Reading Shakespeare: an encounter at the intersection of literature and mathematics

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Abstract: This article presents a hermeneutic exercise at the intersection of literature and mathematics, conducted from the reading of *The Merchant of Venice* by William Shakespeare. Understanding the English playwright as a trans-historical author, the question that arises is which elementary concepts of mathematics and Venice's culture from the 16th century appear in the play, which can instigate discussions in the field of Mathematics Education. Using historiographical references and research developed by renowned scholars of Shakespeare's work, the article shows that, from the play, at least three mathematical elements emerge: the monetary and interest system in force in the Venice portrayed, logic as an art of rhetoric, and the relevance of clearly using measuring instruments to measure quantities. On a broader level, the article serves as an invitation to teachers to consider the potential of incorporating literary works into their mathematics classes and to explore this area of research.

Keywords: Literature and Mathematics. *The Merchant of Venice*. William Shakespeare. Logic. Monetary and Measurement Systems.

Leyendo a Shakespeare: un encuentro en la intersección de la literatura y las matemáticas

Resumen: Este artículo presenta un ejercicio hermenéutico en la intersección de la literatura y las matemáticas, a partir de la lectura de *El mercader de Venecia*, de William Shakespeare. Entendiendo al dramaturgo inglés como un autor transhistórico, la cuestión que se plantea es qué conceptos elementales de las matemáticas y de la cultura veneciana del siglo XVI aparecen en la obra, lo que puede suscitar debates en el ámbito de la Educación Matemática. Utilizando referencias historiográficas e investigaciones realizadas por reconocidos estudiosos de la obra de Shakespeare, se demuestra que al menos tres elementos matemáticos emergen de la obra: el sistema monetario y de intereses vigente en la Venecia retratada, la lógica como arte de la retórica y la relevancia del uso claro de instrumentos de medida para calibrar cantidades. En un nivel más amplio, el artículo es una invitación a los profesores a reflexionar sobre el potencial de la utilización de obras literarias en las clases de matemáticas y en las investigaciones en este ámbito.

Palabras clave: Literatura y Matemáticas. *El Mercader de Venecia*. William Shakespeare. Lógica. Sistemas Monetarios y de Medidas.

Lendo Shakespeare: um encontro no cruzamento entre literatura e matemática

Resumo: Este artigo apresenta um exercício hermenêutico, no cruzamento entre literatura e matemática, realizado a partir da leitura de *O mercador de Veneza*, de William Shakespeare. Entendendo o dramaturgo inglês como um autor trans-histórico, a questão que se levanta é quais conceitos elementares da matemática e da cultura veneziana do século XVI aparecem na peça, que podem instigar discussões no campo da Educação Matemática. Utilizando-se de referenciais historiográficos e de pesquisas desenvolvidas por reconhecidos estudiosos da obra shakespeariana, mostra-se que, da peça, emergem ao menos três elementos matemáticos: o sistema monetário e de juros vigente na Veneza retratada, a lógica como arte da retórica e a relevância do uso claro de instrumentos de medida para se aferir quantidades. No plano mais amplo, o artigo é um convite aos professores para pensarem na potencialidade do uso de obras literárias nas aulas de matemática e nas pesquisas dessa área.

Palavras-chave: Literatura e Matemática. *O mercador de Veneza*. William Shakespeare. Lógica. Sistemas Monetários e de Medidas.

1 Why read Shakespeare

Italo Calvino (1923-1985) was an Italian author and scholar who wrote an interesting book called *Why Read The Classics*. Among his fourteen reasons, we can highlight two to begin this article: "The classics are those books about which you usually hear people saying: "The classics are those books about which you usually hear people saying: 'I'm rereading...' never 'I'm reading...'" (Calvino, 2000, p. 3) and "A classic is a book which has never exhausted all it has to say to its readers" (Calvino, 2000, p. 5), and is in this sense that we consider the work of William Shakespeare (1564-1616), English playwright and poet, as a classic.

Voracious readers and Shakespeare scholars agree that

> The way he portrays death, friendship, revenge, and power, among other aspects of his work, would allow him to manipulate the most enduring traits of our experience, operating, then, with what we can more safely call universality (Gusmão, 2021, p. 77, our translation).

Gusmão (2021) classifies these characteristics, which abound in Shakespeare's plays, as trans-historical and endowed with universal power. And it is because of the power of his texts, with skillfully constructed situations and dialogues, that Bornheim (2007, p. xvi, our translation) recognizes that each of his plays "does not feed any kind of nostalgia – for today's spectator his plays continue to be [current]." His statement corroborates that of Carlson (2021), who says Shakespeare

> created such powerful models of human behavior and action that they have become the models for modern human action in general. Our mental images for how we experience love, betrayal, intrigue, honor, and virtue find striking resonance in Shakespeare's creations (Carlson, 2021, p. 100, our translation).

In turn, Moreno (2021) argues that Shakespeare belongs to everyone and is always contemporary. In his opinion, the bard "remained 'so ours' because he did not lose sight of the 'human being.' He did not neglect his commitment to investigating our faults and vices. He was thirsty to understand us/himself as humanity" (Moreno, 2021, p. 142, our translation). Similarly,

Smith (2021) states that each of Shakespeare's plays is a celebration of the human paradox, whose works, more than allowing, call for rereadings, a characteristic that makes the author relevant in different eras, cultures, and geographies. The dialogues in his plays are "a poetic creation that rejects absolute truths and remains faithful to the mysteries and questions of the world" (Smith, 2021, p. 310, our translation).

Would it be possible (and pertinent) to (re)read at least one of Shakespeare's plays from the perspective of Mathematics Education? Would Shakespeare have something to contribute to modern-day Mathematics Education? Cone (2017) and Saunders (2007) have already answered these questions affirmatively. We now join them. We have chosen to add a layer of discussion on this, using the play *The Merchant of Venice*. The entire action of the play, which we will discuss in more detail later, revolves around a debt. But what does this encourage us to understand about mathematics, commercial practice, and human relations at the time? Debt is, in Shakespeare's text, a mathematical presence that enables us to think about elements of this discipline beyond textbooks (Campos & Montoito, 2010).

Therefore, the objective of this study is to propose a dialogue between literature and mathematics, seeking to encourage reflections and discussions among mathematics teachers regarding the possibility of articulating different areas of knowledge. Thus, we present, as an investigative question: What elementary concepts of mathematics and the culture of 16th-century Venice appear in *The Merchant of Venice* that can spark discussions in the field of Mathematics Education?

To conduct the research, we used the book mentioned and analyzed, from a hermeneutic perspective, how mathematics underlies its dialogues. The hermeneutic exercise was based on traces we found in Shakespeare's work, in an attempt to reach an understanding of the past and the society in which mathematical knowledge was produced. In this sense, we assume hermeneutics as a reflective and investigative thought that seeks to interpret a work (in this case, a play), understanding that "interpreting is not (...) extracting a meaning that would be hidden in things. On the contrary: it is attributing meanings, from a series of experiences to the things that affect us" (Garnica, 2015, p. 16, author's emphasis, our translation). The flexibility of this methodology allowed us to list initial strategic questions that helped to interpret Shakespeare's literary discourse, especially among those read in the dialogues: Which characters are involved and their respective roles in the plot? In the context of the time, what logical and mathematical knowledge emerged from the text? Is it possible to identify racial prejudices in dialogues? What are the potentialities of articulating literature and mathematics in a dramatic text from the late sixteenth century, a time when arithmetic was being disseminated in Venice's society?

Research at the interface between Mathematics and Literature began to emerge in Brazil in the first decade of the 2000s. According to the Capes' theses and dissertations database, the first research is by Eloisa Zacarias, "A matemática de crianças pequenas e a literatura infantil" [Little children's mathematics and literature for children] (2003). The author states that children can begin to understand several basic mathematical concepts through problems surrounding the themes of the stories. From 2010 to 2019, we identified 12 investigations, and from 2020 onwards, 13 studies, which shows a growth, albeit timid, in these studies.

Marinalva Souza, Dilza Côco, and Antonio Henrique Pinto (2016) worked at the interface between literature and mathematics, focusing on quantities and measurements. Alessandra Stachelski and Andréia Dalcin (2023) report on an experience they conducted, in the form of a Literature and Mathematics Club, in which they discussed aspects of culture, society, politics, mathematics, and mathematics education. Cunha and Montoito's (2020)

bibliographic review shows the growth of research in this interface, with 20 titles related to mathematics and children's literature found in Brazilian databases between 2005 and 2017, including articles, theses, and dissertations. On the international scene, we highlight two recent works: Jankvist, Rørbech, and Bremholm (2021) used Denmark as a context and proposed a discussion on the interdisciplinarity between mathematics and literature and affirm that "the aesthetic dimensions of mathematics and literature explicitly illustrate how discursive form and subject-related content are interwoven." Furthermore, they add that interdisciplinary collaboration helps to understand the nature of mathematics and literature, allowing students to contemplate mathematics through the mirror of literature, thereby learning about aesthetics in relation to mathematics. In reflections on mathematics, literature, and language, Yogesh S. Kashikar (2023) states that

> The connection between mathematics, literature, and language runs deep, showing how different disciplines can enrich and inform one another. By exploring these connections, we gain a deeper understanding of the intricacies of human thought and creativity (Kashikar, 2023, p. 538).

In the introduction to the book edited by Nina Engelhard and Rodert Tubbs, *The Palgrave Handbuch of Literature and Mathematics* (2020), the authors show the potential of mathematics for the flow of imagination, saying: "[...] mathematics is not a monolithic system of thought and, though lending itself to repressive and reductive thinking, holds surprising potential for paradox, imagination, creativity, and freedom" (Engelhard & Tubbs, 2020, p. 17).

Given this preamble, in the subsequent sections, we embrace this possibility and work in this "in-between place" (Fux, 2016) inhabited jointly by literature and mathematics, to which we bring, for our assistance, references from both areas, and also from historiography, aiming at the construction of an interpretative hermeneutics of Shakespeare's play that reveals evidence of mathematics.

When we talk about clues, it is important to recall the metaphor about the weave of a carpet by Ginzburg (1989, p. 117): "We could compare the threads of this research to the threads in a carpet. We are at a point where we see them arranged in a tight, homogeneous weave. The consistency of the design is verifiable by casting an eye over the carpet in various directions." In other words, debt (a mathematical presence in the piece) is an element that stands out in the image of this carpet, which we will unravel to understand why it is there. In this process, we can think of the two sections that follow as the direction of the threads: the vertical threads expose the historical panorama of the time in which the play was written and the period portrayed; the horizontal threads are the dialogues and actions of the characters themselves. However, we announce in advance: the debt is logically and mathematically impossible to pay.

2 Vertical threads: Shakespeare, his time, and the play

We will begin by briefly presenting what happens in *The Merchant of Venice*[1]: Antonio, the merchant of the title, sends his friend Bassanio to ask for a loan of 3.000 ducats from Shylock, a Jew who, simply because he was Jewish, was constantly execrated and publicly humiliated in the streets of Venice (including by Antonio). The requested loan, which involves the merchant's ships and products, is for Bassanio, who wishes to win the heart of the beautiful Portia, who lives in Belmont. The young woman is waiting for a suitor and, even though she

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[1] The play was registered for publication in 1598, but it is more likely that its first performance was in 1596 (Heliodora, 2009). The story of *The Merchant of Venice* was inspired by an Italian short story about a Jewish moneylender, *Il Pecorone*, written by Ser Giovanni Fiorentino (Greenblatt, 2011).

loves Bassanio, she cannot accept him without him first passing the test that her father established in his will: the right suitor would be the one who chose the casket (made from three possible options: gold, silver, and lead)[2] that contained the girl's portrait. Bassanio passes the test, and everyone could live happily if it weren't for a terrible incident of fate: Antonio loses his ships in a storm and, according to the contract signed with Shylock, if he is unable to pay the debt, the Jew could take a pound of flesh from the region close to his heart. The dispute ends in the court in Venice, where Portia, who disguises herself as a lawyer and goes unnoticed by everyone, not only manages to make Shylock lose the case but also forces him to donate all his possessions to Antonio and even convert to Christianity. In the end, Shylock, who was socially expelled but sought out time and again for the capital he possessed, ends up bankrupt, without this bringing him any redemption in the eyes of the Venetian people, as he will continue to be an outcast simply for being Jewish.

It is important to highlight that Shylock is the strongest character in the play, the one with the most intense lines and whose personality is the most dual: he is humiliated, but lends money to the one who humiliated him (Act I, Scene III)[3]; he is a father, but suffers much more because his daughter ran away with his money than because she left with a Christian (Act III, Scene I)[4]; he is religious, but not pious[5]. Why would Shakespeare have given so much prominence in his play to a Jew—those who have never read it and only know about it "by hearsay" commonly think that *The Merchant of Venice* is Jewish, such is its projection in the popular imagination from the text—, if they had been expelled from England in 1290 (almost 300 years before Shakespeare's birth) by King Edward I?

> the Jewish community in England had long vanished, and there were no Jews who openly practiced their religion. Yet in fact the Jews left traces far more difficult to eradicate than people, and the English brooded on these traces—stories circulated, reiterated, and elaborated—continually and virtually obsessively. There were Jewish fables and Jewish jokes and Jewish nightmares: Jews lured little children into their clutches, murdered them, and took their blood to make bread for Passover. Jews were immensely wealthy—even when they looked like paupers—and covertly pulled the strings of an enormous international network of capital and goods. Jews poisoned wells and were responsible for spreading the bubonic plague. Jews secretly plotted an apocalyptic war against the Christians. Jews had a peculiar stink. Jewish men menstruated (Greenblatt, 2004, p. 258-259).

The demonization of Jews reached its peak when the Portuguese physician Rodrigo Lopez (c. 1525-1594) (a marrano, that is, a descendant of baptized Portuguese Jews), who had been the personal physician of Queen Elizabeth I since 1586, was accused by the Earl of Essex of being connected to Spaniards who were planning to poison the sovereign. Lopez "was tried and brutally tortured—molten lead was poured into his guts" (Viotti, 2013, p. 121, our

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[2] This challenge brings Shakespeare's text closer to another mathematical element: Probability; however, we will keep the issue of debt as the focus of this article.
[3] "*Signor* Antonio, many a time and oft / In the Rialto you have rated me / About my monies and my usances. / Still have I borne it with a patient shrug / For suff 'ranee is the badge of all our tribe. / You call me misbeliever, cut-throat dog, / And spit upon my Jewish gaberdine, / And all for use of that which is mine own. / Well then, it now appears you need my help" (Shakespeare, 2003, p. 87-88).
[4] "A diamond gone cost me two thousand ducats in Frankfort! [...] I would my daughter were dead at my foot, and the jewels in her ear: would she were hearsed at my foot, and the ducats in her coffin" (Shakespeare, 2003, p. 123).
[5] When Portia, in court, suggests that he be merciful and take triple the amount of the debt in cash (which she could anonymously pay in Antonio's place), Shylock responds: "I charge you by the law, / Whereof you are a well-deserving pillar, / Proceed to judgement. By my soul I swear / There is no power in the tongue of man / To alter me. I stay here on my bond" (Shakespeare, 2003, p. 156).

translation) in a public display that drew crowds[6].

With this, a play written by Christopher Marlowe[7] *The Jew of Malta*, returned to the stage with more success than it had previously achieved. In it, the Jew, Barabbas, is the very essence of evil:

> His daughter had two Christian suitors, and he managed to make them both kill each other. When his daughter converts to Catholicism, Barrabas does not hesitate to kill her. [...] The public was delirious and thrilled by the evil deeds of Barrabas, and his death was greeted with howls of approval. The Elizabethans loved the presence of blood and violence on stage (Viotti, 2013, p. 120, our translation).

If, on the one hand, Greenblatt (2011) defends the thesis that Shakespeare would have witnessed the execution of Lopez[8] and that the cornered figure of the Jew would have led him to imagine one as a character, on the other hand, Heliodora (2009) points out that it is likely that the Burbage family, majority shareholders of the company to which Shakespeare belonged at the time, noticed the great success of Merlowe's revival and asked their main playwright to also produce for them a good box office success about a Jew. "The big difference between the two characters lies precisely in the level of humanization achieved by the author of each one in their creation" (Heliodora, 2009, p. 223, our translation): While Barrabas is caricatured and abject,[9] Shylock is dual, very close to the human, as can be seen when he explains to Salarino, his friend, his motivations for having, as payment, the pound of flesh.

> I am a Jew. Hath not a Jew eyes? Hath not a Jew hands, organs, dimensions, senses, affections, passions? Fed with the same food, hurt with the same weapons, subject to the same diseases, healed by the same means, warmed and cooled by the same winter and summer as a Christian is? If you prick us, do we not bleed? If you tickle us, do we not laugh? If you poison us, do we not die? And if you wrong us, shall we not revenge? If we are like you in the rest, we will resemble you in that. If a Jew wrong a Christian, what is his humility? Revenge. If a Christian wrong a Jew, what should his sufferance be by Christian example? Why, revenge! The villainy you teach me I will execute, and it shall go hard but I will better the instruction. (Shakespeare, 2003, p. 122).

Shylock's claim for equality among men is a strong point in Shakespeare's writing that remains relevant today. However, Shakespeare knew that "his contemporaries found Jews, along with Ethiopians, Turks, witches, hunchbacks, and others, useful conceptual tools" (Greenblatt, 2004, p. 259), that is, textual richness. Being Jewish was a kind of measure, a parameter that populated the English imagination, and Shakespeare did not shy away from these images: "If I do not take pity of her, I am a villain. If I do not love her, I am a Jew"[10] (Shakespeare, 2004, p. 169), Benedick says of his love for Beatrice; "He is a stone, a very pibble stone, and has no more pity in him than a dog. A Jew would have wept to have seen our

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[6] It is now believed that the accusation was unfair and plotted by the Earl of Essex himself, who wanted to rise to higher positions at court, with the Queen's blessing (Greenblatt, 2011).

[7] Christopher Marlowe (1564-1593) was a playwright and contemporary of Shakespeare. There are currently indications that his death, the result of a fight in a tavern, was politically motivated, as he was a Catholic spy amid the Protestant court. His play *The Jew of Malta* achieved notable success.

[8] These arguments are weak: Greenblatt (2011) speaks of this possibility when he comments that it is likely that Shakespeare enjoyed watching executions, given the number of violent and bloody scenes in his plays; Rosenbaum (2011) vehemently contested this claim.

[9] Rosenbaum (2011) highlights that Barrabas wore a red wig, an accessory that the theater had consecrated as a symbol of evil in representations of Judas, the traitor of Christ.

[10] *Much ado about nothing* (Act II, Scene III).

parting."[11] (Shakespeare, 2016, p. 55), Lance says, referring to his dog—two excerpts that highlight Jews as insensitive.

In 1213, Pope Innocent III established restrictive provisions for Jews, who were to differentiate themselves from Christians in their way of dressing, wearing a circular piece of yellow cloth on their heads. Although prohibited for Christians, usury was permitted for Jews, who could practice it in moderation. Jews were forbidden from public work, as well as all activities and services previously performed by Christians. All these discriminations led Jews to practice usury as an alternative means of survival (Caon, 2019).

Usury (charging interest) was present like a weed and contaminated the business and conscience of the people of that time. Although it was prohibited, Shakespeare's own father was accused twice of practicing it, and there is also evidence that Shakespeare was involved in at least one transaction[12]. The laws were unclear and sometimes silent regarding the practice of interest. At the time, the interest rate reached 15% to 25% in transactions in the European economy (Almeida, 1994). "Such fiscal liquidity was highly useful in a society where canon law prohibited Christians from taking interest, but it made the Jews predictable objects of popular loathing and upper-class exploitation" (Greenblatt, 2004, p. 261).

Catholic laws against usury echoed the ancient thinking of Aristotle, for whom reproducing money through usury became a mechanism contrary to nature and, therefore, morally, was condemnable. He questioned this practice: "The most hated sort, and with the greatest reason, is usury, which makes a gain out of money itself, and not from the natural use of it. For money was intended to be used in exchange, but not to increase at interest. And this term usury [τόκος], which means the birth of money from money, is applied to the breeding of money because the offspring resembles the parent" (Aristotle, 1908, p. 46). Aristotle's philosophical reflection in *Politics* shows, in addition to social criticism, a question of morality that permeates Shakespeare's play: "Purely because he was Jewish and, in addition, because he lent money at interest, Shylock would already have, from the outset, met with ill will or condemnation from the public" (Heliodora, 2009, p. 226, our translation).

It can be said that the practice of interest was a human invention resulting from the development of society's economic practices, which greatly helped in building or maintaining the wealth of some families. Wealth and poverty are two eloquent extremes of the power of money, which Almeida (1994, p. 235, our translation), in a sagacious analysis, summarizes

> Accumulation mechanisms crudely reflect the insecurity of wealth and increase business risks. More than accumulation mechanisms, transfer mechanisms are those that most impact: impoverishment and enrichment.

At the time, usury (or interest, as we know it today) was a common practice. Renaissance man embraced quantification and modeled calculation practices, without which one could no longer live. In this sense, inspired by Shakespeare's text, it is worth taking a look at the Italian economy of the days that are the setting for the play:

> In Venice, banking developed a distinctive style which we associate with the name

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[11] *The two gentlemen of Verona* (Act II, Scene III).
[12] A letter, found in the archives of the Stratford Corporation and dated October 25, 1598, links the merchant Richard Quiney, a resident of Stratford-upon-Avon (like Shakespeare), to the playwright. Sent to Abraham Sturley, it says that "our countryman Mr. Wm. Shak. would procure us money," which consisted of a fee of thirty or forty shillings for a loan of thirty or forty pounds (Greenblatt, 2004, p. 271).

giro-bank. The main function of a Venetian banker was not making loans but making payments on behalf of his clients. Even if a merchant had plenty of coins in his treasure chest, [...] He was happy to receive payment by being given credit on the books of a well-known banker. He could use that credit to pay for his next purchase. These credits were not transferred by writing checks, as is done today, but depended on the person who was making a payment appearing in person before the banker, who sat behind a bench under the portico of a church at Rialto, with his big journal spread out in front of him. The payor orally instructed the banker to make a transfer to the account of the person being paid. The banker wrote as directed in his book, which was an official notarial record, so that there was no need of receipts. [...] Everyone of any consequence in business had an account so that he could make and receive payments through the banks (Lane, 1973, p. 147).

The currency used in Portugal at the end of the 16th century was the réis; in London, the sterling; in Seville, the maravedis; in Lyon, the escudos—there was a wide variety of coins in circulation in Europe (Almeida, 1994). Lane (2006) comments that Italy, Genoa, and Florence were the first Western cities to mint gold coins, which came from German, Hungarian, and Balkan mines. The guilder/florin[13] (fiorino, so called because a fleur-de-lis was printed on the coin) was first minted in 1252, in Florence, by order of the powerful Filippo Ugoni. The coin, weighing 3.55 grams of 24-karat gold, was widely accepted in Venice until, in 1284, the city invented its own: the ducat, which had the same weight and fineness as the guilder/florin.

Figure 1: Ducat

Source: Numist Catalog (2024) - Item #114230

The designs printed on the ducat were reminiscent of the ancient Byzantine coins that circulated in Venice: on one side, the Doge[14] kneeling to receive the insignia of Saint Mark; on the other, Christ the Redeemer, holding the Gospel with one hand while blessing with the other.

Shakespeare provides no clues as to why Antonio did not seek out a giro-bank, something that was so common among merchants. We can conjecture nothing about this; on the other hand, we know that by borrowing 3,000 ducats from Shylock, he was taking 1,065 kg of gold from the Jew.

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[13] The guilder/florin is still present in Hungary (Hungarian guilder/forint) and in the constituent nations of the Kingdom of the Netherlands: Curaçao, Sint Maarten (Netherlands Antilles guilder), and Aruba (Aruban guilder).

[14] Doge was the title of the senior-most elected official, the highest magistrate of the ancient republics of Venice and Genoa.

Therefore, we must return to debt, the central mathematical idea of the piece, which instigated this study: from it, we learn a little about the commercial organization of the time in Venice, as well as its monetary system. Shakespeare could have crafted his story around any debt (between two knights, between a nobleman and a servant, between two businessmen), but he chose to make it between a Venetian merchant and a Jew. "He wanted, it seems, to excite laughter at a wicked Jew's discomfiture—not, to be sure, in a play about international intrigue, but in a play about money and love—and he wanted at the same time to call the laughter into question, to make the amusement excruciatingly uncomfortable" (Greenblatt, 2004, p. 278) and the mathematical issue of contracting a debt triggered all of this.

This literary work exhibits mathematical aspects that can be used to foster a different perspective on mathematics in students, as many of them have a negative view of it due to its extensive formalization (Oeschler; Kuehn, 2023). From a mathematical point of view, the situation of a loan occurs with the concept of interest and the question of precision of a measurement: the weight of the pound of flesh that Shylock charges for the unpaid debt. The student is given the opportunity, through and with Shakespeare, to move away from formal mathematics and enter the imaginative realm, trying to understand how mathematical knowledge can help in practical situations in the mathematics of life.

However, as we announced in the introduction, the debt is logically and mathematically impossible to pay off. Following, we will discuss why.

3 Horizontal threads: dialogues and actions of the characters in the play

When Calvino (2000, p. 5) tells us that a classic is a book that "never exhausted all it has to say", we tend to agree with him. In the case of *The Merchant of Venice*, a context emerges from its reading that says a lot: in that society, several arithmetic works were published, which was due to the type of activities carried out there. We can say that Italy was the birthplace of printed arithmetic: the oldest appeared in Treviso, Italy, in 1478, by an unknown author, and was called *Treviso Arithmetic* (Silva, 2003). From that date until 1519, around 40 arithmetic treatises were published, with roots dating back to Arabic mathematics and developed based on the experience of merchants and nautical practice to meet their needs (Almeida, 1994). Mercantile activities of buying, selling, and borrowing money were commonplace, and this was made very clear in *The Merchant of Venice*—mathematics and economic activities went hand in hand. Mathematics was created to meet practical needs, and there was also the opposite: the mathematics constructed was applied to the economic problems of society.

Still in the first act, Shylock, talking to Bassanio and Antonio about the loan of 3.000 ducats, says

> I am debating of my present store, / And by the near guess of my memory / I cannot instantly raise up the gross / Of full three thousand ducats. What of that? / Tubal, a wealthy Hebrew of my tribe, / Will furnish me[15]. But soft, how many months / Do you desire? (Shakespeare, 2003, p. 85).

In this brief excerpt, two concepts involved in the loan transaction appear: capital and time. Furthermore, the idea of mental calculation appears when the cunning Shylock claims to have calculated from memory, since setting up an addition or subtraction calculation presented, at that time, high difficulties. If the calculation were to be divided, then the problem would be

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[15] Beatriz Viégas-Faria, translator of our edition of *The Merchant of Venice* (Shakespeare, 2008), informs us, in a footnote, that it was common for Jews to lend money to each other without charging interest.

considered very serious and reserved for experts (Almeida, 1994).

Renaissance man embraced quantification and modeled calculation practices, without which it was impossible to live at the time. For measurement, instruments such as the scale were used, which is one of the oldest known to humanity. In Shakespeare's plot, as we have already discussed, the problem of measuring a pound of human flesh became crucial in the trial of the merchant Antonio. The merchant could not claim to have been taken by surprise by Shylock's absurd demand, as he had already been warned by him

> Go with me to a notary, seal me there / Your single bond, and, in a merry sport, / If you repay me not on such a day, / In such a place, such sum or sums as are / Expressed in the condition, let the forfeit[16] / Be nominated for an equal pound / Of your fair flesh, to be cut off and taken / In what part of your body pleaseth me (Shakespeare, 2003, p. 89).

By agreeing to the contract, Antonio placed his life in the hands of the enemy, because a promissory note[17] has the same effectiveness as a court ruling, issued during a process, therefore, it can be executed. At the trial, Shylock does not feel sorry for Antonio: "I will not hear thee speak; / I'll have my bond, and therefore speak no more. / [...] I will have my bond" (Shakespeare, 2003, p. 138).

It is in the process that the Doge will seek to uphold the law. First, Bassanio offers to pay the debt for double the amount borrowed, that is, 6.000 ducats (an amount Portia, already his wife, had given him). But Shylock is adamant. The Doge then accepts the participation of a legal expert, who claims to have sought instructions to decide the case. This character is Portia, disguised as a man (named Balthazar), who proposes paying three times the amount borrowed, that is, 18.000 ducats, to tear up the contract. The Jew resists and blusters: "If every ducat in six thousand ducats / Were in six parts, and every part a ducat, / I would not draw them; I would have my bond" (Shakespeare, 2003, p. 150).

Mathematics appears in various ways in Shakespeare's work, and emerges when we analyze the masterfully created dialogues in the plot. In the previous quote, the concept of fractions and their multiples appears. First, Portia suggests paying three times the original amount of the debt, which would yield Shylock 18.000 ducats; to this amount, which he refuses, he adds one more detail: if "were in six parts, and every part a ducat," the multiplication calculation that will result in 36.000 appears but was not verbalized in the dialogue. The Jew is giving up 36.000 ducats. The high value, the result of a mathematical calculation, is included in the text to highlight how resistant the Jew was to any negotiation.

Suspense enters the scene again: the jurist asks for clemency because the Hebrew wants to cut off a pound of flesh, which he has a right to, very close to Antonio's heart. Portia then allows him, and while Shylock celebrates his apparent victory, she shows him the scales for weighing the meat. Figure 2 illustrates a scene from the trial, with Shylock holding the knife, which he was sharpening to terrify Antonio, and the scales.

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[16] In some translations, especially in Portuguese editions, the term that appears is *arrátel*, a Portuguese measurement equivalent to 16 ounces, or 1 pound.

[17] The promissory note is a specific form of credit instrument whose roots lie in the history of the financial and commercial system. Its origins date back to the beginning of the modern banking system, in the late Middle Ages and early Modern Era. In the 15th century, merchants and bankers felt the need for instruments that would facilitate tracking and guarantee payments because commercial activities were in full development in Europe, and financial transactions began to become more complex. In this scenario, the first documents resembling the promissory note appeared, which is essentially a written promise signed by a person or entity that undertakes to make payment of a certain amount at a certain time (Lima, Ferrera & Braga, 2023)

Figure 2: Scene showing Shylock and Portia

Source: Drawing by Debora Dhein.

The situation was very complicated for the merchant, as justice needed to be served, given the clear contract. What saves him is Portia's cunning

> Therefore prepare thee to cut off the flesh. / <u>Shed thou no blood</u>, nor cut thou less nor more / <u>But just a pound</u> of flesh. If thou tak'st more / Or less than a just pound, be it but so Much / As makes it light or heavy in the substance / Or the division of the twentieth part / Of one poor scruple - nay, if the scale do turn / But in the estimation of a hair, / Thou diest, and all thy goods are confiscate (Shakespeare, 2003, p. 159, emphasis added).

The emphasis we made in the previous paragraph highlights the logical and mathematical aspects, previously announced, by which the debt could never be paid off.

From the point of view of logic, here taken in the Greek sense as the art of rhetoric and persuasion (Aristotle, 1926), Portia recognizes Shylock's right to extract a pound of flesh from Antonio's body; however, at the same time, she demands that there be no blood in this operation. However, if blood belongs to the flesh, how can one cut the flesh and not spill blood? From a mathematical point of view, we have a logical impossibility: if meat contains blood, how is it possible to obtain a fraction of it without blood? Shylock, at the same time, both has and does not have the right to his payment, which demonstrates, from a formal logic perspective, a

contradiction. The trap was set for the Jew.

It is also interesting that the entire trial exemplifies contradiction: as Portia's farce goes completely unnoticed, when she establishes herself as an authority in the law, she begins to infringe upon it, since she is not a lawyer and, therefore, lies in court.

We will make a brief digression here: Portia has experience in the art of logical argument. In a verse of love addressed to Bassanio, she says: "One half of me is yours, the other half yours – / Mine own, I would say: but if mine then yours, / And so all yours" (Shakespeare, 2003, p. 125). Skillfully using rhetoric, the character plays with the concepts of whole, part, and half to say she is completely his.

However, let us suppose that, from a logical point of view, Shylock's revenge could be carried out. In this case, mathematical precision would prevent him from having in his hands a pound of Antonio's flesh: we know that, at the time, measuring instruments were somewhat rudimentary and, therefore, the task of precisely cutting a pound (0.45359237 kg) was not simple. Measuring this quantity with a two-pan balance could only give an approximation, which served the purposes of practical life. However, as a measure of weight, a pound is an ideal value, almost impossible to obtain with mathematical precision, mainly because Portia had pointed out that the difference in weight could not be greater than the weight of a hair[18].

Both demands were unfeasible: the first, from a logical point of view; the second, from a mathematical point of view. And Shylock did not consider both of them when proposing the contract. At this point, the trial had an impasse. The Jew, feeling cornered, tries to reverse everything, accepting the tripled money previously offered. However, Portia does not allow it, claiming that he had previously refused the amount and was now subject to whatever justice determined. Using artifices that benefited Christians, Portia recalls the laws of Venice

> Tarry, Jew: / The law hath yet another hold on you. / It is enacted in the laws of Venice, / If it be proved against an alien / That by direct or indirect attempts / He seek the life of any citizen, / The party 'gainst the which he doth contrive / Shall seize one half his goods, the other Half / Comes to the privy coffer of the state, / And the offender's life lies in the mercy / Of the Duke only, 'gainst all other voice (Shakespeare, 2003, p. 160).

The way Portia conducted her legal reasoning shows that she used diffuse logic, which considers more than just two truth values and incorporates a subjective notion of truth, and indicates that the judge interprets the laws according to his own will and may be biased[19]. When analyzing this text by Shakespeare from the perspective of the Philosophy of Law, Silva (2013, p. 333, our translation) states that Portia's pathological sentence is "a vivid and pertinent portrait of the Elizabethan era[20] [...], Portia-Baltazar's decision was received in a euphoric atmosphere by the court assistants, as a direct consequence of the authoritarian excess, which in itself is already arbitrary."

The author is generous, since he allows the 21st-century reader to extrapolate the dramatic story, which can be compared to a math problem: both the legal and the mathematical

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[18] Just out of curiosity, and considering that the expressed value is slightly variable, we thought it would be interesting to comment on how difficult it would be to achieve this degree of precision, since the weight of a strand of hair is estimated to be between 0.62 and 0.78 milligrams (Martínez-Velasco, Vázquez-Herrera, Maddy & Tosti, 2017).

[19] This is another very current topic in Brazil, and could provide students with reflections on comparisons between current Brazilian law and the law of Venice in the 16th century.

[20] "Isabel" is the Spanish version of "Elizabeth;" therefore, the "Isabel's era" in the Portuguese version is equivalent to the "Elizabethan era," an expression used in our translation and more commonly used by other authors.

problem require data and a solution strategy to be resolved. In the case proposed in the play, there is a debt, the payment of which does not involve money, but "a piece of human flesh." What are the possible strategies to solve this problem? In the play, solving the problem means trying to save Antonio's life. The first step is to identify potential strategies, just like in a math problem. The second is to implement this strategy. Naturally, Portia, when deciding to tackle the problem, already had a strategy in mind—appealing to the law that prohibited a Jew from spilling the blood of a Christian, added to the difficulty of cutting exactly a pound of human flesh. With these variables, the chance of winning was high. Just as we still do today, for a mathematical problem, we choose the best strategy to reach a solution successfully.

The theme of interest returns to the scene of the drama when Antonio, in an attitude of apparent benevolence, proposes to the Doge

> So please my lord the Duke and all the court / To quit the fine for one half of his goods, / I am content, so he will let me have / The other half in use, to render it / Upon his death unto the gentleman / That lately stole his daughter. / Two things provided more: that for this favour / He presently become a Christian; / The other, that he do record a gift, / Here in the court, of all he dies possessed / Unto his son Lorenzo and his daughter (Shakespeare, 2003, p. 161-162).

With such speech, not only does Shakespeare punish the Jew immensely, but he also presents Antonio—who, let us remember, was not a saint, as he spat and cursed the Jew at the Rialto just for being Jewish—as a pious man. It is quite likely that the audience would have been even more sympathetic to the Venetian merchant.

From this conclusion, we understand how, for Shakespeare, debt serves as a narrative device to distinguish between good and bad, good and evil. Underlying the text, the mathematics involved in the commercial contract between Antonio and Shylock is the trigger for the ancient philosophical discussion between Justice and Morality, which echoes from the "ancient plays [which] contained scenes of trials—sometimes taking the form of the Last Judgment—in which Justice and Mercy fought for the soul of humanity" (Heliodora, 2009, p. 229, our translation)[21].

The mathematics of debt is both a real, everyday issue and an allegory for us to think about the relationships between people and cultures, as well as the clashes between power and justice. The proposal for critical mathematics for teaching, based on a 16th-century piece of literature, provides us with the resources to bring up-to-date reflections on social problems, including the differences between social classes and ethnicities that society itself emphasizes.

4 Final thoughts

Although he does not quote Shakespeare verbatim, D'Ambrosio makes a statement about several literary works, with which we agree and, we believe, can be expanded to include the writings of the English playwright: "I recommend reading these texts and I am sure that the reader will understand the direct relationship they have with education and, especially, with mathematics education" (D'Ambrosio, 2012, p. 14, our translation). Beyond mathematical questions, it is worth highlighting the potential that literature has, in Morin's (2004) perspective, as a school of life or a school of human understanding, as many works enable us

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[21] Heliodora (2009) compares Portia to Our Lady in *O auto da compadecida (A Dog's Will)*, by the Brazilian writer Ariano Suassuna, whose play was also inspired by medieval plays.

to understand what we do not understand in ordinary life. In this ordinary life, we perceive others only externally, whereas on the screen[22] and in the pages of a book, they appear to us in all their dimensions, subjective and objective (Morin, 2004, p. 50, our translation).

Furthermore, we agree with neuroscientist Damásio (2018, our translation), when he states that literature is useful to science, justifying: "[...] Literature is extraordinarily useful because it is a very rich entry into the mind, an entry that utilizes subjective life, feelings." He adds the phrase that comes to terms with what we share, considering Shakespeare as a neuroscientist: "When people ask me who the greatest scientist of all time is, I answer: in my field, it is Shakespeare" (Damásio, 2018, online, our translation). We have much to learn from the playwright, as in his writings, he weaves through the plots of life that people get involved in, whether from an emotional, social, economic, religious, or cultural perspective.

The Merchant of Venice, a play that explores the relationship between Christians and Jews set against the backdrop of a romance, emphasizes the constant struggle between humankind and both extremes (good and evil). Evil is to be eradicated, and its opposite (good) is to be pursued. The same dynamic occurs in mathematics, where true and false confront each other. The search for the truth of constructed mathematical knowledge must be sought just as the good is. And the false must be overlooked in favor of the true: there is a parallel here between mathematics and philosophy. And, at the crossroads of Shakespearean textual conjectures, logic is an efficient aid.

The messages we can extract from Shakespeare's thought in this comic-dramatic play are not limited to philosophy, law, literary creation; they touch, as we have pointed out, on mathematics. Exploring the potential of such rich and insightful sixteenth-century writing can be a signal to encourage students to look at literary texts beyond the written word, to go beyond the obvious, to sharpen their imagination, creativity, and interpretation; it can also be an element for training teacher-readers (Maria, 2009), whose reading practice transcends the discipline taught and allows them to establish multiple relationships with different knowledge, periods, and cultures.

From a neuroscience perspective, Damásio (2022, p. 45, our translation) shows the importance of creative imagination

> When we relate and combine images in our mind and transform them with our creative imagination, we produce new images that signify ideas, both concrete and abstract. We create symbols, and we record in our memory a significant part of all the imagery production. By doing this, we expand the archive from which we draw much of our future mental content.

Mathematics is not the preserve of math books. The discussions presented here show their presence in literature. From the glimpse of debt, when we scrutinize Shakespeare's text, we locate many other mathematical presences: the principle of non-contradiction that emerges from an accurate analysis of the requirement to extract a pound of flesh without spilling blood; the old concept of interest that is part of financial education and appears in negotiations; an old measure of weight (the pound) and the impossibility, at the time, of verifying its accuracy using a scale; the financial and commercial system organized by the bankers of Venice; part of the history of money. In this study, it is necessary to emphasize that we did not explore other mathematical concepts in the piece that could be worked on, such as probability, as mentioned

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[22] The author extends the recognition of this potential to cinema as well.

in footnote 2.

All these presences of mathematics—each of them appearing in *The Merchant of Venice* with different levels of prominence—are threads that weave a human and non-Manichean story, full of conflicts, doubts, decision-making, love, hate, and other manifestations of humanity. All because—and here, at the end, we once again wish to highlight the playwright's recognized genius—Shakespeare

> uses a prism to analyze every subject he proposes to address, he seeks to examine it from all sides, to know each of its thousand facets [...].

> The nature of Good and Evil, the benefits and burdens of power, one's own identity and the identity of others, past and new values, the discordance of human feelings, the labor pains of the new society, the pains of the other, which grows old, nostalgia for the (idealized?) time when life was not so complicated and dangerous—in relation to all this, the only attitude capable of encompassing the multiple nature of life is that of permanent investigation. It is because he never sticks to a single answer, because of his multi-conscious apprehension of reality (a single prism generates thousands of reflections), that Shakespeare rings so true even today (Lacerda, 2021, p. 111-112, our translation).

The Merchant of Venice does not directly address mathematics. However, what we discussed in this article are possible interpretations of visible and invisible mathematics in Shakespeare's play, which we can encourage mathematics teachers to explore in the classroom—this in-between space between literature and math. Literature, which evokes many feelings, combined with mathematics, where reasoning predominates, makes a beautiful pair because feelings are essential to the learning process. Feelings reside in the brain (Damásio, 2022)—thus, within the person experiencing them—and give us valuable insight because they motivate our actions. For this reason, some neuroscientists now understand that feeling is a basic form of cognition. Bringing together what is already deeply connected in our brain (feeling and reasoning) highlights the contributions of neuroscience to teaching.

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