically significant based on the Chi-square test ($\chi^2(1) = 0.471$, $p = .493$) (Table 1). Regarding sub-item Q12b, 77.1% of the experimental group and 67.3% of the control group provided correct responses which is not statistically significant differences ($\chi^2(1) = 1.114$, $p = .285$)

(Table 1).

### 4.2. History of Technology Contribution to the Conceptualization of Force Vector

Item Q8 consisted of four sub-items: Q8a, Q8b, Q8c1, and Q8c2 (see **Appendix B**). In sub-items Q8a, Q8b, and Q8c1, students were asked to find the fulcrum and draw the effort force (the force exerted by the person) in the corresponding images, where different types of levers are depicted (first type for picture a, third type for picture b and second type for picture c). In item Q8c2, they were asked to draw the resistance force (the force exerted by the nut). Correct answers in sub-items Q8a, Q8b, and Q8c1 were those where students had correctly found the fulcrum and drawn the desired force, and incomplete answers when they had only drawn one of the two.

During the pretest, a small percentage of both groups gave correct answers. Specifically, in Q8a, 16.7% of the experimental group and 32.7% of the control group gave the correct answer. In Q8b, 2.1% of the experimental group and 2% of the control group gave the correct answer. In Q8c1, 14.6% of the experimental group and 18.4% of the control group gave the correct answer, and finally, in Q8c2, 35.4% of the experimental group and 28.6% of the control group gave the correct answer. The comparison of the answers of the two groups with the Chi-square statistical test for sub-item Q8a ($\chi^2(2) = 3.981$, $p = .137$) (Table 1) and for Q8c1 ($\chi^2(2) = 0.364$, $p = .834$) (Table 1) and the exact Fisher test for sub-item Q8b ($p = .674$) did not show statistically significant differences between the two groups. Notably, the fewest correct answers were given in sub-item Q8b as it was the most demanding task.

During the posttest, both groups showed improvement. Specifically, in sub-items Q8a, 81.3% of the experimental group and 71.4% of the control group, while in sub-question Q8c1, 70.8% of the experimental and 53.1% of the control group correctly showed the fulcrum and the exerted force point. The remaining percentage in both the experimental and control group either provided responses with no correct answer or did not answer at all. The application of the Chi-square criterion in sub-item Q8a ($\chi^2(1) = 1.293$, $p = .255$) (Table 1) and in Q8c1 ($\chi^2(2) = 3.945$, $p = .139$) (Table 1) did not show statistically significant differences between the answers of the two groups. In contrast, in the most demanding task in Q8b, 43.8% of the experimental and 20.4% of the control group answered correctly, and the application of the Chi-square criterion showed a statistically significant difference ($\chi^2(2) = 13.379$, $p = .001$) (Table 1). Also, in Q8c2, 83.3% of the experimental and 61.2% of the control group answered correctly, and the application of the Chi-square criterion showed a statistically significant difference in this item as well ($\chi^2(1) = 5.900$, $p = .015$) (Table 1).

### 4.3. History of Technology Role in NOS and NOT

According to the pretest results, in sub-item Q1, both the experimental and control group of primary student teachers provided naive answers regarding technology. Specifically, 41.7% of the experimental group and 38.8% of the control group listed only artifacts of modern and high technology, with computers being the most popular example. Additionally, 29.2% of the experimental group and 36.7% of the control group associated technology with improving human daily life, albeit with a limited perspective, as they only referred to examples of modern and high technology. After the teaching intervention, the experimental group provided improved responses (partially informed) and the number of responses with only examples of modern and high technology artifacts decreased significantly. A percentage of 39.6% of the experimental group, compared to 26.5% of the control group, reported the historical dimension of technology, recognizing that technology has appeared since the beginning of human civilization, "from ancient times", or cited examples of low-tech artifacts, such as the "wheelbarrow" the "ramp" or a combination of these. A percentage of 16.7% of the students in the experimental group, compared to 2% of the control group, referred to technology as an artifact and added other aspects, such as technology as "knowledge" and as a "process". The remaining percentage in both the experimental and control group provided naive answers. Overall, 56.3% of the responses of the students in the experimental group shifted from naive responses to partially informed responses about technology, compared to 28.6% of the control group's responses, but no students gave informed answers. This shift in responses was also statistically significant according to the Chi-square test ($\chi^2(1) = 7.612$, $p = .006$) (Table 1).

According to item Q2, it was found during the pretest that both the experimental and control group gave naïve answers. Most responses in both groups, 72.9% of the experimental group and 65.3% of the control group, categorized technology as applied science, while the next highest percentage, 18.8% of the experimental group and 30.6% of the control group, identified technology as "practical" and science as "theoretical". After the intervention, 37.5% of the experimental group students provided more than one difference, describing in greater detail compared to 8.2% of the control group's answers. They were also able to generalize the descriptions beyond the examples discussed during the instructional process. Overall, 54.2% of the students' answers shifted from naive answers to partially informed answers, compared to 20.4% of the control group's answers, but no students gave informed answers. The difference in the shifts of the answers was statistically significant, as indicated by the Chi-square test ($\chi^2(1) = 10.548$, $p = .001$) (Table 1).

The findings of the open-ended item Q2 are reinforced by the closed-ended sub-item Q15.10: The applied science is what we call technology. Initially, during the pretest, 6.3% of the experimental group and 10.2% of the control group disagreed with the statement, without a statistically significant difference according to the Chi-square test. During the post-test, 27.1% of the experimental group and 10.2% of the control group disagreed with the statement, and the difference was statistically significant according to the Chi-square test ($\chi^2(2) = 6.949$, $p = .034$)

(Table 1).

Regarding the open-ended question Q13 (*What do you think scientists and engineers work on?*), both the experimental and control group gave naive responses, according to the pretest. The majority of both the experimental group (60.4%) and the control group (63.3%) reported engineers' engagement with "practical" issues as an application of the theory developed by scientists. Additionally, 27.1% of the experimental group and 26.5% of the control group reported the engineers' engagement in the construction of machines and artifacts. During the posttest, most of the students continued to give naive responses. A total of 58.3% of the experimental group and 63.3% of the control group continued to report technologists' engagement with "practical" issues, and 25% of the experimental group and 32.7% of the control group continued to report technologists' engagement in the construction of machines and artifacts. However, 16.7% of the experimental group and only 2% of the control group gave partially informed responses. The remaining percentage in the control group provided no answers. Finally, Fisher's exact test demonstrated that the difference in the shifts of the groups' responses from naive to partially informed was statistically significant ($p = .016$) (Table 1).

In Table 2, examples of characteristic answers to open-ended questions Q1, Q2, and Q13 are listed, illustrating the shift from naive responses to partially informed answers.

Table 2. Examples of characteristic answers to open-ended questions Q1, Q2, and Q13 regarding the change of pattern from naive answers to partially informed answers.

| Open-ended question Q1: *What is technology*? (*Give examples*) | | |
|---|---|---|
| **Answer code** | **Pretest<br>Example quote** | **Posttest<br>Example quote** |
| **T19** | "Application of the theory of sciences (space robotics)" | "When I hear the word technology, various mechanisms come to my mind that have been combined and helped humans since ancient times. Technology includes both a wheelbarrow and a computer. Today, technology is based on mathematical, physical, mechanical, and other knowledge, which is why it is advancing faster (e.g. spaceships, robots, satellites). It also helps other sciences (biology, genetics, physics)." |
| **T30** | "When I hear the word technology, I think of progress and development. This applies to technological devices such as computers, electronic devices, and anything that evolves over decades (for example, different software that existed on older computers or different software in today's era)." | "When one hears the word technology, they may think of topics related to mechanics, constructions, etc. that humans have built and designed from very old times (i.e. ways of constructing a machine based on simple machines) up to the present day. However, today all of these usually function with computers, whereas in the past they were powered by humans or animals." |

Continued

| Open-ended question Q2: *In your opinion, are there any differences between Technology and Science? List them* | | |
|---|---|---|
| **Answer code** | **Pretest Example quote** | **Posttest Example quote** |
| **T12** | "There are no differences because technology needs science." | "Technology deals with the construction of machines, with design, records processes, and generally deals with how something can be done, while science deal primarily with natural phenomena and their interpretation." |
| **T10** | There are significant differences, as science has a theoretical background and is independent of time, unlike technology, which is its application. | They are different but have a dynamic relationship. Science mainly concerns the environment that we can observe and is based on phenomena that already exist. Technology creates practical applications and objects. It is the creations of humans, but it changes and evolves rapidly, satisfying but also creating needs. |
| **Open-ended question Q13:** ***What do you think scientists and engineers work on? Can you provide examples for each?*** | | |
| **Answer code** | **Pretest Example quote** | **Posttest Example quote** |
| **T24** | "The scientist deals with a subject that concerns not only the everyday life of humans but also touches on more theoretical issues (such as how organisms behave), while the engineer is exclusively concerned with technology and how machines work (for building a house)." | "The scientist deals with why things happen around us and more theoretical issues. Engineers deal with how to create different things or provide solutions to get the best, functional, and more economical outcome for a task we want to do. Generally, they design and suggest how to create the things that people need." |
| **T29** | "Scientist = scientific method. Engineer= improvement of machines." | "There is great dependence on the occupations of both. Roughly, the scientist deals equally with theory and practice, while the engineer knows the principles and rules but focuses more on the design and application of objects and solutions for society." |

## 5. Discussion

According to the pretest findings, for the first research question, students generally failed to provide correct or complete answers in both groups. This can be attributed to the fact that they had not been formally taught the corresponding subject matter, neither in the context of secondary education nor in their undergraduate program. For those students who gave a correct answer, it can be attributed to the fact that levers are such common simple machines used daily (Marulcu & Barnett, 2016; Norbury, 2006), that students mention them intuitively without having a clear understanding of their types, characteristics, and differences between them.

After the teaching intervention, both groups demonstrated improvement in all items related to the first research question. Specifically, in the more challenging tasks related to distinguishing between lever types and citing everyday life applications, students in the experimental group provided statistically significantly higher percentages of scientifically accepted answers than students in the control group. These findings are aligned with previous research, indicating that the integration of history of science in science and technology teaching can enhance both the cognitive and process-oriented outcomes (Clough, 2006, 2020; Klassen, 2006b). The findings emphasize challenges encountered by students in distinguishing between the second and third lever types, as the only identification of the fulcrum proves to be inadequate. Nevertheless, it is noteworthy that within both groups, a significant percentage of students (20.8% in the experimental group and 26.5% in the control group) exhibit a narrow focus on the fulcrum, a pivotal structural component of a lever. This observation can be attributed to sensory-perceptual information (in this case, through the visual channel), which may contribute to persistent misconceptions (Driver et al., 1994). Finally, although many researchers identify difficulties in understanding the relationship between force, distance, and the calculation of mechanical advantage, and generally consider this specific topic demanding in teaching (Lehrer & Schauble, 1998; Leuchter & Naber, 2019; Rivet & Krajcik, 2004), both groups showed significant improvement in calculating mechanical advantage without exhibiting a statistically significant difference between them.

Furthermore, in response to the second research question, in the most challenging task concerning the vectorial characteristics of force and accurately depicting the direction of the force requested (as shown in the image of a person with a broom), students in the experimental group demonstrated a statistically significant higher percentage of correct responses. This particular finding is noteworthy, considering that this specific topic, despite being taught from lower secondary school to university education, appears to be demanding for students (Van Deventer et al., 2007). As noted by other researchers, challenges arise in relation to levers, specifically in identifying the load, determining the distance of the force direction (force arm), and the resistance (resistance arm) from the fulcrum (Leuchter & Naber, 2019). These elements are crucial for identifying the lever type.

Finally, although many researchers identify difficulties in understanding the relationship between force, distance, and the calculation of mechanical advantage, and generally consider this specific topic demanding in teaching (Lehrer & Schauble, 1998; Leuchter & Naber, 2019; Rivet & Krajcik, 2004), both groups showed significant improvement in calculating mechanical advantage without exhibiting a statistically significant difference between them.

According to the initial findings to the third research question, students' recognition of the dimension of technology as an artifact and even as a high-tech gadget is consistent with the findings of other empirical studies (Clough et al., 2013; Compton & Compton, 2013; De Vries, 2016a; Knight & Cunningham, 2004; Rau & Antink-Meyer, 2020). Additionally, the computer is the dominating example students gave regarding technology. This finding is also supported by De Vries' (2016a) research. The remaining three perspectives, technology as knowledge, as processes, and the human dimension of technology, are mentioned rarely or not at all (De Vries, 2016a). These findings reflect the narrow perception widely held by society and prominently projected through various media platforms such as the internet, magazines, and television (Compton & Compton, 2013; De Vries, 2016a). According to Clough (2013) and Kruse (2013b), students generally hold a positive view of technology as a helpful tool in daily life, solving problems encountered by people. This simplistic perspective is developed outside of school and is reinforced by the daily use of various devices from a young age. Although not explicitly taught, this view emerges as a "natural" result with a focus on technology's facilitative role and positive outcomes. Following the instructional intervention, students' initial naive perceptions shifted towards more informed ones as they acknowledged other dimensions of technology, including both old and high-tech artifacts. This statistically significant shift in the experimental group is attributed to the instructional intervention provided.

Also, the initial findings of this research regarding the difference between technology and science are in line with the findings of other researchers. Constantinou et al. (2010) observed difficulty in distinguishing the purposes and differences between science and technology in their study, which involved students and primary school graduate teachers. A high percentage of teachers consider technology as an application of science, and similarly, students at all school levels share the same opinion (De Vries, 2016a; Hadjilouca et al., 2011; Ryan & Aikenhead, 1992). The above finding is attributed by the researchers to the fact that this view is often directly taught in the school context or strongly influenced by the media, the internet, technology and market stakeholders, and technology products (De Vries, 2016c; Kruse, 2013b), and it is frequently expressed in textbooks as well (Gardner, 1993, 1999). Additionally, after the instructional intervention, a statistically significant percentage of students in the experimental group managed to provide details and more than one difference. These findings are further supported by the results of the closed-ended question 15.10. It is also noteworthy that a remarkable percentage in both groups struggle to move away from the alternative idea that technology is an application of science. This finding is emphasized by other researchers who believe that the resistance to changes in students' alternative ideas about Technology is reinforced, among other factors, by the complex nature of NOT (Kruse, 2013b).

## Limitations

There are several limitations in the present study that do not permit generalization.

The research sample was limited, convenient, and lacked gender balance. Additionally, further limitations are associated with the study's restricted duration. Finally, a follow-up test was not feasible because participants had already graduated, and further communication with them was impossible.

## 6. Conclusion and Implications

The present study investigated whether primary student teachers can acquire science and technology concepts, as well as aspects of NOS and NOT, through a unified approach in the context of history of technology. The findings suggest that integrating the history of technology into the teaching of science and technology among primary student teachers can be an effective means to enhance the conceptualization of science and technology ideas, incorporating core concepts such as the vector nature of force and the three types of levers, as well as aspects related to NOS and NOT.

The study gives the perspective of investigating more simple machines or incorporating more extensive sections related to mathematics. Specifically, it is proposed to extend the instructional intervention to other topics, such as robotics. Leonardo da Vinci was involved in the study and construction of "automata", which were devices that performed movements and were often anthropomorphic or zoomorphic (Rosheim, 2006). Additionally, levers and the law of levers can be used to introduce concepts such as the average, which can be correlated with the balance point of a lever (Flores, 2008), or concepts related to parabolas or the volume of a sphere (Schiffer & Bowden, 1984).

Many researchers argue that educators often tend to "teach the way they were taught", although there have been limited empirical studies conducted in this area (Oleson & Hora, 2014). In this context, an interesting extension of research would involve monitoring students during their internships or as teachers to assess the degree to which they incorporate the history of science and technology into their teaching based on the approaches they learned during their studies. In the current study, an instructional intervention was developed and implemented using the history of technology as a means of introducing elements related to NOS and NOT, employing an explicit instructional approach (Lederman & Lederman, 2019). Nevertheless, alternative effective methods of engagement have been suggested in conjunction with the explicit approach when introducing NOS and NOT, such as incorporating inquiry-based activities, utilizing socio-scientific issues as a foundation for instruction, and employing other instructional strategies. An intriguing expansion of this research would involve comparing it with the previously mentioned instructional interventions to determine the most effective approaches and identify specific areas of improvement (Lederman & Lederman, 2019).

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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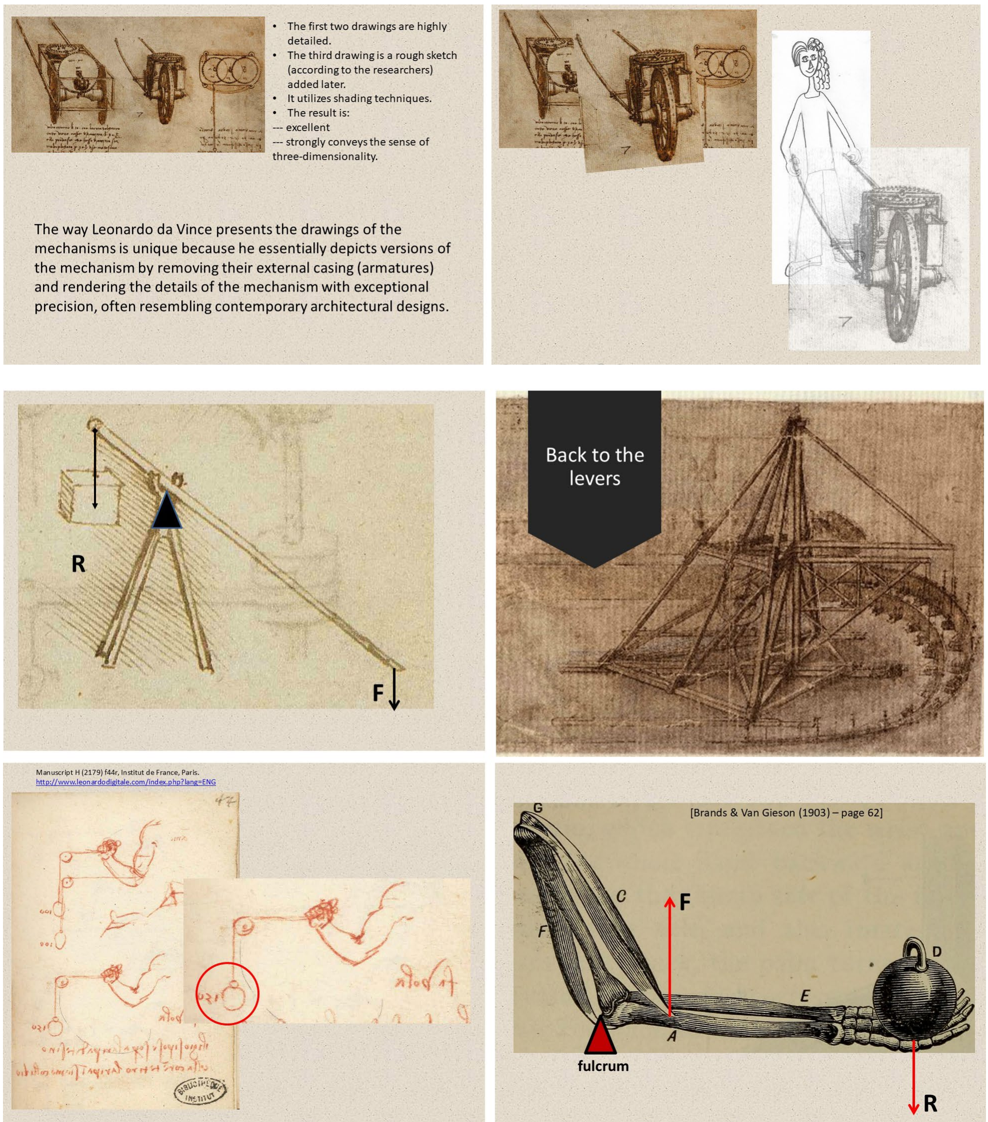
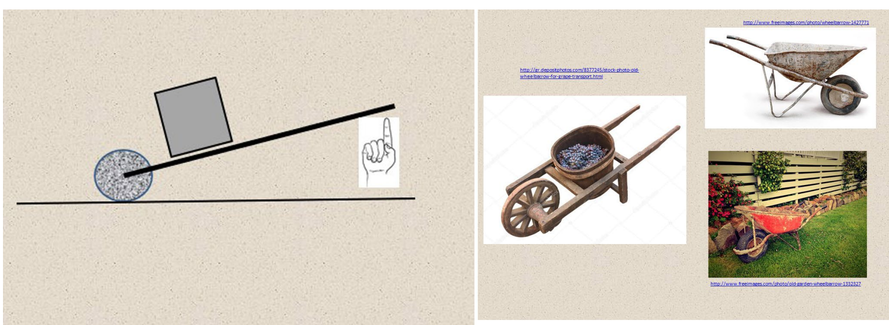
# Appendices

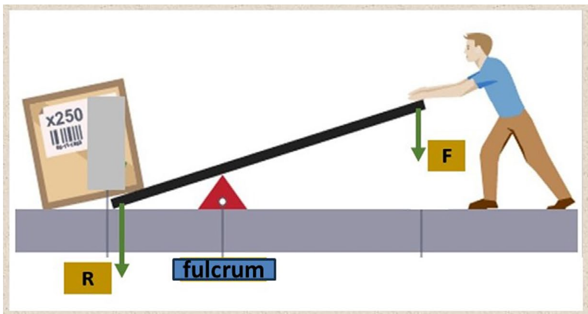
## Appendix A

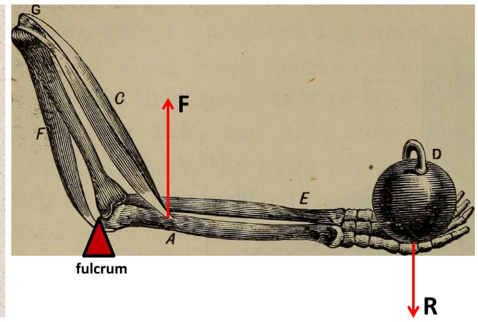
1) Samples of PowerPoint presentations supporting the instructional intervention for the experimental group.




2) Samples of PowerPoint presentations supporting the instructional intervention for the control group.





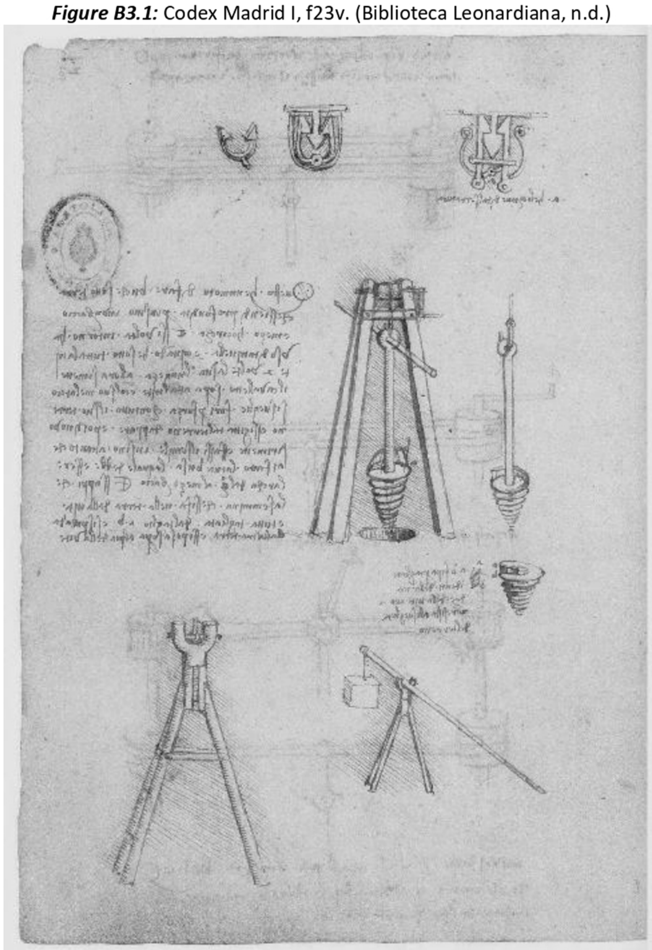

3) Samples of the worksheets supporting the instructional intervention for the experimental group.

**B2.2)** In a few words, formulate a simple rule for someone to easily distinguish the three types of levers.

**Task B3**

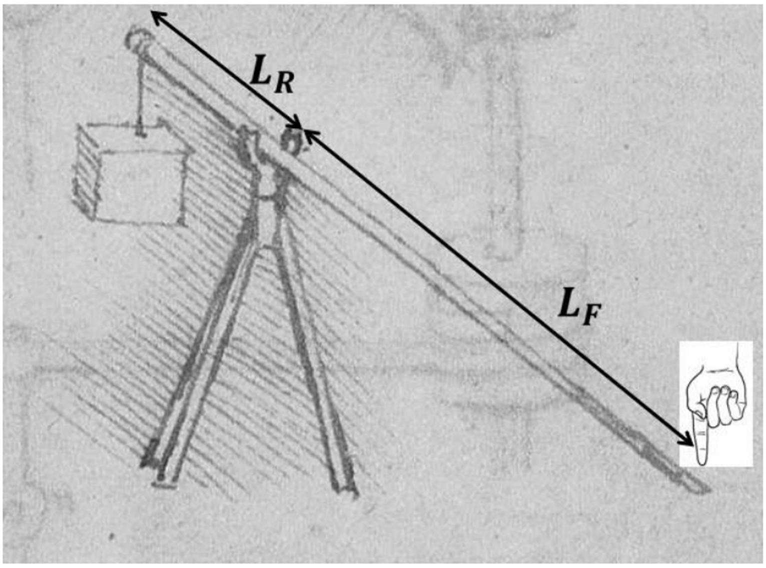
**B3.1)** In Leonardo da Vinci's manuscript, the Codex Madrid I f23v (Figure B3.1), he has sketched details of various mechanisms and a lever that was used by people since ancient times for lifting heavy objects. Can you locate the lever? (encircle it). What type of lever is it?.......... (fill in)

***Figure B3.1:*** Codex Madrid I, f23v. (Biblioteca Leonardiana, n.d.)



**B3.2)** The following Figure B3.2 depicts an enlarged view of the lever designed by Leonardo in the manuscript mentioned above. Mark the fulcrum (Y) on the image and draw the effort force (F) and the resistance force (R).

***Figure B3.2:*** Codex Madrid I, f23v, (Biblioteca Leonardiana, n.d.)




**B3.3)** If we assume that Leonardo's lever shown in Figure B3.2 has a total length of 1.5m (150 cm), find the mechanical advantage for the given scenarios by completing column 3 of Table B3.1 below.

Table B3.1:

| $L_F$ (cm) | $L_R$ (cm) | $MA = \frac{L_F}{L_R}$ |
|---|---|---|
| 30 | 120 | |
| 50 | 100 | |
| 100 | 50 | |
| 140 | 10 | |

4) The corresponding samples of worksheets supporting the instructional intervention for the control group.

**B2.2)** In a few words, formulate a simple rule for someone to easily distinguish the three types of levers.

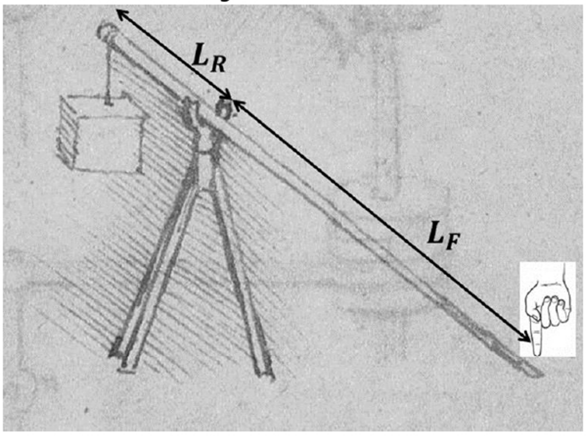
| |
|---|
| |

**Task B3**

**B3.1)** In Image B3.1, a lever is shown, which has been used by people since ancient times to lift heavy objects.

What type of lever is it?………. (fill in)

***Figure B3.1:*** Lever




**B3.2)** Mark the fulcrum (Y) on the image and draw the effort force (F) and the resistance force (R).

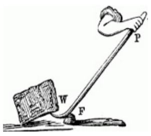
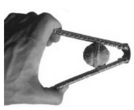
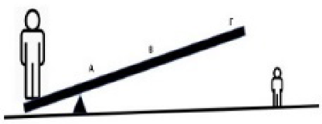
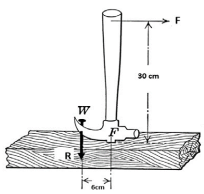
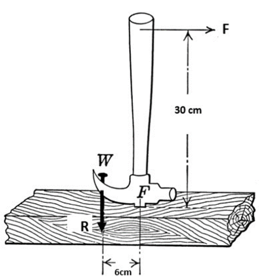
**B3.3)** If we assume that Leonardo's lever shown in Figure B3.2 has a total length of 1.5m (150 cm), find the mechanical advantage for the given scenarios by completing column 3 of Table B3.1 below.

**Table B3.1:**

| $L_F$ (cm) | $L_R$ (cm) | $MA = \frac{L_F}{L_R}$ |
|---|---|---|
| 30 | 120 | |
| 50 | 100 | |
| 100 | 50 | |
| 140 | 10 | |

## Appendix B

The questions and answer codes of the questionnaire presented in this research:

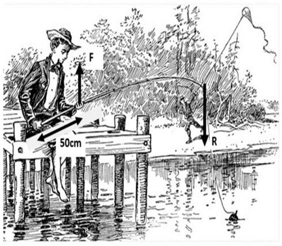
| Answer code | Questions and sub-questions of the questionnaire |
|---|---|
| **Q1** | "What is technology? (Give examples)" |
| **Q2** | "In your opinion, are there any differences between Technology and Science? If so, list their major differences" |
| **Q6a** | "How many types of levers do you know? (Please list them by name)" |
| **Q6b** | "How can we distinguish between the types of levers?" |
| **Q7** | "For each type of lever you know, mention at least one example of an object we use in everyday life." |
| **Q8a** |  In the following image, mark a ▲ where the fulcrum is located and draw the force that the person exerts on the object. |
| **Q8b** |  In the following image, mark a ▲ where the fulcrum is located and draw the force that the person exerts on the object |
| **Q8c1** |  In the following image, mark a ▲ where the fulcrum is located and draw the force that the person exerts on the object |
| **Q8c2** |  Design the force exerted by the nut on the nutcracker |
| **Q9c** |  What type of lever does the seesaw belong to? |
| **Q11a** |   The tool in the image is a lever that belongs to the _______ type (fill in the blank). |
| **Q11b** |   Based on the information provided in the image, what is the mechanical advantage of this tool?<br>A. 0.2<br>B. 5<br>C. 0.5<br>D. I don't know<br>Explain your answer. |

**Continued**

**Q12a**

A fishing rod is basically a lever that belongs to the _______ type (fill in the blank).

**Q12b**




Based on the information provided in the image, what is the mechanical advantage of the fishing rod? The fishing rod has a length of 120cm.

A. 0.2

B. 5

C. 0.5

D. I don't know

Explain your answer

**Q13** What do you think scientists and engineers work on? Can you provide examples?

**Q15.10** Applied science is called technology.

A. I agree

B. I disagree

C. I don't know