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Research Article

Thinking Like Scientists in the Classroom: Middle School Inquiry into Zhang Heng's Seismoscope as a Historical Black Box

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Abstract: Black-box activities are acknowledged as useful methodologies in science education, as they engage students in the role of scientists, prompting them to deduce concealed mechanisms from observable evidence. This study examines the thinking of middle school pupils when faced with an authentic historical enigma: Zhang Heng's seismoscope, a second-century Chinese apparatus considered the first instrument to document earthquakes. The absence of the original mechanism, which remains unknown to experts, creates a genuine setting for inquiry-based learning. The intervention encompassed four eighth-grade classes (ages 13-14) in a Greek lower secondary institution. Students, organized into small groups, were tasked with hypothesizing and illustrating the internal mechanism of the seismoscope following an introduction to its exterior construction and historical background. Their designs underwent analysis for scientific validity and were juxtaposed with academic reconstructions. The findings indicated that numerous students presented scientifically credible processes grounded in Newton's First Law of Motion, many of which closely mirrored reconstructions given by experts. Other solutions demonstrated a limited comprehension, divergent interpretations, or creative extrapolations, including water tubes or contemporary sensors. Significantly, scientifically valid proposals did not exclusively originate from the highest-achieving students, implying that open-ended black-box activities enable a variety of learners to exhibit reasoning abilities. The results suggest that historical black-box activities can successfully connect curricular content with genuine inquiry, promoting both conceptual comprehension and recognition of the provisional nature of scientific knowledge.

Keywords: black-box activities; Zhang Heng's seismoscope; middle school physics; inquiry-based learning; nature of science

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1. Introduction

Science education seeks to enhance students' conceptual comprehension and to foster their acquaintance with the methodologies and epistemological foundations of scientific investigation, sometimes referred to as the Nature of Science. Research has consistently emphasized that promoting students' engagement with the elements of Nature of Science – such as the provisional nature of scientific knowledge, the significance of empirical evidence, and the creativity inherent in scientific modeling – represents a fundamental objective alongside content acquisition (Lederman, 2007; Osborne et al., 2003).

This work serves as an empirical contribution to the field of science education research. This paper details a classroom intervention involving Grade 8 students in Greece, utilizing Zhang Heng's seismoscope as an authentic historical artifact to promote inquiry-based learning. This study investigates how students apply Newtonian mechanics to a new and authentic environment by involving them in hypothesizing the internal mechanism of the seismoscope. The article emphasizes the capacity of historical black-box activities to foster scientific reasoning, creativity, and a profound comprehension of the Nature of Science. A commonly endorsed method involves employing black-box or mystery-box activities, wherein learners assume the role of detectives striving to elucidate concealed mechanisms based on limited observable evidence.

These activities promote active engagement and foster the development of hypotheses, experimentation, and the substantiation of results (Rode & Friege, 2017). They offer students opportunity to encounter scientific uncertainty, recognize the provisional nature of scientific models, and cultivate critical process skills, such as communication and debate (Abd-El-Khalick & Lederman, 2000; Bett et al., 2023). Previous research frequently highlighted black-box exercises to enhance conceptual comprehension (Rosenzweig & Wigfield, 2016), however contemporary studies have accentuated their significance in fostering reflection on epistemological matters in scientific education (Erduran & Dagher, 2014).

In addition to their cognitive and epistemological benefits, black-box activities are often characterized as highly interesting for pupils. By introducing a riddle lacking an apparent answer, they stimulate curiosity and promote collaborative inquiry (Shernoff et al., 2016; Rakedzon & Van Horne, 2024). When executed with care, such exercises connect abstract concepts to real-world contexts, enabling learners to function "like scientists" by developing and justifying models that are limited by empirical evidence yet receptive to modification.

This paper introduces an innovative use of a black-box activity through a historical example: Zhang Heng's seismoscope, created in second-century China. The original instrument has not endured, and its internal operation is unknown, rendering it a true enigma for both students and modern scientists.

The device is considered the earliest scientific equipment for recording earthquakes (Yan, 2007; Wang, 2004), and its application in the classroom provides cognitive and epistemic benefits. This corresponds with the middle school physics curriculum, including Newton's First Law of Motion, while also immersing pupils in the uncertainty inherent in genuine scientific research. This study sought to determine if middle school students could engage in scientific reasoning by hypothesizing about the internal mechanism of Zhang Heng's seismoscope, and to what degree they could apply previously acquired physics concepts, through the integration of a historical black box into a classroom intervention.

2. Materials and Methods

The research was performed with eighth-grade students (ages 13–14) in a Greek lower secondary institution across two successive academic years. Four classes participated, each consisting of roughly 15 pupils, who collaborated in groups of three to five. The intervention was devised and executed by the classroom instructor, a doctorate candidate, and lasted two instructional hours at the conclusion of the academic year. This timing assured that all participating students had previously learned the fundamental principles of mechanics, including Newton's equations of motion, energy, and the conservation of energy, so equipping them with the requisite foundation to engage with the exercise.

The intervention was unrelated to the official Greek lower secondary physics curriculum. At the Grade 8 level, students are required to solidify their comprehension of Newton's laws of motion, the principle of energy conservation, and the function of forces in initiating or modifying motion. Through interaction with Zhang Heng's seismoscope, students could use Newton's First Law of Motion in a unique and historically accurate setting, thereby enhancing educational outcomes beyond conventional problem-solving activities. This congruence underscores the pedagogical viability of integrating historical black-box activities into current curricular frameworks, enhancing required learning objectives while promoting inquiry, creativity, and epistemological awareness.

The intervention utilized Zhang Heng's old seismoscope as a tangible black box. Students were presented with an activity via a brief text, derived from historical sources, detailing the effective functioning of the seismoscope in identifying a far earthquake during the Han period. A concise account of the device's exterior characteristics was also presented, aligning with academic reconstructions (Hsiao & Yan, 2009; Sleeswyk & Sivin, 1983). Figure 1 illustrates Zhang Heng's seismoscope, the ancient Chinese apparatus considered the earliest known instrument for documenting earthquakes.

The descriptions were deliberately concise and comprehensible to prevent overwhelming pupils with superfluous historical information and to enable them to speculate about the internal mechanism. Each group was provided with a worksheet featuring a schematic cross-section of the seismoscope, depicting the external construction while omitting the inside details. Students were directed to theorize the construction of the internal mechanism, in accordance with the historical context and materials accessible in second-century China. The exercise did not include the physical building of models, allowing students to suggest scientifically viable solutions without limitations imposed by their technical skills.

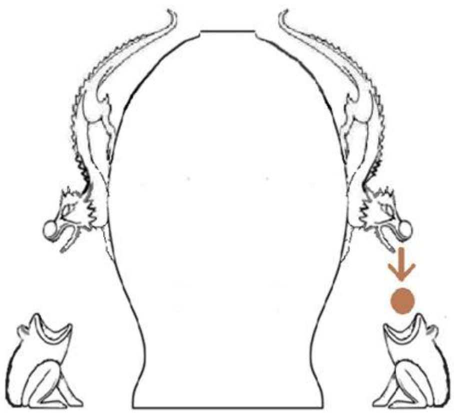

Figure 1. Zhang Heng's seismoscope, an ancient Chinese instrument for detecting earthquake direction.

This intervention was intentionally open-ended, in contrast to most black-box exercises in scientific education where the teacher specifies the range of possible answers or supplies materials (Rode & Friege, 2017; Krell & Hergert, 2019). Students were neither guided toward a specific scientific idea nor provided with preselected resources. They were permitted to utilize whatever physics ideas they had learned over the academic year to substantiate their proposed designs. This design decision aimed to promote higher-order cognitive processes, beyond mere application to encompass analysis, synthesis, and assessment, as outlined in the advanced tiers of Bloom's taxonomy (Adhikari, 2024; Krathwohl, 2002).

Upon completion of the group work, students presented their solutions to the entire class. They were requested to elucidate and justify their selections, specifically correlating their proposed mechanisms to pertinent physics principles. Class discussions prompted reflection on the historical background, especially the technological constraints and materials accessible in second-century China. The procedure was documented via the compilation of student worksheets, researcher field notes, and photographs of the designs. The data were qualitatively examined by categorizing student replies into solution groups, emphasizing their scientific legitimacy and alignment with established academic reconstructions of Zhang Heng's seismoscope.

For analytical purposes, student ideas were classified into certain categories, including inverted pendulum, pendulum, direct contact, hybrid mechanisms, and inventive or scientifically dubious proposals. The coding scheme was initially constructed inductively from the data and subsequently modified through comparative analysis with reconstructions documented in the literature. To improve openness, categories were evaluated by two independent raters knowledgeable in physics education research, and conflicts were reconciled through conversation. Despite high inter-rater agreement, any discrepancies contributed to the refinement of category definitions, so guaranteeing that the classification of student models was both methodical and reliable.

3. Results

The examination of the worksheets and classroom presentations yielded a thorough understanding of how middle school pupils tackled the task of hypothesizing on the internal mechanism of Zhang Heng's seismoscope. The findings are categorized by solutions, accompanied by figures illustrating the students' ideas. Each category elucidates the scientific rationale and the constraints of student cognition, while concurrently emphasizing analogies with academic reconstructions from literature.

3.1. Inverted Pendulum-Based Mechanisms

A considerable number of student groups suggested ideas grounded in the principle of the inverted pendulum. These solutions exhibited a vertical configuration that maintained equilibrium until disrupted by seismic activity.

In the first variation (figure 2), students constructed a core vertical column stabilized in an erect orientation, with a sphere positioned above. A radial platform encircled the column, segmented into eight channels, each directing towards the maw of a dragon. As the ground trembled, the column inclined and displaced the ball, causing it to slide into the adjacent dragon's mouth. Students specifically rationalized this design by invoking Newton's First Law of Motion, elucidating that the ball would maintain its state of rest while the container was in motion, thus indicating the direction of the seismic disturbance. This rationale closely mirrors Hagiwara's instrument as delineated by Hsiao and Yan (2009) and corresponds with Liang's reconstruction referenced in Feng and Yu (2006).

Figure 2. Student reconstruction of Zhang Heng's seismoscope based on an inverted pendulum mechanism, illustrating the release of a ball into the dragon's mouth according to Newton's First Law of Motion.

In the second variation (figure 3), students positioned a radial disk atop a vertical beam, with eight balls situated at the extremities of spokes aligned with the dragons' jaws. Upon shaking, the disk inclined and discharged the ball in the epicentral direction. The pupils highlighted that this system functioned on the concept of inertia: the balls opposed motion when the container was in motion, resulting in the release of a solitary ball. This model aligns with Hsiao & Yan's reconstruction of the seismoscope (Hsiao & Yan, 2009), illustrating the significant conceptual overlap between student reasoning and academic interpretations.

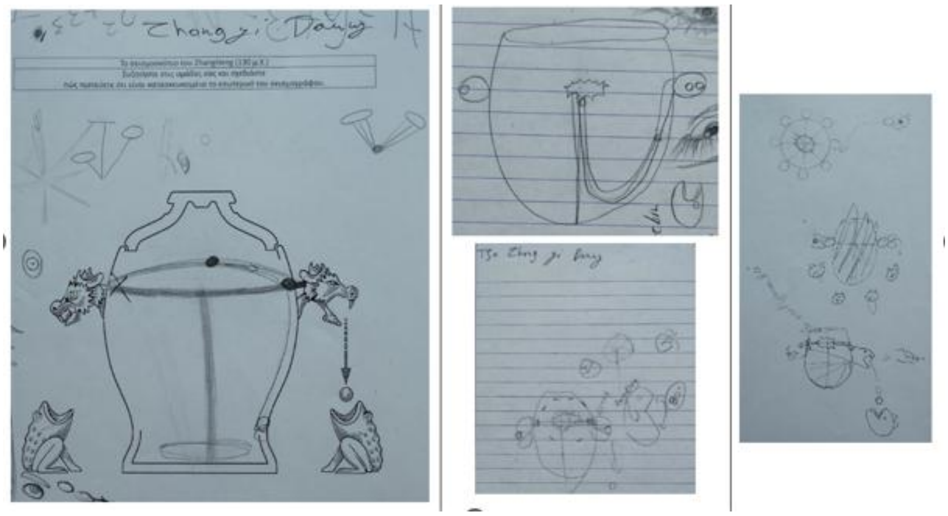

Figure 3. Student reconstructions of the seismoscope using a radial disk mechanism, where inertia causes a ball to roll into the epicentral dragon's mouth.

A third group introduced a hybrid design (figure 4) that integrated a radial platform with baseballs positioned at the base of the seismoscope. In this scenario, the base balls remained stationary due to inertia, whereas the container was displaced by the earthquake. The relative motion shifted the platform, causing the bronze ball to be released into the designated dragon. This design, while similar to the model of Hsiao and Yan (2009), provided more flexibility through the facilitation of multidirectional motion. Students noted that this design may potentially release multiple balls with strong ground motion, which they saw as a plausible consequence of seismic activity.

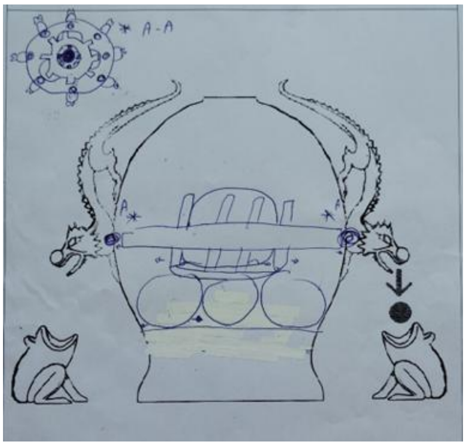

Figure 4. Hybrid student design of the seismoscope, combining a radial platform with base balls to trigger directional release through relative motion and inertia.

These versions illustrate that students could not only retain and apply Newton's First Law but also creatively extend it into innovative systems. Their solutions demonstrated advanced reasoning, while without direct instruction on seismoscopes.

3.2. Pendulum-Based Mechanisms

A significant segment of replies pertained to pendulum-based designs. Students deduced that a pendulum hung from the container's roof would remain still throughout ground movement, so facilitating the release of a ball in the appropriate direction.

Three groups formulated adaptations of this concept (figure 5). In each instance, the pendulum was conceived as a sensitive, inertia-driven element capable of functioning autonomously from the motion of the container. Students recognized inertia as the fundamental principle, once more using Newton's First Law. During classroom lectures, they elucidated that when the ground trembled, the pendulum would remain temporarily stationary, and its movement in relation to the container would activate a ball release mechanism.

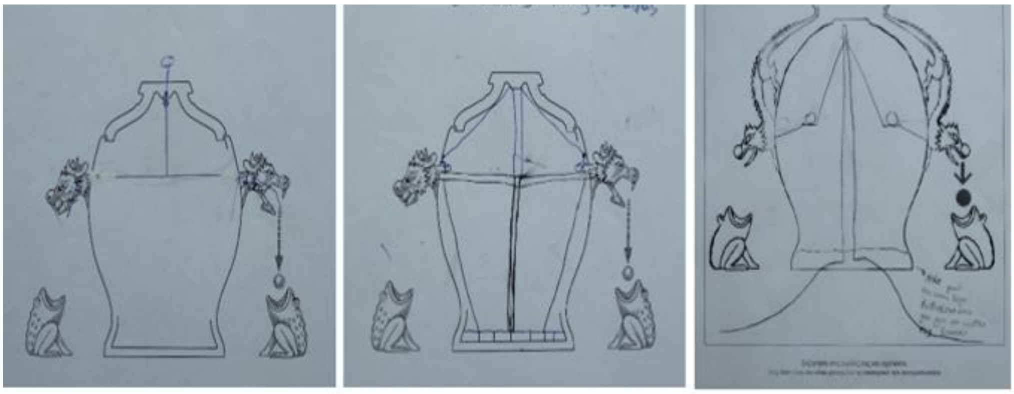

Figure 5. Student proposals of pendulum-based mechanisms for Zhang Heng's seismoscope. In these designs, a suspended pendulum remains momentarily fixed during seismic motion, and its relative displacement triggers the directional release of a ball.

Notwithstanding this robust conceptual foundation, their solutions were impeded by a functional restriction. If the pendulum traversed the axis of seismic motion, it could theoretically discharge two spheres: one toward the epicenter and one in the opposing direction. While students recognized the potential for the pendulum to reverse, they failed to pinpoint the precise issue of double release. They also did not provide further strategies to avert it. This underscores the incomplete application of their scientific understanding, indicating that although they could discern the fundamental principle, they struggled to anticipate the comprehensive ramifications of the mechanism's behavior.

3.3. Direct Contact Mechanisms

A limited number of groups suggested methods involving direct physical interaction among the balls contained within the seismoscope. In these instances (figure 6), students conceptualized the balls positioned such that the seismic wave would immediately displace one of them from equilibrium, resulting in its descent into the respective dragon's mouth.

Although these ideas seemed credible to the pupils, they possessed a major flaw: they would have indicated the opposite direction of the earthquake. The ball was conceived as being propelled from behind instead of being stationary due to inertia, resulting in a reversal of the true epicentral orientation.

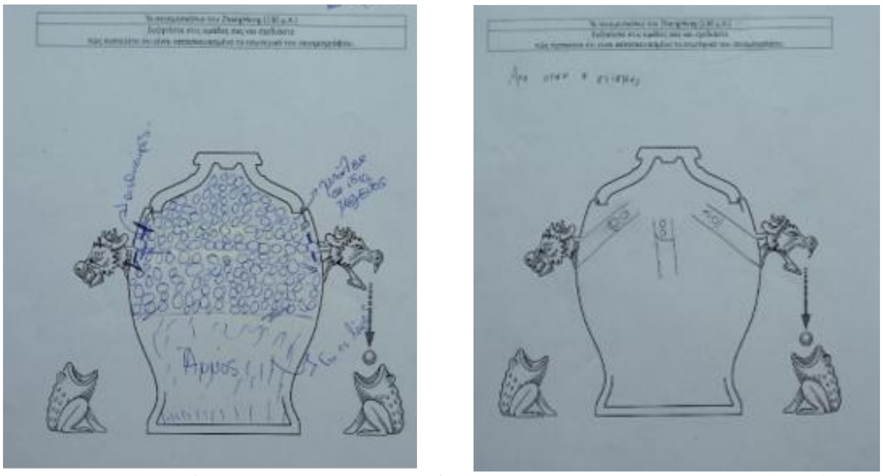

Figure 6. Student proposals of direct-contact mechanisms for Zhang Heng's seismoscope, in which seismic motion was imagined pushing a ball directly into a dragon's mouth.

Furthermore, students did not directly reference Newton's First Law in their elucidations of these models, indicating a tenuous connection to the school curriculum. These designs underscore the propensity of certain students to depend on intuitive notions of force and motion instead of utilizing the formal principles they have been instructed in.

3.4. Imaginative and Scientifically Implausible Mechanisms

The exercise also generated proposals that were creative yet scientifically untenable. In one instance, students incorporated contemporary components, including sensors and electrical impulses, into the seismoscope's mechanism (figure 7). Their design was intricately complicated; yet, they did not elucidate the connection between the seismic wave and the ball release mechanism. Furthermore, the idea overlooked the historical context of second-century China, instead depending on twenty-first century technologies (Wu et al., 2021).

A different group proposed a technique utilizing eight elongated radial tubes filled with water that radiated outward from the seismoscope (figure 8). They believe the seismic wave would propagate through the water and instantly initiate the release of a ball.

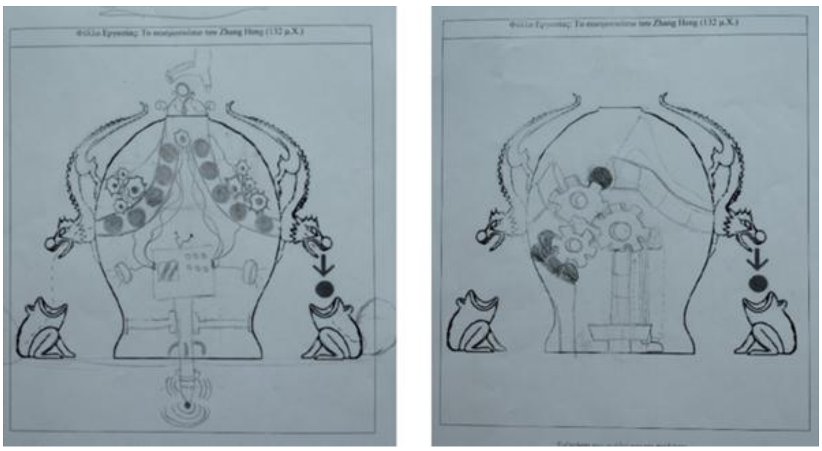

Figure 7. Imaginative student proposals for the seismoscope mechanism, incorporating modern elements such as sensors and electrical signals beyond the historical context.

This design depicts an alternative understanding of wave propagation, wherein pupils regarded seismic waves as instantaneous signals sent over a medium. The absence of formal instruction in wave physics undoubtedly influenced this reasoning among the pupils.

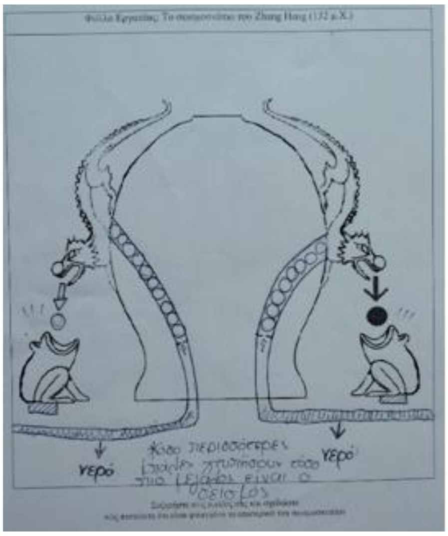

Figure 8. Student proposal of a water-tube mechanism for the seismoscope, imagining seismic waves traveling through radial tubes to trigger ball release.

In a concluding example (figure 9), students deliberated the potential utilization of springs in the original seismoscope. They ultimately dismissed the proposal due to uncertainty over the existence of springs in the second century. The suggested design ultimately excluded springs; however, the discourse reveals a profound consideration of the technological constraints of the era. Historical sources indicate that non-coiled springs were recognized in antiquity, although coiled springs became prevalent in subsequent seismographs (Yan, 2007).

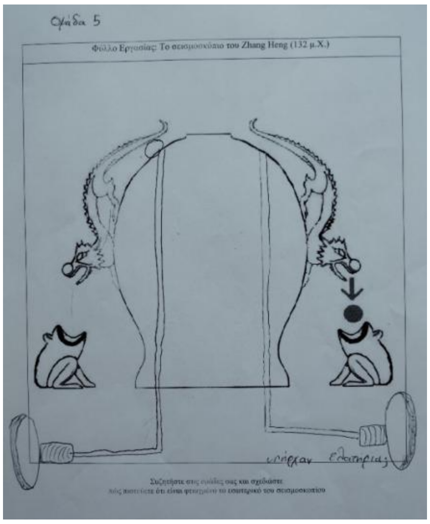

Figure 9. Student discussion of a spring-based mechanism for the seismoscope, reflecting consideration of technological possibilities in the historical period.

The categorization of student solutions demonstrated a distinct continuum. At one end were scientifically credible designs grounded in inertia, closely matched with the physics curriculum and academic reconstructions. In the center were partially viable solutions that integrated elements of scientific reasoning yet exhibited conceptual deficiencies. At the opposite end were fanciful or non-scientific ideas that, albeit erroneous, exhibited ingenuity and illuminated pupils' pre-existing conceptions.

The distribution of solutions offered insight into student engagement. Significantly, scientifically valid models did not consistently originate from the most accomplished students. In numerous instances, students with mediocre performance suggested answers that nearly mirrored academic reconstructions. This indicates that open-ended black-box activities can reveal latent capabilities and cognitive abilities not often measured by conventional examinations.

The activity illustrated that even scientifically erroneous designs possessed instructional merit. The intervention facilitated the visibility of students' thought processes, so fostering chances for discussion, critique, and refinement of ideas. The innovative approaches particularly highlighted the extent of students' engagement with the issue, demonstrating their motivation to create practical answers despite their existing scientific comprehension.

4. Discussion

This intervention aimed to examine if middle school pupils could employ scientific reasoning when faced with the genuine black box of Zhang Heng's seismoscope. By prompting students to theorize about the internal mechanism of a gadget whose original construction is lost, the activity positioned them similarly to scientists: engaging with partial evidence to develop models that must align with established data. The results indicate that numerous students successfully established significant linkages between their existing understanding of physics and the new situation, while also identifying and exposing alternate perspectives.

A significant conclusion was the recurrent identification of Newton's First Law of Motion as the foundational principle of their proposed systems. This illustrates that students successfully transferred essential curricular knowledge from mechanics to an unfamiliar situation, a skill deemed fundamental to scientific literacy (Bybee, 2013; Osborne, 2014). The resemblance of numerous student responses to reconstructions suggested by researchers (e.g., Feng & Yu, 2006; Hsiao & Yan, 2009) further emphasizes their ability to reason in alignment with the scientific community. These findings corroborate previous assertions that black-box exercises facilitate students in "thinking like scientists" through the formulation, testing, and justification of models (Lederman & Abd-El-Khalick, 1998).

The less successful or scientifically erroneous designs were equally significant. Proposals like the "magical" black box or water-filled radial tubes illustrate prevalent alternative notions regarding wave propagation and experimental apparatus. Although these notions may initially seem erroneous, they also demonstrate students' inventiveness and eagerness to investigate beyond traditional solutions. Studies in science education indicate that innovative proposals serve as effective catalysts for discussion, as they facilitate the confrontation and refinement of naive conceptions (Vosniadou, 2019). Consequently, even the scientifically improbable designs enhanced the educational value of the activity by rendering student reasoning observable and subject to communal evaluation.

The intervention also emphasized significant epistemological aspects of science. Students recognized that Zhang Heng's seismoscope, a true historical enigma, remains incomprehensible even to scientists regarding its precise mechanism. This acknowledgment facilitated their understanding of the provisional nature of scientific knowledge and the reality that scientific models are perpetually open to modification upon the introduction of new information. These observations align with the objectives of teaching the Nature of Science, which highlight uncertainty, inventiveness, and the pivotal role of empirical testing (Erduran & Dagher, 2014; Lederman, 2007). Analogous assertions have been articulated in modern contexts, including earthquake education in primary schools, where both empirical investigations of students' scientific literacy regarding seismic phenomena (Tsiouri & Kotsis, 2021) and the utilization of digital tools such as ChatGPT have been implemented to foster inquiry and underscore the tentative nature of scientific knowledge (Kotsis & Tsiouri, 2024). The focus on epistemological comprehension aligns with recent research on scientific literacy among pre-service teachers and students in Greece, revealing ongoing deficiencies in their capacity to engage in inquiry and assess evidence (Stylos et al., 2023; Tsoumanis et al., 2023). The activity liberated students from the binary of "correct" vs "incorrect" responses, enabling them to confidently substantiate their models while engaging with science as a dynamic and changing discipline. This method illustrates broader findings that emphasize how alternative notions might underpin the assessment of learning progressions and address misconceptions in fundamental physics principles, such as force (Kotsis & Panagou, 2022). This activity corresponds with broader dialogues regarding the importance of experimental work in inquiry-based learning (Kotsis, 2024a; Olschewski et al., 2023) and illustrates how AI-generated experimental designs can assist educators in rectifying misconceptions and promoting conceptual transformation (Kotsis, 2024b).

The group format of the intervention facilitated collaborative learning, communication, and reasoning. Students deliberated on different designs, articulated their rationale to peers, and justified their selections employing scientific principles. These processes correspond with overarching demands in science education to develop twenty-first century competencies, including critical thinking and collaborative problem-solving (National Research Council, 2012). The elevated engagement levels noted throughout the activity align with recent studies indicating that black-box challenges foster curiosity and motivation in science classrooms (Rode & Friege, 2017).

A comparison of the current middle school study and a parallel intervention with high school students offers valuable insights into the developmental trajectory of students' thinking when faced with Zhang Heng's seismoscope as a historical enigma. Although both researches aimed to engage learners in true inquiry by hypothesizing the underlying mechanism of the seismoscope, variations in age, prior knowledge, and classroom atmosphere influenced the outcomes in unique ways.

At the secondary education level (ages 16–17), pupils had attained a more sophisticated comprehension of mechanics. Their proposed models demonstrated this sophistication: the majority were solidly rooted in Newtonian physics and had designs utilizing inertia, pendulums, and lever systems. A few of these answers closely mirrored academic reconstructions of the seismoscope (Hsiao & Yan, 2009; Feng, 2024; Feng & Yu, 2006), indicating that older students could apply theoretical knowledge to a new and historically accurate challenge. Their reasoning demonstrated an understanding of the technological limitations of second-century China, reflecting an ability to situate their models within the historical framework.

Conversely, the middle school pupils (ages 13-14) exhibited a constrained knowledge foundation yet demonstrated a remarkable expanse of creativity. Their designs encompassed scientifically acceptable inertia-based mechanisms, pendulum systems with functional constraints, and direct-contact models that demonstrated intuitive rather than formal reasoning. Furthermore, various groups suggested innovative yet scientifically untenable solutions, such water tubes and contemporary electronic sensors. Despite being less precise, these approaches possessed educational significance by revealing students' alternate views and fostering constructive classroom discourse (Vosniadou, 2019; Kotsis & Panagou, 2022).

The epistemic aspect of the exercise also exhibited distinct variations across the two levels. The exercise underscored the provisional and inventive nature of scientific knowledge for high school pupils, illustrating that even modern scientists remain uncertain about the internal mechanics of the seismoscope. The activity emphasized to middle school pupils that science is an uncertain and dynamic process (Lederman, 2007; Erduran & Dagher, 2014). The acknowledgment that "even experts do not know the answer" democratized engagement and motivated all learners – irrespective of their achievement level – to confidently share ideas, reinforcing broader assertions that inquiry-based activities can reveal competencies not always evident in conventional assessments (Kuhn, 2010).

The comparison indicates that the seismoscope black-box activity functions on two complimentary levels. At the high school level, it functions to enhance conceptual comprehension and link abstract physics concepts with historical artifacts. During the middle school phase, it served as an initiation into scientific reasoning and creativity, promoting curiosity, cooperative problem-solving, and an understanding of the Nature of Science. The two implementations demonstrate how the identical historical black-box activity may be adeptly modified for various educational contexts, providing suitable age advantages throughout the secondary school range.

It is important to acknowledge certain limits. The activity prioritized design above model construction, preventing students from experimentally testing the practicality of their processes. Certain less realistic designs may have been rectified had students been mandated to construct and evaluate tangible prototypes. Moreover, the reductionist approach to seismic phenomena – viewing earthquakes as a singular force rather than intricate wave dynamics – constrained the analytical depth in certain groups. This constraint indicates that seismic waves were not officially incorporated into the curriculum until the subsequent academic year.

Moreover, subsequent research could investigate the adaptation of the exercise for older pupils or in international contexts. For older learners, the intervention might be expanded to include formal education on seismic waves and experimental evaluation of student-designed processes, thereby enhancing conceptual comprehension. Cross-national applications would facilitate the investigation of how cultural and curricular circumstances influence students' reasoning regarding historical scientific instruments. Ultimately, elucidating the replicability of the intervention across other educational contexts would enhance its viability as a transferable model of inquiry-based practice in science education.

The discovery that scientifically valid solutions did not consistently originate from the highest-achieving students indicates that open-ended black-box activities may democratize classroom engagement by enabling various learners to present innovative and scientifically significant ideas. According to Kuhn (2010), this substantiates the assertion that inquiry-based methodologies can reveal and cultivate competencies that may remain obscured in conventional assessments.

5. Conclusions

This study investigated the incorporation of a historical black-box activity into middle school science education, centering on Zhang Heng's ancient seismoscope. The intervention involved students hypothesizing about the underlying workings of the seismoscope, thereby prompting them to think like scientists when faced with a genuine problem whose solution is elusive even to specialists.

The results indicated that numerous student groups suggested scientifically viable solutions grounded in Newton's First Law of Motion, directly connecting their existing knowledge of mechanics to a new setting. Many of these designs exhibited notable similarities to reconstructions suggested by academics, indicating that middle school kids may produce models aligned with scientific literature. The intervention simultaneously unveiled alternative and inventive solutions that, despite being factually wrong, demonstrated ingenuity and provided excellent entrance points for conversation and conceptual development.

In addition to cognitive advantages, the practice enhanced students' comprehension of the Nature of Science. Through confronting the ambiguity associated with the unresolved enigma of the seismoscope, students directly encountered the provisional, evidence-driven, and amendable nature of scientific knowledge. The task's open-ended design fostered cooperation, argumentation, and critical thinking, while offering a stimulating atmosphere for involvement.

The findings advocate for the integration of historical black-box exercises into scientific courses to enhance conceptual understanding and epistemic insight. Zhang Heng's seismoscope possesses distinct advantages due to its historical legitimacy, direct connections to Newtonian mechanics, and persistent enigma. Subsequent research ought to broaden this study by implementing the intervention across larger student cohorts, integrating quantitative assessments of learning outcomes, and investigating its applicability at various educational tiers. Moreover, mandating students to create and evaluate physical models could further augment the inquiry process, allowing them to revise or dismiss their hypotheses based on experimental input.

In conclusion, historical black boxes like Zhang Heng's seismoscope serve as potent instructional instruments that link scientific content with genuine inquiry. Their application in the classroom helps foster scientifically literate students who comprehend fundamental physics ideas and recognize the processes and uncertainties inherent in scientific research.

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Institutional Review Board Statement: The study was conducted in accordance with the ethical standards of educational research. All procedures involving student participants were reviewed and approved by the appropriate institutional and school authorities in Greece. Participation was voluntary, parental consent and student assent were obtained prior to involvement, and data were collected and analyzed anonymously to ensure confidentiality.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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