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Zooming in the Timeline: Investigation of the Case of Pseudo-Archimedes by Preservice Teachers

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ABSTRACT

The study proposed an inquiry-based activity for an undergraduate History of Science (HOS) course. The activity aimed to promote collaboration, engagement, and motivation among students from various disciplines. The participants in this activity were 40 undergraduate students enrolled in different teaching programs at a private university. The course followed a timeline approach to teaching HOS, supplemented by weekly research questions and short activities. The specific focus of this activity was to investigate whether Archimedes designed a water clock. Students worked in groups to conduct research on the question and develop a group claim based on the evidence they collected. The course discussions resulting from this activity yielded comprehensive outcomes that contributed to the course's timeline, covering the transition from antiquity to the Middle Ages. These discussions touched upon various historical events, including the closing of the Platonic Academy, the birth of the House of Wisdom, cultural and geographical factors in the translation movement, and the concept of pseudepigrapha. Importantly, the study noted that many of these events between antiquity and the Middle Ages were not commonly mentioned in traditional HOS course books. By engaging in this activity, participants were able to zoom into the timeline and uncover fascinating historical events. The research, collaboration, and discussions brought about a sense of excitement among the students. This activity demonstrated that incorporating such an approach can enhance the narrative nature of HOS courses. The success of the activity depends on the time allocated and the content of the course, suggesting that it could be tailored to different contexts and course objectives.

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INTRODUCTION

Greater degree of understanding of science seems to me of importance for the welfare of the nation (Conant, 1947, p. 26).

The history of science is an academic discipline that explores the development and evolution of scientific knowledge and the scientific process. It involves researching and studying various aspects, including the origins of scientific facts, the contributions of scientists and their methodologies, the influence of society and the environment on scientific progress, and the interactions between science and other fields such as philosophy, religion, and the arts (Tekeli et al., 2012). The primary objective of studying the history of science is to shed light on the process of scientific development. It aims to provide insights into how scientific ideas and knowledge have evolved over time as well as the factors that have influenced their formation and dissemination. Engaging in the history of science as a research activity can serve multiple purposes. It can help motivate students to learn subjects that they may find challenging by presenting the historical context and narratives behind scientific concepts. Additionally, it can contribute to changing the public's perception of scientists by highlighting their contributions, methodologies, and the societal impact of their work. Studying the history of science can also encourage informed participation in discussions and decision-making processes regarding the application of technology and scientific advancements. Finally, it fosters an appreciation of science as an integral part of culture, emphasizing its interconnectedness with various disciplines and its role in shaping society. Overall, the history of science serves as a valuable tool for achieving educational, cultural, and societal goals by promoting a deeper understanding of the scientific enterprise and its significance in human history (Brush, 1989, p. 60).

Although the definition of history of science is related to many aspects of science education, it has become an important domain for every individual since it contributes to the development of the nature of science and attitudes towards science (Gallagher, 1991; Irwin, 2000; Krajsek & Vilhar, 2010; Lykknes & Wittje, 2012; Sonmez, 2008; Teixeira, Greca, & Freire, 2012), and eventually, scientific literacy (Abd-El-Khalick, 2005; Lederman, 1998; Lin & Chen, 2002; Turgut, 2007), which is a common aim for educational policies worldwide (Bybee, 1997). These intricate concepts can sometimes be seen in definitions of relatively new issues such as qualified individuals or 21st century skills, as the business world in this century has growing needs for individuals equipped with these skills more than ever (Roterham & Willingham, 2010; Wagner, 2008).

In the age of nanotechnology, quantum, or, according to some sources, the influence age, education cannot be separated from the needs of the world. However, there have been drawbacks in this relation, namely, curricular and pedagogical failings or beliefs that science subjects are too boring, which often result in the drifting away from science majors. In such a scenario, the history of science can help rectify the situation (Matthews, 1999). The history of science can either be taught per se or enrich other relevant disciplines with historical components through investigating historical cases and short stories (Clough, 2006; Rosell & Vilumara, 2010; Tasar, 2003). It can be taught at every level of education in the form of legends and anecdotes (Rosell & Vilumara, 2010). When teaching the history of science, the role of the teacher is crucial, yet most teachers have little or no instruction in the history of science (Brush, 1989, p. 60; Wang & Marsh, 2002).

In this study, a historical debate of interest, the case of pseudo-Archimedes, was chosen as a mediatory activity in order to advance from antiquity to the Middle Ages in an undergraduate history of science (HOS) course that was taught through a historical timeline approach. The activity was an in-class inquiry activity planned by the lecturer as it was suitable for the timeline approach, and it included several events from different time periods covering more than a thousand years.

The inquiry activity and the guided classroom discussion thereafter drew a high level of attention from the participants, resulting in them lasting longer than planned and revealing many issues related to the topic. Although the majority of these issues revealed were not in the course content, there were relevant, interesting, and significant results that are worth reporting in this article. In this respect, the outcomes of the class discussion activity were explained from a historical perspective with the necessary primary sources, which is thought to be useful for historians of science who teach non-history majors to create a more entertaining and attention-grabbing course atmosphere. The extracurricular historical information presented in this study can be used to extend the content of the traditional history of science courses by, indeed, zooming in on the timeline. The case of pseudo-Archimedes in the classroom discussion activity aimed to seek answers to the following research questions:

RQ1: How do preservice teachers gather information in order to support their claim regarding the question of whether Archimedes designed a water clock or not?

RQ2: What are the issues preservice teachers relate to the water clock of Archimedes in their discussion?

BACKGROUND

How to teach, what to teach, or how to support the student's learning in science education has always been a debated issue, resulting in many approaches that have been evolving since their first appearance (see Wavering, 1980). The path was bumpy, and there have been breakthroughs and retreats in the development process of science education.

The *post-Sputnik reaction* in the 1950s and 1960s, the *science for all* movement in the 1970s and 1980s, and *standards-based science education* reform in the 1990s were remarkable milestones in science education (Wang & Marsh, 2002). These initiatives unveiled the superiority of the constructivist theory against old-fashioned instruction and allowed science education to come together with a lot of benefits for every aspect of life (Martin, 2009, p. 196; Rosen & Salomon, 2007). Since then, practitioners no longer had to transfer their memorized knowledge but obtained the opportunity to create their own unique inquiry activities associated with daily life, individualize them for specific groups, and enrich them with certain skills, beliefs, awareness, and attitudes. Together, such a science educational philosophy was settled in educational reforms around the world as scientific literacy (Duschl, 1990, p. xi; Martin, 2009, p. 547). Scientific literacy, on the other hand, came with a sidekick in definition: scientifically literate individuals were expected to possess an understanding of scientific knowledge together with an understanding of the nature of science, which is one of the most commonly stated objectives of science education (Kimball, 1967). Lederman’s (1985) research verified the process and reported that inquiry was a determinant factor in students’ conceptions of the nature of science. Griffiths and Barman’s (1995) research included more dramatic results, implying the necessity of the nature of science for a useful science education. In other words, scientific knowledge, the nature of science, and inquiry are mutually inclusive concepts. In a quick conclusion, it can be expected from free creative minds and imagination in an inquiry environment to be curious about the nature and the *story* of the research subject. In this respect, discovering the nature of science revived the earlier contextualist belief that science education should teach science by teaching it in its social, historical, philosophical, ethical, and technological contexts (Matthews, 1990). These concepts, together with the nature of science, are strongly related to each other and are mostly seen as a separate course covering all of these issues for non-history majors. They can be referred to under a more elderly and commonly used concept: the history of science.

It has already been mentioned that the history of science can be taught as a separate course or as an enrichment to other courses. Enrichment in a policy-based manner is mostly seen in K–12 grades’ curricula. On the other hand, a separate type of such a course at the university level is usually encountered as *the history and nature of science* (HNS), *the history, philosophy, and nature of science* (HPNS), or simply the *history of science* (HOS). The inquiry activity subject to this study was carried out in a selective course named HOS.

As Matthews (1990) reported, the discussion of integrating the history of science into science education has a long history that dates back to 1855, beginning with some individual efforts in Britain. The discussion was heated, particularly in the mid-twentieth century (Duschl, 1990, p. 35; Teixeira, Greca, & Freire, 2012). It was shortly before the space race when James Conant (1947) declared the call for a union of forces to create a nationwide understanding of science with the aid of the history of science. While the social and academic discussions on understanding science were going on, Russia’s victory in the first round of space exploration with the Sputnik-1 satellite supported Conant’s claims. His book, *On Understanding Science* (Conant, 1947), was a strong hypothetical leap forward that would soon be realized and seriously reflected in the educational reforms.

The initial idea was pretty simple and similar to today’s views: understanding science through understanding the nature of scientific endeavor (Matthews, 1990). Although there are benefits to supporting science education with the history of science, it should not be forgotten that science education is built upon a lot of components that have to work all together to create scientific literacy, which is briefly developing knowledge of subject matter and concepts, manipulative skills, logical structures, creative problem solving, scientific processes, and the nature of science (Wavering, 1980). Yet, with the support of the history of science, students can understand what science is about and how it is conducted, learn key skills such as the ability to read and interpret primary sources, which science curricula might not include, develop certain argumentation skills, learn about their disciplines' past and the original life story, and learn about the manner of work of major players in their fields (Gooday et al., 2008). The history of science can provide meaningful perspective about scientific concepts, processes, context, and culture (Wang & Marsh, 2002). It can show how science changes over time by explaining the dynamic and organic progress of science, which is very difficult to practice through inadequate textbooks. These benefits can contribute to the students' professional identity more effectively than their standard textbook and laboratory routines (Gooday et al., 2008).

Similar to scientific literacy, HPNS-related aims secured their positions in educational policies and curricula a long time ago. National Science Education Standards (NSES) by the National Research Council (NRC, 1996) aim to develop the tentativeness and empirical nature of science through inquiry; the national curriculum in England: science programs of study (NCE, 2013) aims to develop understanding of the nature, processes, and methods of science through inquiry; the Australian science curriculum is based upon developing understanding of how science works through inquiry (ACARA, 2022). These are just a few examples from three different continents of the world; however, the emphasis on scientific inquiry is remarkable. Accordingly, this study was produced from a scientific inquiry as well, relying on the question of whether Archimedes designed a water clock or not.

There are also misuses of history as well as science itself (as pseudoscience; see Martin, 2009, p. 46) arising from political agendas or anti-science views due to many factors, such as hyper-religiosity. Nevertheless, the collaboration of history of science and science education and ensuring efficient historical thinking about science can overcome such misuses (Gooday et al., 2008). Essentially, it is a reasonable aspiration to expect that a proper science education producing perfect scientific literacy will be highly resistant against such attacks on science. For this reason, the first research question in this study briefly investigates the sources that preservice teachers use in their scientific inquiry in terms of credibility and authenticity.

What is the Case of Pseudo-Archimedes?

The case of pseudo-Archimedes is about false attribution to Archimedes, which is believed to have originated from a translation error in the Golden Age of Islam. Translation was an important way of transferring knowledge in the 9th-century Muslim world. At the beginning of the century, classical works from Greece, Persia, and India began to appear in Arabic. While western knowledge was rapidly being internalized by Muslim scholars, translations continued, not in the way of today's translators. There is much evidence that Muslims were not just translating old manuscripts but were interpolating, which was a way of interpreting. Some interpretations misguided subsequent Muslim scholars as well as their modern-day colleagues, even Leonardo and Copernicus. The case of pseudo-Archimedes starts with the works of Muslim scholars such as Ridwan and al-Jazari, where they attributed two water clock designs to Archimedes depending on a treatise. Up until today, no proof has been found that Archimedes worked on a water clock.

METHOD

In this study, qualitative methods were used to compile the data. The participants were 40 undergraduate students who were registered for an elective history of science course (HOS) from teaching programs in the faculty of education at a private university in Turkey. There were 19 preservice teachers from the English language teaching department, 11 from primary school education, 8 from early childhood education, and 2 from psychological counseling and guidance who participated in the activity. Participants had already been working collaboratively in groups of five since the beginning of the course. In other words, members in each group were familiar with each other, and they were used to communicating and working together. There were 8 groups labeled with numbers 1 to 8, and each group included at least two participants from the English language teaching department since the participants from other departments have lesser proficiency in English. In this way, groups were balanced in terms of comprehending primary sources, which were in English.

The Procedure

The historical content of the HOS course was taught through a timeline approach supported with weekly research questions or short discussion activities. The timeline approach for the historical content was used in this course as it helps to teach the chronology of historic events and is a useful way to categorize these events into themes, eras, and topics (Fillpot, 2007). The discussion activity described in this study was presented to the participants at the end of the fourth week, and they had to carry out the research until the next course. Participants were guided by the question of whether Archimedes designed a water clock or not. They were also asked to support their claims with evidence.

The discussion was administered by the author of this article, who is also the lecturer of the course, through three steps in line with the research questions. In the first part of the course, a discussion question was asked again, and the lecturer requested the groups choose a foreperson to bring forward the answer with explanations based on their evidence. Each group presentation took 2 to 4 minutes. Meanwhile, other groups took notes. This first part lasted approximately 35 minutes. In the second part, each group had 5 minutes to prepare rebuttal questions for the other groups. The third part was the longest-lasting, which was basically a question-and-answer session but revealed many historical issues that were related to the water clock of Archimedes. Besides administering the discussion, the lecturer took field notes in the first part according to the claims and evidence presented by the group representatives, and in the second step, he recorded the discussion outcomes on the whiteboard in an effort to construct connections between the issues revealed in the discussion. The following findings are based on the notes taken by the authors during the classroom presentations and discussions.

FINDINGS

Findings were categorized according to the research questions of the study. The first part of the findings is about *the way of gathering information* (RQ1) and the second part is about the classroom discussion titled as *zooming in the timeline* (RQ2), which was investigated in three themes based on the data gathered, titled as *introduction to the Golden Age of Islam*, *transfer of the knowledge*, and *the case of pseudo-Archimedes*.

1. The Way of Gathering Information

The first research question investigated how preservice teachers gather information in order to support their claims regarding the question of whether Archimedes designed a water clock or not, and it was based on the first part of the discussion procedure. There were 8 collaborative groups that participated in the activity. 5 of the groups proposed that Archimedes designed a water clock (1, 2, 3, 7, 8: supporting groups), and the remaining groups were against this idea (4, 5, 6: opposing groups). As for the evidence in their presentations, it was seen that the research was fruitful. Although they did not present enough literary evidence, there was a high level of curiosity in their research. According to the presentations, most of the explanations were based on basic internet searches, that is to say, mostly from free encyclopedias, blogs or forums, online newspapers, and academic articles that include technical mechanisms of Archimedes that are related to water clocks. Supporting groups showed Clepsydra and Antikythera mechanisms as evidence, as they had seen in some internet sources that they were attributed to Archimedes. The table shows the sources of the information that groups had gathered.

Table 1. Sources of the information

Main source of the data	Groups	Sub-source of the data	Groups
Internet search engine	All	Online encyclopedias	1, 3, 4, 5, 7, 8
		Blogs or forums	1, 2, 3, 4, 6, 7
		Online newspapers	2, 3, 7, 8
		Academic articles	4, 5, 6

Shortly after the course, a confirmatory internet search was conducted by the authors in order to follow the search path that groups used. The internet inquiry focused on using the search criteria as an *Archimedes water clock*. As claimed by the supporting groups, there were a lot of websites reporting that Archimedes designed a water clock, including personal blogs, forums, online newspapers, and academic articles. These results can easily lead anyone to conclude that Archimedes had designed a water clock. In addition, the search engine suggestions after the first inquiry can easily misdirect the inquirer as they include Clepsydra and Antikythera mechanisms, which seem to be highly related to Archimedes. However, if the inquirer keeps searching, there will be more scholarly results. In this way, one can reach better answers than from the other non-scientific sources that will be investigated in the *discussion*.

2. Zooming in the Timeline

The second research question investigates the issues preservice teachers relate to the clock of Archimedes in their discussion questions. The reason this section and the article are titled zooming in on the timeline is that the questions preservice teachers asked in the course discussion revealed detailed information that is not included in most of the HOS courses or mentioned in most of the HOS/HPNS course books. As explained in the procedure, the third part of the activity was a question-and-answer session. Each of the groups spoke several times in this session, both asking and answering, in addition to predicting and interpreting. Relevant issues are taken into account for the in-depth investigation. The findings below are grouped into themes according to their outcomes.

2a. Introduction to the Golden Age of Islam

This part of the discussion was entitled as the *introduction to the Golden Age of Islam* due to the focus on the general features of the period.

The discussion started with two main questions from groups 1 and 2, respectively. The first one was about Archimedes and al-Jazari's connection and how al-Jazari could know about Archimedes in a very different time and location. The second one was about the survival of knowledge for centuries despite wars and marauding everywhere in history. Group 5 replied that books were very important sources of knowledge, therefore they were valuable, and al-Jazari knew about Archimedes because all of the ancient Greek books were translated into Arabic in this period, which is called the Golden Age of Islam. They elaborated on their idea by pointing out that in undesirable events, books were the first to be saved. Group 2 asked again whether Arabic books and knowledge survived too. Group 5 replied that Arabic knowledge also survived, but Europeans somehow captured Arabic books in the 15^{th} century and expanded their knowledge. They indicated that Ibn-i Sina is important in Europe under his European name, Avicenna.

2b. Transfer of the Knowledge

This part of the discussion was named *transfer of the knowledge* as the discussion was shifted to the noticeable events the Golden Age of Islam, mainly the translational events.

Group 3 asked how and why ancient Greek books were taken to the Arab lands. Group 4 replied that it was because both the library in Alexandria and the Academy of Plato in Athens were closed by the Romans, and most of the scholars there moved to other lands where science was more respected. Then group 7 asked how the foreign scholars worked collaboratively without a common academic language like English today. Group 4 replied that in the 9^{th} century, the translation movement started, and there were many people who spoke both Arabic and Greek, so language was not a big problem. Group 5 added that there were also translation mistakes. Group 4 asked what Group 5 meant by mistakes. Group 5 replied that there were not sworn translators like todays, so there were mistakes and modifications in those translations. They gave the example that there were many works of Archimedes in Arabic that were not, in fact, his works. Group 4 indicated that it was the reason they believe Archimedes never designed a water clock. Then group 8 asked if Archimedes had not designed a water clock and why al-Jazari described his water clocks. One member of group 4 then replied with excitement: *I think there is a fake Archimedes*. Group 1 then asked if Group 4 also knew who the fake could be and why someone would imitate Archimedes. Group 4 replied that they believe al-Jazari had made it clear when he wrote about al-Qatan or al-Qajan. They suggested that it is impossible that Archimedes could attribute a design to someone with an Arabic name, as seen in al-Jazari's book: *Otherwise, all the world should have known about al-Qajan or al-Qatan*. Group 2 asked about the consequences of this kind of mistake. Group 6 replied that it's called pseudepigrapha, which means false attributions in history due to translation errors and modifications.

2c. The Case of pseudo-Archimedes

The discussion moved forward to the relationship between Archimedes and al-Jazari and the interpretation of Group 8.

After their request to speak, Group 8 suggested that if it was the fake Archimedes al-Jazari was explaining about, al-Jazari might never have seen Archimedes' original works. Group 6 agreed with them and explained that it might be because of the facts that al-Jazari lived far away from Baghdad and also lived at the end of the Golden Age, so some translation errors were possibly known before, but after two centuries later, they were forgotten. Group 7 asked what would happen if al-Jazari already knew about the fake Archimedes and deliberately used the name. Then group 3 added, "What if the fake one's name is Archimedes too?" The end of the discussion was connected to al-Qajan's (or al-Qatan's) name again and whether he might be the author of the book al-Jazari used as a reference and if it might be another translation mistake, this time not from Greek to Arabic but Arabic to English or Turkish.

Naturally, the end of the discussion did not reveal any right answers but rather prosperous predictions. The main ideas were about the factors that led al-Jazari to explain the works of a fake Archimedes. In the course discussion, groups 4, 5, and 6 were in the answering position as they had more accurate answers, and the other groups were in the questioning position. In the presentation part of the course (see Findings *1, The Way of Gathering Information*), groups 4, 5, and 6 opposed the water clock of Archimedes. It can be concluded that their research was more comprehensive. Opposing groups contributed to the HOS course regarding the *closing of the Alexandria library and the Ptolemic Academy*, *the birth of the Golden Age of Islam, translation movement and the house of wisdom*, *internalization of misunderstandings and translation errors*, *the concept of pseudepigrapha*, and *the factors leading al-Jazari to explain the works of Archimedes*. In addition, the finding about *al-Qajan (or al-Qatan)* attracted attention and seems to be highly related to the case of pseudo-Archimedes.

DISCUSSION

Discussion is presented through the themes identified in the findings.

1. The Way of Gathering Information

Generally, the group presentations included bits of both correct and incorrect information. In the following paragraphs, how a classic internet search can lead to correct and incorrect sources is shown.

On the correct side, the major finding was that all groups provided al-Jazari's treatise, *The Book of Knowledge of Ingenious Mechanical Devices*, as academic evidence. This can be due to the fact that when the water clock of Archimedes is searched online in the most famous free encyclopedia, the water clock is strongly associated with Archimedes and al-Jazari with Donald R. Hill's reference (Hill, 1974). This treatise is easily accessible since the English version by Hill can be viewed online and the printed Turkish version (Tekeli, Dosay, & Unat, 2002) by the Turkish Historical Society is available in the university library. When the English version is viewed, one can by any chance find out that Archimedes never designed a water clock, which was described by al-Jazari, because Hill (1974) describes the issue in the additional notes section. On the other hand, in the Turkish version, one can most likely believe that Archimedes designed a water clock since there is no information about pseudo-Archimedes. So, as seen in the group presentations in the first part, it can be concluded that no one has noticed the pseudo-Archimedes in the notes section of Hill (1974).

On the incorrect side, it can be seen that in the top results of such a search, let alone the water clock, Archimedes also seems to be the inventor of all types of clocks. When the source of this information is pursued, for instance, the famous free encyclopedia cites an article by Moussas (2011) in which Archimedes is described as the inventor of the water clock based on the Arabic treatise, actually the pseudo-Archimedes, which will be discussed in the following sections (p. 15).

On the other hand, extending the scope of both the correct and incorrect sides, a classic internet search can come up with excessive information through various sources, such as blogs or newspapers. This kind of knowledge mostly appears without sources. However, in this case, it was the type of knowledge that enriched the course discussion since every participant had something to share, ask about, interpret, or predict. In this sense, the enrichment was more noticeable in the third part of the course. Since finding the right answer was not the aim of this research activity, the results were satisfactory for the sake of the course.

2. Zooming in the Timeline

Zooming in the timeline section is discussed under three sub-categories according to the findings.

2a. Introduction to the Golden Age of Islam

The concept of knowledge and how it can survive for centuries was the main issue in the third part of the course. Knowledge is the understanding of a subject that is based on experience. The definition lets us think about how persistent experiences can be against disappearing. Knowledge has the capability to survive for centuries and to move to other geographical locations, even if it is not recorded. The Muslim world had a thirst for knowledge starting at the beginning of the 9th century. Plus, they had an amazing opportunity to gather all their scientific experience from their neighbors, Byzantium, India, and others, where they could travel eagerly to collect knowledge (Mokyr, 1992, p. 39). Knowledge moved to thirst, and this period until the 13th century is named as The Golden Age of Islam. Muslims of the Golden Age were in the effort of developing scientific accumulation with or without knowing that the knowledge would move away from them in a few centuries.

The Muslim world played an important role in transferring the knowledge of classical scientific works to the western scientific community starting in the late Middle Ages (van Dalen, 2011). In other words, the Muslim world was the heir of classical civilization (Mokyr, 1992, p. 39). The transmission had important consequences for the development of Islamic thought and culture as well as the European Renaissance in the following centuries. For instance, the similarity between the works of Copernicus and the Islamic planetary theories is worth investigating (Sabra, 1987, p. 227).

The main reason for being the knowledge bridge was the loss of original scripts because of various events such as demolition of libraries, sacking of cities, hostile points of view on science, and being still unearthed. In this regard, al-Nadim explains the incident of the Romans burning fifteen camel-loads of Archimedes' books (al-Nadim, 2017, p. 683). It is also known that many treatises, such as *Lemmas of Archimedes* (Heath, 1897, p. 241; Hogendijk, 2014, p. 260) and the geometry works of Apollonious (Hill, p. 12), were available only in Arabic. However, the Muslim world was not just a repository of knowledge. Muslim scholars enhanced the then-present scientific knowledge in many fields such as mathematics, engineering, medicine, astronomy, and philosophy. In mechanical engineering, particularly clock making, the *Banu Musa Brothers*, *Ridwan al-Saati* and *al-Jazari* were some important characters of the Golden Age.

It would be interesting to answer the question of how and why ancient Greek knowledge was transferred to the Arabic lands with the dream of al-Ma'mun, the 7th caliph of the Abbasid Caliphate, as al-Nadim narrates. According to the story, al-Ma’mun saw in his dream that Aristotle was sitting on his throne. They had a philosophical conversation about goodness. After his dream, al-Ma’mun exchanged letters with Roman kings in order to get the books that were locked in the cellars of Roman lands (al-Nadim, 2017, p. 621). al-Nadim also describes a temple that a Muslim delegation somehow entered, which had been forbidden to be entered since the Romans became Christians, and where they had seen as many as a thousand camel-loads of ancient books. al-Nadim indicated that this event happened in the time of Sayf al-Dawla (916–967, the first ameer of Aleppo Emirate), which would be between the years 945 and 967 (al-Nadim, 2017, p. 622).

2b. Transfer of the Knowledge

This part of the discussion was mainly about the salient factors in the transfer of knowledge in the Middle Ages. There are many examples in the history of science of translations coming with restorations, interpolations, or amendments. Sometimes the aim was to *fill the gaps* of the former studies. For example, Hill informs us about Wiedemann’s identification of Apollonious of Perga (Hill, 1974, p. 12). Wiedemann presents sufficient evidence to suggest that the Arabic translation of Apollonius' works may not be original but rather a modified version created by a Byzantine craftsman, which was subsequently translated into Arabic in its modified form.

One recent example is the 17th-century translation of *Lemmas of Archimedes* (The Book of Assumptions) by Borelli and Ecchellensis (Hogendijk, 2014, pp. 260–261). The authors prepared their study based on one Arabic translation and one commentary, which is the 6th-century work of Eutocius of Ascalon (460–540). There were fifteen propositions in the Arabic editions, but seventeen in Borelli and Ecchellensis’ translation. Hogendijk identified that the authors had adapted the seventeenth proposition from Eutocius’ commentary; however, the sixteenth proposition, which could not be traced back to Archimedes, was from Arabic scholar Al-Kühi’s book *On Filling the Gaps*. The Arabic version of Lemmas is also not completely original in its acquired form, and some of it might be a collection of a later Greek writer (Heath, 1897, xxxii).

Heath compared various translations and original manuscripts of Archimedes that could be matched. Among successful translations in both Latin and Arabic, he presents detailed information about how corrections and interpolations took place in almost every translation (Heath, 1897, pp. xxviii–xxxviii). For instance, Heath makes a list of Archimedes' works that he verified and leaves off that section as follows:

"Some Arabian writers attribute to Archimedes works *(1) On a heptagon in a circle, (2) On circles touching one another, (3) On parallel lines, (4) On triangles, (5) On the properties of right-angled triangles, (6) a book of Data*; but there is no confirmatory evidence of his having written such works" (Heath, 1897, p. xxxviii; al-Nadim, 2017, p. 683).

The translation process was so massive that, at the beginning of the 11th century, it was reported that there were more than a million books in the Cairo library, including 18.000 volumes in the philosophy section (al-Andalusi, 2014, p. 37). In such an event, one can undoubtedly expect to find perfect translations to Arabic, too (al-Andalusi, 2014, pp. 15–39; Heath, 1921, v. I, pp. 361-364). For instance, Syria-born Greek Questa b. Luqa was known to be a master translator who used to bring books from Byzantium and translate them into Arabic (al-Andalusi, 2014, p. 24). Carra de Vaux confirmed a genuine and accurate translation of *The Mechanics of Heron* by Luqa from the year 864 (Hill, 1974, p. 11). Today, when talking about translation, people rely on the fact that the translated text has exactly the same meaning as the text in the original language. As mentioned before, there are many examples in the history of science where translations came with modifications. In the Golden Age, there were so many interpolated translations that many books had to be re-translated or restorated (al-Andalusi, 2014, pp. 38–39). On this issue, Abdelhamid I. Sabra used the concepts of interpretations, reconstructions, extensions, developments, reworkings, reception, and appropriation in his research (Sabra, 1987, p. 225). Believing that there were not any malicious intentions of Muslim scholars to make such changes, the word interpretation is more appropriate in the following investigation.

Elaborating on the concept of interpretation, first, it has a perfect definition for what the scholars did in history. According to the Lexico (2021), interpretation is *the action of explaining the meaning of something; an explanation or way of explaining; a stylistic representation of a creative work or dramatic role*. Each part of the definition suits the use of this concept. Early scholars, or translators, were unconsciously misguiding their successors, but it was their own way of explaining, their representation of the original work, like a cover version of a song. Perhaps they never imagined that the original resources would disappear.

Second, interpreting is an important element of school science as it is one of the science process skills to be taught in classrooms all over the world. This educational aim might seem irrelevant to the subject. In fact, it constitutes a portrait of early scholars who had certain scientific skills that are aimed at being taught in schools today. Moreover, those scholars never had the chance to be involved in a proper education system. This aspect of the discussion is related to science education and can be used to develop nature of science views as the aim of history of science courses (Irwin, 2000; Krajsek & Vilhar, 2010; Lykknes & Wittje, 2012; Sonmez, 2008), which is a basis for scientific literacy (Abd-El-Khalick, 2005; Lederman, 1998; Lin & Chen, 2002; Turgut, 2007).

In this section, the aim is to discuss the reasons why early scholars chose interpretation over exact translation. It can be seen that there are many variables that influence their way of reproducing and developing science. The variables that need to be considered when investigating the process of transmission of scientific knowledge were identified as: *the actors of the transmission process and their experience in the original language; Different characteristics of the languages and loss of meanings in translation process because of the lack of terminology; Proper understanding of scientific models and methodologies in the original works; Cultural background of the actors in the transmission process* (van Dalen, 2011, p. 448).

For instance, Thabit ibn Qurra (836–931) spoke Arabic, Syrian, and Greek perfectly and translated many Greek works. When he moved to his native city, Harran, he was excommunicated from the sect he belonged to, so he moved back to Baghdad (Duhem, 2012, p. 61). These translation issues can be presented as further examples to discuss the cultural aspect of the nature of science. Another issue was the change in Greek names in translation to Arabic and from Arabic to Latin. It is very well observed for Heron of Alexandria (i.e., Iran, Iranius), Archimedes (i.e., Arsamides, Arsanides, Ersemides, Arsamithes, Alaminides; in Duhem, 2012, p. 65), and Euclid (i.e., Uclides, Icludes; in Heath, 1921, v. I, p. 355). Heath describes the Arabic intention to adapt some of the Greek names to Arabic in order to show a romantic connection to the Muslim world, such as *Ucli-dis,* which means an integration of a key (*Ucli*) and a measure or geometry (*dis*), eventually meaning the key of geometry. As a result, let alone the scientific works, names barely survive in the translations affected by social, cultural, geographical, or other factors mentioned or not mentioned above.

Until the 19th century, how many scholars made false attributions to Archimedes or how many scholars realized it was not the real Archimedes is unknown. But it is sensible to express that there have been many intermediary works that misguided the successor scholars. Such falsely attributed or falsely ascribed treatises are called pseudepigrapha (Stone, 1996, p. 270). According to Canavas, knowledge of Archimedean treatises appears in direct translations and compilations of excerpts that are both originally Arabic and translations from other Greek sources (Canavas, 2010, pp. 207–212). Canavas presents a remarkable example of pseudodepigrapha in which the Arabic translation—the only sample available—of *Mechanics* by Heron of Alexandria includes quotations from Archimedes, some of which are attributed to Heron (Canavas, 2010, p. 210).

2c. The Case of pseudo-Archimedes

In this part of the discussion, participants questioned the relationship between Archimedes and al-Jazari and made predictions on the topic. The case of pseudo-Archimedes is based on the Arabic attributions to Archimedes, specifically those made by Ridwan and al-Jazari, who unknowingly attributed a treatise to Archimedes. Later, in the 20th century, some historians referred to the author of the Arabic treatise as Pseudo-Archimedes. The treatise is a compilation of mechanical works and water-clock designs, consisting of references to the works of Archimedes, Philon, Heron, and Vitrivius (probably), and including scientific elements from Greece, Byzantium, and the Muslim world (Hill, 1974, p. 271). The writer of the book is unknown; the English translation was published in 1976 by Donald R. Hill under the name *On the Construction of Water-clocks* (Hill, 1976).

Many of the works of Muslim scholars had not reached the scientific world for a long time. Starting with the valuable efforts of Eilhard Wiedemann (1852–1928) and Fritz Hauser, Bernard Carra de Vaux (1867–1953), Ananda Coomaraswamy (1877–1947), Rudolf Riefstahl (1880–1936), George Sarton (1884–1956), Aage Gerhardt Drachmann (1891–1980), and Donald Hill (1922–1994) are just a few examples of 19th and 20th century orientalists who presented Muslim works to the world. Carra de Vaux is probably the first observer on the list to see the manuscripts of al-Jazari before 1891 (Riefstahl, 1929, p. 206). Moreover, he was considered the first describer of the clock of Archimedes, which is believed to have never existed (Hill, 1974, p. 10).

In fact, before Carra de Vaux, 10th-century historian al-Nadim presented the earliest reference known to the clock of Archimedes in *The Fihrist* with the attribution to *The Water Clock Which Drops Round Weights* (clepsydra) (al-Nadim, 2017, p. 683). Moreover, Ridwan al-Sa'ati in his book named *Book on the Construction of Clocks and their use* (1203) with the descriptions of *The Bab Jayrun Clock of Damascus* (Flood, 2000, pp. 114-138) and al-Jazari in his book *The Book of Knowledge of Ingenious Mechanical Devices* (1206; Hill, 1974), are the other early describers of the clock of Archimedes. There were others, too. Niccolò Tartaglia (1499–1557) was a mathematician who translated the works of Euclid and Archimedes into Italian. He edited a book by 13th-century geometer Jordanus de Nemore and added a chapter named *Treatise on Weights* (for the electronic version of this treatise, see Echo, 1565), including attributions to Archimedes, which are proven to be not of Archimedes but someone continuing his works (Duhem, 2012, p. 99). These works were identified as those of an unknown author from the 8th century (Dugas, 1955, p. 95). Duhem discusses how these Archimedes-attributed works influenced subsequent scholars, such as Leonardo (Duhem, 2012, p. 100). For a long time, the conical valves of al-Jazari, for example, were thought to have appeared first in Leonardo da Vinci's drawings (Hill, 1974, p. xiii, in Foreword of Lynn White, Jr.). It is not known if they were independent inventions or if Leonardo took direct or indirect inspiration from al-Jazari. Conical valves have a chronological importance as they were not presented by Philon (1st century B.C.) or Heron (1st century A.D.) but used by *pseudo-Archimedes* (8th century), the Banu Musa Brothers (9th century), Ridwan (12th century), and al-Jazari (12th century) (Hill, 1996, pp. 354–355). Heron is known to be familiar with Archimedes' works (Heath, 1921, v. I, p. 295). If Archimedes had published a treatise about conical valves, Heron should have mentioned them, but they were not used. These dates provide evidence that the pseudo-Archimedes should be a very early Muslim work that was written before Banu Musa's time (Hill, 1974, p. 10). In conclusion, the use of conical valves in the treatise of pseudo-Archimedes presents an excellent example of interpretation as it is a compilation of earlier works that include original ideas and inventions of the writer.

I followed the method of the excellent Archimedes' remarks al-Jazari in the first chapter of his book, where he explains us his research and development process on water clocks. He then continues in following words: *'Archimedes described [another instrument] which he attributed to [a certain] al-Qajan or al-Qatan* (Hill, 1974, p. 17). al-Jazari's statements deserve further investigation.

The first issue to discuss is the level of knowledge of Archimedes in the Muslim world. It is widely known that Muslims are quite familiar with the works of Archimedes (Canavas, 2010, p. 208). Undoubtedly, al-Jazari quoted many earlier scholars such as Archimedes (pseudo), Banu Musa, astronomer al-Usturlabi (10th century), and Apollonious (this one is debated, and in some sources, it is also referred to as pseudo-Apollonious), which proves he could reach some earlier sources. However, al-Jazari's opportunities to reach scientific sources could be limited due to geographical and temporal factors: al-Jazari lived in Diyarbakir region of south-eastern Anatolia, which is not very close to the House of Wisdom in Baghdad (827 kilometers away in today's measurement). Correspondingly, about this issue, the 11th-century Andalusian Muslim scholar al-Andalusi mentions that there were not enough books from India due to the distance (al-Andalusi, 2014, p. 60). Besides, al-Jazari lived in the late 12th century, almost four hundred years after the beginning of the translation movement. He was an engineer in the palace, and there is no information about him leaving the Artuqid palace of Diyarbakir. For instance, both contemporaries, al-Jazari and Ridwan, were not aware of each other's works (Hill, 1974, p. 10). Another supportive proposition on the issue is that al-Jazari's reputation did not spread beyond the Jazira until sometime after his death (Hill, 1991, p. 181). With this information, considering the two clock descriptions are the only connections between al-Jazari and Archimedes, it can be assumed that al-Jazari could never reach an original work of Archimedes.

The second issue is Archimedes' attribution to clockmaker al-Qajan or al-Qatan, which also gained noticeable interest in the class discussion. Neither Hill nor other historians investigated this statement, and there is no one with this name in the history of science. This statement of al-Jazari is nonsense in every aspect, unless there was a clockmaker who lived before the time of Archimedes with the name al-Qajan. It can be assumed that there was none, because al-Qajan is an Arabic name and Archimedes visited Egypt far before Arabs settled there. On the other hand, if al-Jazari knew about Archimedes but did not know anything about al-Qajan—clearly he did not, as he also never mentioned him again and he only refers to him as pseudo-Archimedes referring to al-Qajan—there appears to be another piece of evidence for the probability that al-Jazari also did not know very well about Archimedes, provided that he would know about the date Archimedes lived.

There is a tendency for the historians to believe that a Muslim scholar had written a book under the name of Archimedes, which they later called pseudo-Archimedes, and al-Jazari thought it was an original work by Archimedes. In the Golden Age, there is no example of a Muslim scholar taking and using a western name as an author; therefore, it should not be the case that the author of the pseudo-Archimedes intentionally named himself Archimedes. Rather, al-Jazari might just have had a book with "Archimedes" written on the cover, and he might have known that Muslims had written it; maybe just the front matter of the book was missing. Dohrn-van Rossum has another idea about the names: *Perhaps the mention of Archimedes was merely intended as a generic name that honored the Greek authorities as a whole* (Dohrn-van-Rossum, 1996, p. 73).

CONCLUSION

The HOS course inquiry activity on the question of *whether Archimedes designed a water clock or not* has brought the discussion to an extensive investigation of the period from different perspectives. Besides *zooming in the timeline* by revealing many events through historical short stories, this discussion activity, as the main methodological approach of the course, covered a wide set of historical events and subjects and can be modified according to the time to be spent and the content of the course. In addition, it was observed that participants developed positive attitudes towards history, experiencing a lot of fun, imagination, and curiosity both in their collaborative research and classroom discussions. History of science courses mostly have gaps between certain dates with a timeline or any other teaching approach. Such a discussion activity would be beneficial for course students to fill the gaps in the historical transitions, and it might help to resist the boring nature of the narrative HOS courses.

The inquiry-based methodological approach of the course, with respect to the second research question, revealed a lot of historical events, eventually putting this research onto a side path where the author sought answers to the water-clock question. The discussion part was constructed upon historical evidence based on the claims of the groups. As it can be seen, history has much to show, and it can be zoomed in forever. As a non-history major HOS lecturer, the author of this research zoomed in on the timeline with the participants of the course in an effort to enrich the contents of the HOS courses. In that case, the final conclusions can be shaped by the historical outcomes of the research:

Interpretation of Muslim scholars via translation movements and loss of the original documents led to limitless examples of pseudo-pseudepigrapha, resulting in a snowball accumulation of misunderstandings reaching as far back as the 20^{th} century, such as in the case of pseudo-Archimedes. Historians choose to use the pseudo-Archimedes name for the book itself. The pseudo-Archimedes is a compilation of earlier works, and the only evidence of Ridwan's and al-Jazari's connection to Archimedes is the pseudo-Archimedes, which builds evidence for the fact that they never knew about the original works of Archimedes. On the other hand, there is a probability that Muslim scholars were attributing this to the pseudo-Archimedes being aware that the writer of the book was a Muslim. Thus far, it is not known.

The main focus of the classroom discussion was based on al-Jazari's explanations about Archimedes' attributions to al-Qajan or al-Qatan. al-Jazari would have investigated if there had been a Muslim clockmaker, and he would not miss out on the fact that Archimedes' quote about someone who lived later than him was nonsense. With respect to 19^{th} and 20^{th} century historians, the aim of this discussion activity was to investigate the factors behind the case of pseudo-Archimedes, and the main claim on the topic was the fact that Ridwan and al-Jazari were aware that the author of the book was a Muslim and that the treatise of pseudo-Archimedes was not a direct translation but rather an interpretation since they were excellent observers and interpreters possessing very high levels of creativity and imagination, ahead of their time.

The technical elements of the water clocks and other mechanisms have been studied thoroughly by Donald Hill and other historians by now. Therefore, in order to find out more about the writer of the pseudo-Archimedes, future studies can focus on the mention of al-Qatan and what al-Jazari really meant by quoting him. Maybe the original Arabic script should be checked again in this respect. Furthermore, the archaeological work started in 2018 and is going on in Diyarbakir Artuqid palace, where al-Jazari used to live, and soon the world of history and science will learn more about al-Jazari, hopefully. It would be revolutionary to see a library, a book collection, or a storage facility for the mechanisms of al-Jazari come to light.

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